UNIVERSITY OF NOVI SAD
Technical Faculty “Mihajlo Pupin”
Zrenjanin, Republic of Serbia

XII International Conference

Industrial Engineering and Environmental Protection IIZS 2022

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Publisher:

Technical Faculty “Mihajlo Pupin”, Zrenjanin, University of Novi Sad, Đure Đakovića bb, 23101 Zrenjanin, Republic of Serbia

For publisher:

PhD Dragica Radosav, Dean of Technical Faculty “Mihajlo Pupin”, Zrenjanin

Technical preparation:

MSc Luka Đorđević, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia
PhD Mića Đurđev, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia
MSc Borivoj Novaković, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia
PhD Marina Naodović, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia
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INTRODUCTION

Departments of Mechanical engineering and Department of Environmental protection of Technical Faculty "Mihajlo Pupin", Zrenjanin, has organized the XII International Conference Industrial Engineering and Environmental Protection – IIZS 2022.

The topics of scientific conference «IIZS 2022», cover the fields of Industrial Engineering and Environmental protection: Mechanical Engineering, Energetics and process technique, Designing and maintenance, Oil and gas engineering, Health and environmental protection, Environmental management, Occupational safety and Engineering management.

The main goals of the conference are: innovation and expansion of knowledge engineers in industry and environmental protection; support to researchers in presenting the actual results of research projects, establishing new contacts with leading national and international institutions and universities; popularization of the faculty and its leading role in our society and the immediate environment, in order to attract quality young population for studying at our faculty, cooperation with other organizations, public companies and industry; initiative for collecting ideas in solving specific practical problems; interconnection and business contacts; introducing professional and business organizations with results of scientific and technical research; presentation of scientific knowledge and exchange of experiences in the field of industrial engineering.

We would like to express our gratitude to the partners of the conference – „Aurel Vlaicu" University of Arad, Faculty of Engineering, Arad, Romania; University "St. Kliment Ohridski", Technical Faculty, Bitola, Macedonia; University Politehnica Timisoara, Faculty of Engineering, Hunedoara, Romania; University of East Sarajevo, Faculty of Mechanical Engineering East Sarajevo, B&H, Republic of Srpska; University of Giresun, Faculty of Engineering, Giresun, Turkey for supporting the organization of the 12th International Conference «IIZS 2022». We are also grateful to all the authors who have contributed with their papers to the organization of the scientific meeting «IIZS 2022».

We would like to extend our special thanks to the Ministry of Education, Science and Technological Development, Republic of Serbia, The Provincial Secretariat for Higher Education and Scientific Research, and the management of Technical Faculty "Mihajlo Pupin", University of Novi Sad, for supporting the organization of the Conference «IIZS 2022».

The IIZS Conference became a traditional meeting of researchers from all over the world, every year. We are open and thankful for all useful suggestions which could contribute that the next, XII International Conference - Industrial Engineering and Environmental Protection, become better in organizational and program sense.

Chairman of the Organizing Committee
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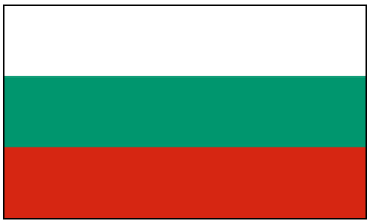

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XII International Conference Industrial Engineering and Environmental Protection 2022 (IIZS 2022)
October 06-07, 2022, Zrenjanin, Serbia

Plenary Session

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COMPACT UHF AMATEUR RADIO QUAD ANTENNA FOR INDOOR USE

Tomislav Barić[1], Hrvoje Glavaš[1]
[1]Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology, Osijek, Croatia
e-mail: tomislav.baric@ferit.hr

Abstract: Due to the confined space in which they are typically used, directional ultra high frequency (UHF) antennas for indoor use should be particularly compact. Also, due to the frequent need to manually direct (rotate) the antenna, it must be relatively light with good mechanical characteristics. By simultaneously considering the compactness of various types of antennas, weight, electrical, electromagnetic, mechanical, and radiation properties of antennas, several types of antennas are particularly suitable for directional UHF amateur radio antennas for indoor use. In this sense, various types of quad antennas stand out. Despite the fact that Quad antennas have excellent performance and electromagnetic properties, because of their complicated and slow construction, they are not popular among radio amateurs. This article presents a new idea in the selection of materials for the construction and construction solution of Quad antennas for indoor use. The presented construction solution simultaneously ensures a simple construction but with significantly reinforced mechanical characteristics compared to the typical constructions of Quad antennas. This article presents the design of compact UHF Quad antennas suitable for indoor applications. The presented antennas are dual stacked Quad antennas. Impedance matching was achieved by coaxial cables. The antennas are built for the frequency of 446 MHz, the so-called personal mobile radio (PMR). Both antennas were tested for mechanical stress typical for their use such us moving and rotating the antennas. After prolonged use, no damage, deformation, or weakening of the joints was observed. Numerical calculations and optimizations of the presented antennas were performed using 4nec2 software. The measured voltage standing wave ratio (VSWR) of the presented antennas is below 1.5.
Key words: amateur radio, compact antenna, quad antenna, pmr radio, stacked antenna

INTRODUCTION

More and more people, and thus also radio amateurs, live in urban areas. Typical for urban environments is a very scarce (limited) space in which radio amateurs can install antennas. Also, when directional antennas are installed in buildings, in a space such as a balcony, the antenna must be of small dimensions. Given that the physical dimensions of antennas are to a certain extent proportional to the wavelength of the electromagnetic wave, ultra-high frequencies (UHF) are suitable for antennas of smaller dimensions. These are the main reasons why frequencies, below the very-high frequency (VHF) (more precisely, below 144 MHz) are becoming less and less popular among radio amateurs. Due to the reasonably small dimensions of the antennas, UHF is extremely popular. Reasonably small dimensions of UHF antennas open the possibility of their indoor use. The above is of particular interest to radio amateurs who live in buildings without balconies where antennas could be installed. Also, directional antennas for indoor use can be rotated easily by hand without the need to use a rotator. Furthermore, in the winter period, it is not necessary to go out on the balcony to change the orientation of the antenna if it does not have a built-in rotator. Unlike antennas for outdoor installation, where free space can be provided around the antenna to prevent unwanted interference, this is often not the case with antennas for indoor use. Therefore, when choosing an antenna for indoor use, types of antennas that are naturally not susceptible to interference should be preferred. The above is valid for both reception and transmission (common mode currents). Also, radio amateur antennas for indoor use need to be rotated often, their position changed, and they should be stored after use. As a result of the mentioned actions, there is a possibility of their accidental mechanical damage. That is, the mechanical and electrical connections on the antenna can weaken. Accidental impacts to the antenna elements are also possible and they can be deformed or become misaligned. The above may cause a change in the electromagnetic properties of the antenna, which will result in unstable communication with possible interference. Therefore, when designing antennas, a special attention should be given to the mechanical properties of antennas.

Due to the limited available space in the typical use of directional antennas for indoor use, they are expected to be extremely compact, i.e. the maximum possible gain for a certain boom length. Several types of antennas are particularly suitable for building UHF amateur radio antennas for indoor use. The types of Quad antennas [1-3] such as, ordinary Quad, BiQuad, DoubleQuad and Hentenna stand out in particular. Quad antennas have an excellent radiation pattern, electromagnetic properties and a relatively high gain for a certain boom length. With careful design of the Quad antenna, a wave impedance of exactly 50 ohms can be achieved [1]. Also, they are significantly less prone to problems caused by common mode currents compared to Yagi antennas. Because of the above, they can be fed directly with a coaxial cable. That is, when using them, it is not necessary to adjust the impedance, nor is it necessary to use special techniques to attenuate common mode currents, except in rare cases. Also, for the same boom length, they have a higher gain than Yagi antennas [1]. However, by using typical construction solutions for making Quad antennas it is difficult to achieve satisfactory mechanical characteristics of Quad antennas for indoor use. In contrast, as shown in the article, the use of aluminium L profiles for the production of Quad loops and PVC L profiles for supporting Quad loops significantly improves the mechanical characteristics of the Quad antenna [4]. This paper presents a new technical solution in the design and construction of a Quad antenna that has reinforced mechanical characteristics. In order to achieve the highest possible gain, without increasing the length of the boom, the technique of stacking antennas was used. Thus, high gain and compactness of the antenna were achieved simultaneously. Two compact Quad antennas for indoor use have been built. One with a total of six, and the other with a total of eight elements (loops) has been built. Modelling, simulation and optimization of antenna parameters were performed using 4nec2 software [5]. The operating frequency of the presented antennas is 446 MHz (so-called personal mobile radio (PMR)). Common electrical parameters and VSWR were measured using a vector analyzer.

QUAD ANTENNA CONSTRUCTION

In this section, we will look briefly at the typical construction solutions of Quad antennas, and then at the improvements we have introduced in order to reinforce mechanical construction Quad antennas. Typically, Quad antenna elements are mounted on a horizontal boom either by using a spreader (Fig. 1.a [4]) or by laying the element on the boom (Fig. 2.b [4]). Common to both construction solutions is that the elements (loops) can be easily damaged (deformed) or twist and become misaligned under the action of external forces. For example: during very strong wind, during contact with a tree branch, etc. Such simple technical solutions meet the needs of most radio amateurs if the antenna is used as a stationary antenna (with or without rotator). In the beginning of use of Quad antennas they were used for short-wave (SW) frequencies. Due to the fact that the wavelength on the SW frequencies is of the order of tens of meters, the loops are made of thin wire. A thin wire is stretched around the spreader, which gives the loops a rectangular shape. The spreader is made of insulating material, typically wood or plastic so that the loops are galvanically isolated from other metal parts of the antenna. The spreader is fixed to a horizontal boom and the boom is fixed to a vertical mast (Fig.1a).

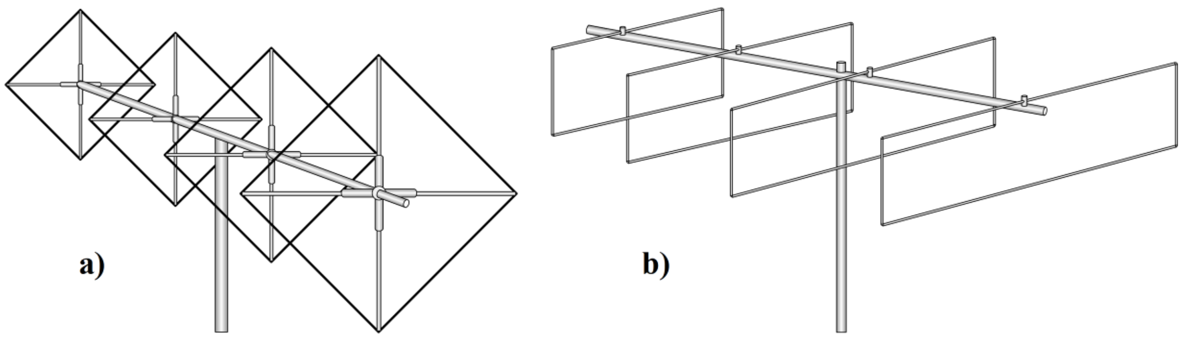

Fig. 1. Four elements Quad antenna, a) typical construction using a spreader, b) oblong type Quad antenna, construction where the elements lie on the boom.

Radio amateurs continued to use this typical design on both VHF and UHF. In the meantime, aluminium tubes began to be used instead of thin wire to make loops (reflectors, drivers and directors) of Quad antennas. Due to the mechanical stability of loops made of aluminium tubes, new structural designs have appeared as shown in Figure 1b. By using aluminium tubes to make Quad antenna loops, they become self-supporting with a consistent loop shape. This eliminates the need to use a spreader to maintain the shape of a rectangular loop, and at the same time, its role as a loop carrier disappears. This led to the emergence of Quad antenna versions in which the loops were fixed to the boom using plastic clamps (Fig. 1b). The listed technical solutions for manufacturing Quad antennas have satisfactory resistance to mechanical stresses that typically occur during their use. However, if there is a need to build a Quad antenna that is light but mechanically more resistant to mechanical stress, it is necessary to change the approach to structural design [4]. In order to achieve this, we made the elements of the antenna (reflector, driver and directors) from an aluminium L profile (10 mm x 10 mm x 1 mm) (Figures 2a and 2b, antennas assembled by the authors). Supports of loops are made of PVC L-profiles (25 mm x 25 mm x 1.5 mm) (Figures 3a and 3b). Supports of Quad elements and elements are connected using M3x10mm screws. Supports of elements are connected to boom using the same type of screws. The boom is secured to the mast using a factory made aluminium bracket. The mast is an aluminium tube with a rectangular cross-section (25 mm x 25 mm), one meter high. We have assembled two antennas. Both are so-called stack antennas, composed of two identical antennas placed one above the other vertically.

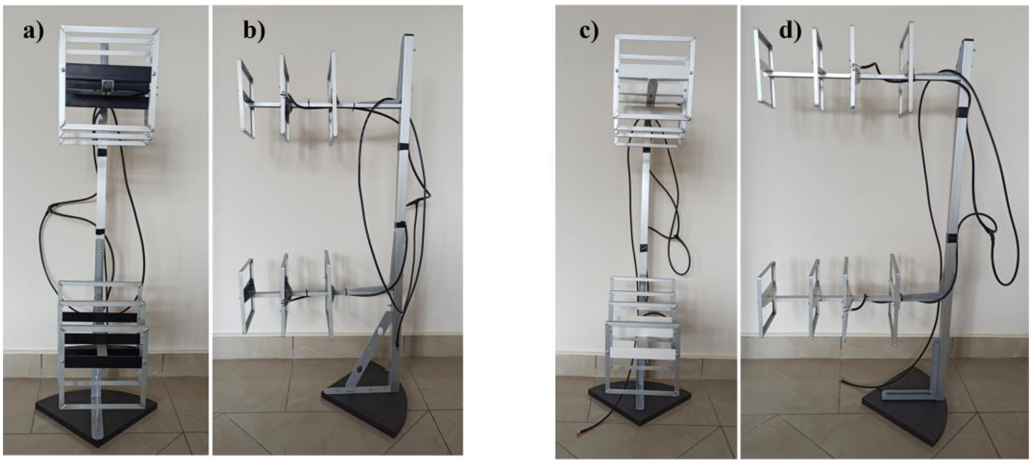

Fig. 2. Stacked antennas for indoor use. The antennas consist of a pair of Quad antennas. a) Front view and b) side view of two stacked Quad antennas, each with three elements. c) Front view and d) side view of two stacked Quad antennas, each with four elements.

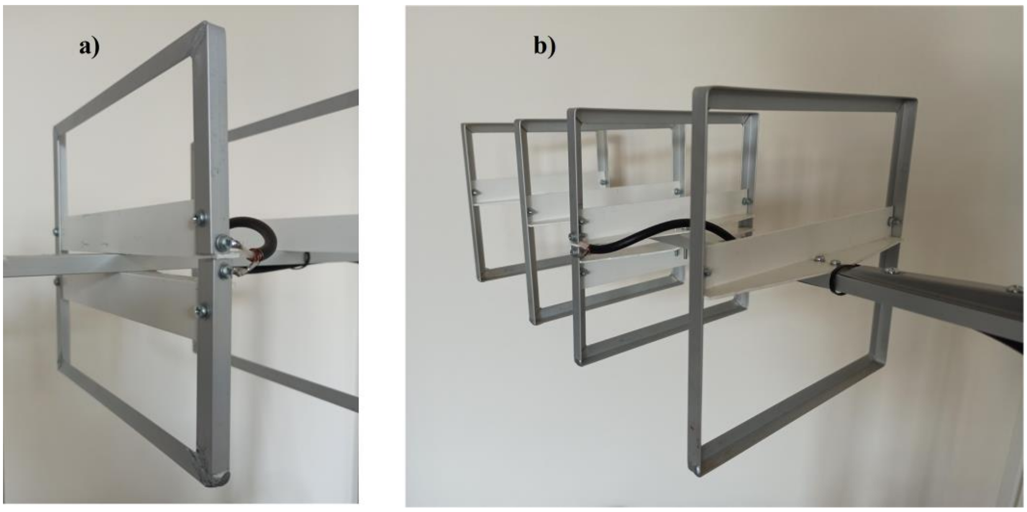

Fig. 3. a) A detailed view of the feed point. b) A detailed view of the loops supports

The mast is fixed to the wooden base using a factory-made aluminium bracket. A special feature of vertically stacked antennas is that they have a wide horizontal radiation pattern (radiation beam). Extra gain (theoretically +3 dBi) in relation to the individual antennas was achieved by vertical narrowing of the radiation beam. Due to the relatively wide horizontal beam of radiation, this directional antenna is suitable in situations where one of the operators is mobile and its exact location is not exactly known. Feeding of the antenna is described in more detail in the following chapter.

FEEDING TWO ANTENNAS

Properly feeding two 50 ohm antennas requires equal power distribution between the two antennas and maintaining the entire system at impedance of 50 ohms [6]. One way this can be achieved is by using 75 ohm impedance coaxial cables. If, at the model level, a coaxial cable is represented as a transmission line (Fig. 4. [7]) and the antenna impedance as a load connected to the transmission line, then the input impedance at the beginning of the coaxial cable can be determined by the expression [7]:

$$\underline{Z}_{\text{in}} = \underline{Z}_0 \cdot \frac{\underline{Z}_{\text{L}} \cdot \cos(\beta \cdot l) + \text{j} \cdot \underline{Z}_0 \cdot \sin(\beta \cdot l)}{\underline{Z}_0 \cdot \cos(\beta \cdot l) + \text{j} \cdot \underline{Z}_{\text{L}} \cdot \sin(\beta \cdot l)} . \tag{1}$$

Where: $\underline{Z}_{\text{in}}$ - is input impedance, $\underline{Z}_0$ - is characteristic impedance of a transmission line, $\underline{Z}_{\text{L}}$ - is load impedance, β - is wavenumber ($2\pi/\lambda$), l - is transmission line (coaxial cable) length.

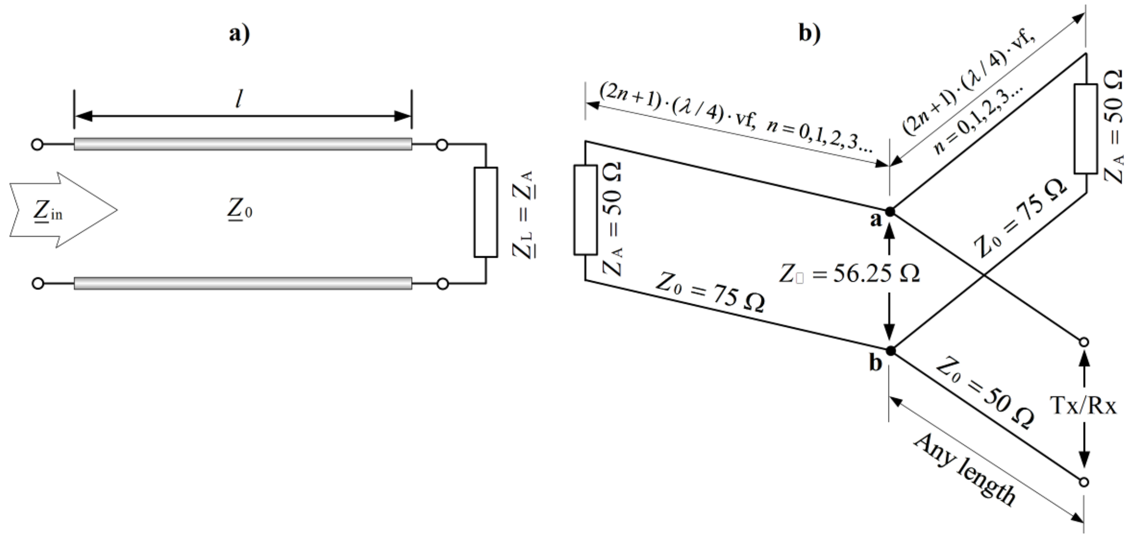

Fig. 4. a) Coaxial cable presented as a transmission line. b) Schematic diagram showing the parallel connection of two coaxial cables with a characteristic impedance of 75 ohms on coaxial cable with a characteristic impedance of 50 ohms. Coaxial cables are presented as a transmission line.

If the length of the transmission line is exactly one-quarter wavelength ($l = \lambda/4$), then the factor $\beta \cdot l$ is: $\beta \cdot l = (2\pi/\lambda)\cdot(\lambda/4) = \pi/2$, therefore it is $\cos(\beta l) = \cos(\pi/2) = 0$, $\sin(\beta l) = \sin(\pi/2) = 1$. This allows the expression (1) to be simplified to the form [7]:

$$\underline{Z}_{\text{in}} = \frac{Z_0^2}{\underline{Z}_{\text{L}}} \tag{2}$$

Using an analogous procedure for $L = 3\lambda/4$ the same expression for the input impedance is obtained. Expression (2) holds for any odd multiple of a quarter of the wavelength (λ/4, 3λ/4, 5λ/4, 7λ/4…). That is, taking into account the velocity factor (vf):

$$l = (2n+1)\cdot\frac{\lambda}{4}\cdot \mathrm{vf}, \quad n = 0,1,2,3,...\infty \tag{3}$$

Using the obtained expressions, it is possible to determine equivalent impedance obtained after matching the impedances using a 75 ohm coaxial cable as the impedance transformer. It is objective to assume that each of the antennas is electrically well built and its impedance is purely ohmic in nature and is 50 ohms ($\underline{Z}_{\mathrm{A}} \approx 50\,\Omega$). From the perspective of a 75 ohm coaxial cable, the impedance of the antenna corresponds to the load at its end i.e. $\underline{Z}_{\mathrm{L}} = \underline{Z}_{\mathrm{A}} \approx 50\,\Omega$. The characteristic impedance of a 75 ohm cable is $Z_0 = 75\,\Omega$. The input impedance, ie the impedance at the end of the coaxial cable opposite to the antenna according to expression (2) is $\underline{Z}_{\mathrm{in}} = 75^2/50 = 112.5\,\Omega$. The equivalent impedance between points "a" and "b" (Fig. 4.) corresponds to the equivalent impedance of the parallel connection of the previously obtained impedance, i.e.

$$\underline{Z}_{\square} = \frac{\underline{Z}_{\mathrm{in}}\cdot\underline{Z}_{\mathrm{in}}}{\underline{Z}_{\mathrm{in}}+\underline{Z}_{\mathrm{in}}} = \frac{1}{2}\cdot\underline{Z}_{\mathrm{in}} = \frac{1}{2}\cdot 112.5 = 56.25\,\Omega\,. \tag{4}$$

Although stacking two identical antennas theoretically increases the gain by 3 dBi, due to the losses in the coaxial cable, the practical increase in the gain of the stacked antenna is smaller. One part of the losses is in the main 50 ohm cable, and the other part of the losses is in the 75 ohm cables that are connected to each individual antenna. We used the same types and lengths of coaxial cables for both stacked antennas. The length of each branch of the 75 ohm coaxial cable is approximately 79 cm. The length of the 50 Ohm coaxial cable is two meters. Considering the attenuation in coaxial cables (0.3 dB/m), the equivalent attenuation is 0.9 dBi. That is, approximately one dBi. Therefore, in both cases of stacked antennas, the gain is approximately +2 dBi higher than the gain of an individual antenna.

SIMULATION RESULTS

Modelling, simulation and optimization of antenna parameters were performed using 4nec2 software [5]. For numerical calculations, 4nec2 software uses the numerical method of moments. The simulations were performed for an operating frequency of 446 MHz (so-called personal mobile radio (PMR)). The L profiles from which the reflector, driver and directors (10 mm x 10 mm x 1 mm) are built are modelled using a corresponding equivalent complex structure consisting of cylindrical conductors (Figure 5). In doing so, it was adopted that each individual cylindrical conductor has a diameter which corresponds to the thickness of the L profile. During the process of optimizing the antennas, we purposefully sacrificed about 0.5 dBi so that the antennas have a wider bandwidth. The obtained dimensions of the elements of each antenna and element spacing are summarized in Tables 1-2.

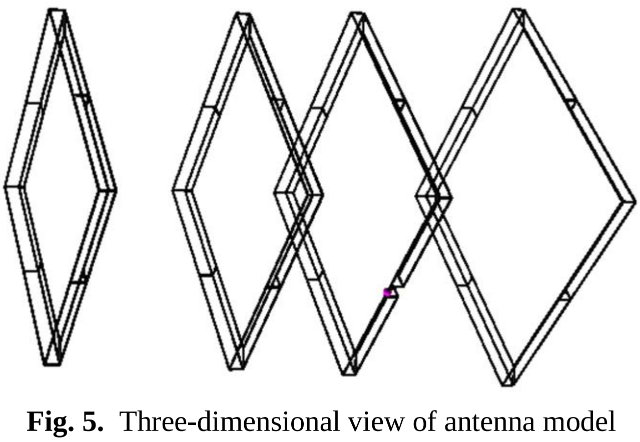

Fig. 5. Three-dimensional view of antenna model

Table 1. Three elements Quad dimensions

	Dimensions	
	Expressed in wavelength	Expressed in cm
Wavelength	1.000	67.2
Reflector side	1.190	20.0
Driver side	1.095	18.4
Director1 side	0.980	16.5
Distance reflector-driver	0.186	12.5
Distance director-driver1	0.149	10.0

Table 2. Four elements Quad dimensions

	Dimensions	
	Expressed in wavelength	Expressed in cm
Wavelength	1.000	67.2
Reflector side	1.179	19.8
Driver side	1.071	18.0
Director1 side	1.011	17.0
Director2 side	0.950	16.0
Distance reflector-driver	0.200	13.5
Distance director-driver1	0.129	8.7
Distance driver1-driver2	0.190	12.8

Using the 4nec2 software, 2D and 3D radiation patterns were obtained (Figures 6. and 7.). By repeatedly repeating the simulations for different vertical antenna distances (distances between the booms), we noticed that the maximum gain is achieved at a distance between the booms that corresponds to one wavelength. The radiation diagrams at maximum gain are shown in Figures 6. and Figures 7.

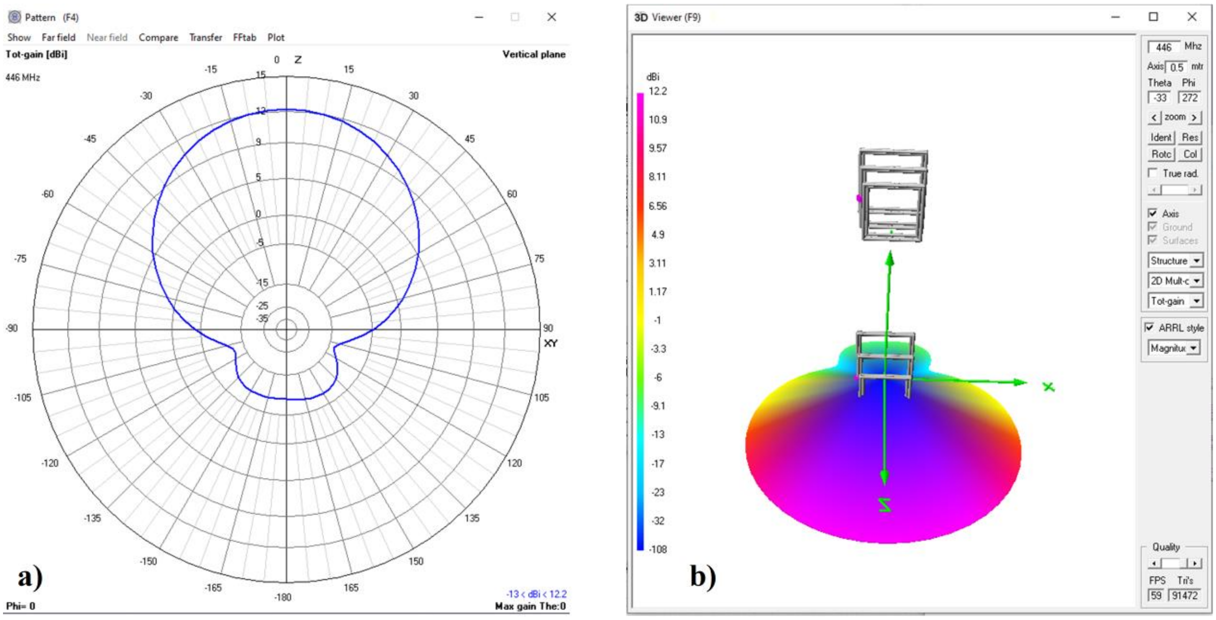

Fig. 6. Two stacked Quad antennas, each with three elements, radiation pattern (total-gain in dBi), three-dimensional view of antenna model and radiation pattern (total gain in dBi)

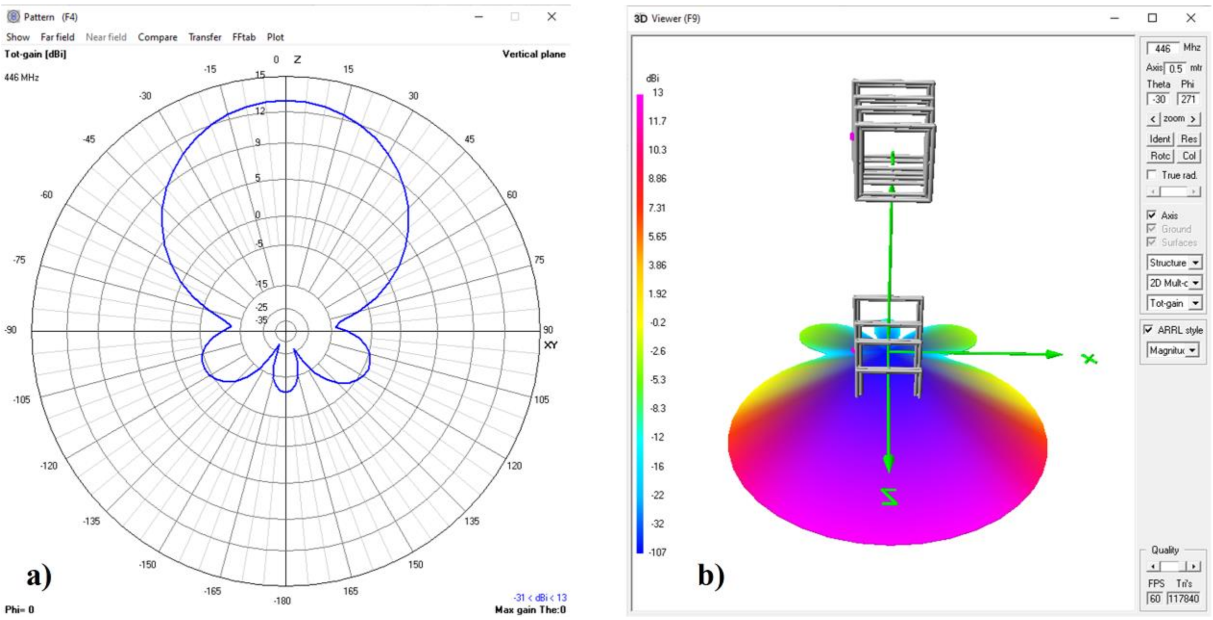

Fig. 7. Two stacked Quad antennas, each with four elements, radiation pattern (total-gain in dBi), three-dimensional view of antenna model and radiation pattern (total gain in dBi)

MEASUREMENT RESULTS

Common electrical parameters: impedance, components of complex impedance, S11 parameter, equivalent series capacitance (ESC), equivalent series inductance (ESL) and the voltage standing wave ratio (VSWR) were measured using the PS100 RF vector antenna analyzer meter [8]. Screen shots of the vector analyzer during the measurement are shown in Figures 8-9.

Fig. 8. Common electrical parameters of a two stacked Quad antennas and VSWR vs frequency of a two stacked Quad antennas, each with three elements.

Fig. 9. Common electrical parameters of a two stacked Quad antennas and VSWR vs frequency of a two stacked Quad antennas, each with four elements.

RESULTS AND DISCUSSION

The individual Quad antennas from which the presented stacked antennas for indoor use are made are well designed and have an impedance of approximately 50 ohms. According to the presented theoretical model (expression (4)), the expected impedance of a two stacked Quad antennas is approximately 56 ohms. Impedance of 54 ohms (Fig. 8.) was determined by measurement for an antenna consisting of a two stacked Quad antennas, each with three elements. That is, the impedance of 56 ohms (Fig. 9.) was determined by measurement for an antenna consisting of a two stacked Quad antennas, each with four elements. Both measured values are in high agreement with the theoretical prediction. At the operating frequency, both antennas have an VSWR lower than 1.5, which is considered an excellent result. According to Figures 8 and 9 (right figures), for VSWR lower than 1.5, both antennas have a bandwidth that is about 20 MHz wide. The theoretical gain for a stacked antenna consisting of two antennas, each with three elements, is 12 dBi (Fig. 6.). The theoretical gain for a stacked antenna consisting of two antennas, each with four elements, is 13 dBi (Fig. 7.). The obtained simulation results are consistent with the literature [1]. Considering the losses in coaxial cables, the actual gain is approximately one dBi lower for both antennas (see chapter feeding two antennas). Both antennas were tested and no problems with common mode currents were observed. The mechanical resistance to stress is excellent, after prolonged use, all connections remained tight. Also, several accidental impacts did not deform the loops, nor did they cause their misalignment.

CONCLUSION

Quad antennas have an excellent radiation pattern, electromagnetic properties and a relatively high gain for a certain boom length. With careful design of the Quad antenna, a wave impedance of exactly 50 ohms can be achieved. Also, they are significantly less prone to problems caused by common mode currents compared to Yagi antennas. Because of the above, they can be feed directly with a coaxial cable. That is, when using them, it is not necessary to adjust the impedance, nor is it necessary to use special techniques for attenuation of common mode currents, except in rare cases. Also, for the same boom length, they have a higher gain than Yagi antennas. However, by using typical construction solutions for making Quad antennas it is difficult to achieve satisfactory mechanical characteristics of Quad antennas for indoor use. In contrast, as shown in the article, the use of aluminium L profiles for the production of Quad loops and PVC L profiles for the production of supports of Quad loops, significantly improves the mechanical characteristics of the Quad antenna. As a disadvantage of the use of L profiles made of aluminium and PVC, we can state that the production of Quad antennas is significantly slower compared to using typical materials in a typical Quad design.

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SEISMIC VULNERABILITY OF MASONRY BUILDINGS BASED ON CALCULATION OF STRUCUTRAL DAMAGES

Marijana Hadzima-Nyarko[1], Gordana Pavić[1], Držislav Vidaković[1], Ema Pušić[1]
[1]Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering and Architecture Osijek, Osijek, Croatia
e-mail: mhadzima@gfos.hr

Abstract: Earthquakes are considered one of the strongest and most destructive natural forces since its consequences, in addition to material damage and damage to buildings, are human suffering, large economic losses and costs related to the care of the population after the earthquake. The two earthquakes that struck the Republic of Croatia two years ago demonstrated this. In order to reduce earthquake risk, this paper presents an earthquake risk assessment methodology based on the hybrid seismic vulnerability method. The hybrid seismic vulnerability method is based on the calculation of the Damage Index, i.e., the structural damage of the building. The building is represented by a single degree of freedom model. The described methodology was applied in an area of the city Osijek in the eastern part of the Republic of Croatia.
Key words: seismic vulnerability assessment, masonry building, Single Degree of Freedom system, Damage Index formula

INTRODUCTION

Earthquakes represent one of the most dangerous and destructive actions for humanity and everything that man has created. The consequences of an earthquake, in addition to human casualties and material damage, also cause enormous financial costs for the restoration or construction of new buildings and the care of people whose homes were destroyed in the earthquake [1].
The impact of earthquakes on urban areas is a complex problem that can simultaneously arise from several causally related hazards and consequential risks (tsunamis, liquefaction, landslides, etc.) and cause enormous material and human damage accompanied by socio-economic problems and crises [2], [3].
Croatia is located in an area of high seismicity, which is confirmed by the catastrophic earthquakes that occurred in the past (Cissa 361, Dubrovnik 1667, 1979, Ston 1996) as well as the recent ones in Zagreb and Petrinja (2020). The damage that occurred as a direct consequence of the dynamic response of the structures to the seismic ground motion emphasized the unreliability of earthquake predictions and the damage they can cause.
Earthquake risk is associated with the potential loss of life, injuries and damage to buildings and other material assets. It is determined by a probability function of three determinants of risk: hazard, exposure and vulnerability [1].
When establishing an earthquake risk model, in addition to the earthquake hazard at a certain location, it is necessary to include the exposure of the built environment and the population, and associate the appropriate level of physical vulnerability to the individual types of buildings [4].
There are various rapid and qualitative seismic vulnerability methods, as well as various quantitative methods based on structural conditions and modeling of seismic behavior, available to assess the seismic vulnerability of structures. In this article, the hybrid approach, which is based on the calculation of Damage Index (*DI*) of a Single Degree of Freedom (SDOF) system representing a real building is described.
The rest of the paper is organized as follows. The main components of seismic risk assessment (seismic hazard and vulnerability) are introduced, followed by the description of the used *DI* function and properties of the applied accelerograms. Seismic *DI* spectra for original records and different scaled records are then presented, and finally, the seismic vulnerability assessment is presented.

SEISMIC HAZARD

The Republic of Croatia is part of the Mediterranean-Trans-Asian belt; therefore, its entire area is characterized by pronounced seismic activity. Two earthquake zones stand out in particular: the coastal area and the northwestern continental part. The seismic zone of the coastal area, in the direction of northwest to southeast, stretches from the border with Slovenia to the area of Senj, with smaller breaks near Šibenik and Split, to Dubrovnik and its surroundings, which is an extremely seismic area. In this zone, earthquakes are the result of the subduction of the Adriatic platform under the Dinarides, which is caused by the movement of the African plate towards the Eurasian plate. The second zone stretches from the border with Slovenia west of Karlovac, through the Žumberačko mountains and Medvednica all the way to Kalnik and Bilogora, and in the area of the city of Zagreb it joins the active zone that stretches from Pokuplje. In this belt, earthquakes are caused by the movement of the Dinarides and the Alps [5].
Seismic hazard represents the probability of exceeding the value of the selected parameter of ground motion in a certain period. The strength of ground motion is most often expressed using the intensity or MCS scale. Earthquake hazard is assessed on the basis of assumptions, data on seismicity, using empirical and theoretical knowledge, as well as statistical methods. At the beginning of 2012, the Croatian Standards Institute accepted the new earthquake hazard map and included it in the National Anex to HRN EN 1998-1:2011 [6]. The new map was created for return periods of 95 and 475 years, it refers to the ground type A, which is defined as rock, and the peak acceleration of the bedrock is expressed in units of the acceleration of Earth's gravity.
Osijek is situated in the south-central Pannonian basin, along the Danube and Drava rivers, in a zone with lower seismic activity than the rest of Croatia. According to the seismic hazard map for a return period of 475 years, the peak acceleration for the area of the city of Osijek is 0.12g. Since there are no available accelerograms in the observed area, earthquake accelerograms from the PEER Ground Motion Database (available at: https://ngawest2.berkeley.edu/) were chosen for the specified peak acceleration. Details of the selected earthquakes are given in Table 1.

Table 1. Details of selected earthquakes from PEER Ground Motion Database

Earthquake Name	**Year**	**Station Name**	**Magnitude**	**Distance to rupture plane *R*rup (km)**	**Shear wave velocity *V*s30 (m/sec)**
Coyote Lake	1979	San Juan Bautista_ 24 Polk St	5.74	19.7	335.5
Coalinga-01	1983	Parkfield - Cholame 1E	6.36	43.68	326.64
Taiwan SMART1(5)	1981	SMART1 I06	5.9	26.4	309.41
Chalfant Valley-03	1986	Bishop - LADWP South St	5.65	24.41	303.47
Morgan Hill	1984	Capitola	6.19	39.08	288.62
Hollister-04	1986	Hollister Differential Array #3	5.45	14.11	215.54
N. Palm Springs	1986	Palm Springs Airport	6.06	10.84	312.47

SEISMIC VULNERABILITY

Earthquake vulnerability refers to the amount of damage, as a result of an earthquake of a certain intensity, that could occur in the structure. The amount of possible damages when assessing the earthquake vulnerability of buildings is determined by a number of factors, including the intensity of the earthquake, the condition of the soil, the static systems of the structures, structural elements and materials, the condition of the structure, etc. When assessing the seismic behavior of structures, it is extremely important whether the building is designed to withstand earthquakes (newer buildings designed according to modern seismic codes) or whether it is designed to withstand only its own weight (historical buildings). The choice of a particular method is determined by the nature and objective of the study, the characteristics of the building or group of buildings being studied, the available information, the suitability of a particular seismic vulnerability assessment method, the organization that receives the results and makes decisions [7].

The seismic vulnerability assessment methods require large amounts of various input data and can generally be divided into three groups: empirical, analytical and hybrid methods.

Empirical methods for assessing vulnerability are based on the observations of damages sustained during past seismic events. It can be pointed out that empirical methods are very subjective since they are based on experience gathered from observed damages on various types of buildings. These methods are employed at the territorial level when the available information is limited and for a rapid preliminary assessment of a building or a large number of buildings. These qualitative assessments are typically developed on-site using evaluation questionnaires and visual inspections. The results provide an earthquake vulnerability rating of low to high for each building. The vulnerability class and vulnerability index incorporate the most often used empirical methods [7].

In contrast to empirical methods, analytical methods are based on computer simulations that predict structural damage due to earthquakes, and vulnerability is expressed numerically (e.g. total displacement, ultimate strength, etc.) [8]. These are quantitative methods that require many attributes to model the actual physical characteristics of the real building, which takes more time and is much more complex. They are most often used to assess the vulnerability of buildings of great importance, such as hospitals, schools, historical buildings, museums, etc. [7].

Hybrid methods correspond to a combination of empirical, analytical and experimental methods for assessing the earthquake vulnerability of buildings with the aim to obtain more reliable results for a group of buildings [9].

DAMAGE INDEX

Damage Index (*DI*) can be define as a mathematical model that describes the condition of structural damage and is most directly connected to earthquake damage. *DI*, which represents the degree of structural damage, ranges from 0 to 1. A value of 1 represents the collapse of the building, and 0 represents an undamaged state. For *DI* values between 0 and 1, some qualitative or quantitative indicators of expected degradation, such as the number and types of cracks or its sizes, spalling of cover concrete or crushing of concrete, decrease in strength capacity, or buckling of reinforcement, must be specified.

Several methodologies and critical evaluations for assessing structural deterioration as well as different definitions of *DI* have been studied during the last few decades [10], [11]. Damage indices might be local or global (taking into account the whole structure), probabilistic or deterministic, structural or non-structural etc. Other classifications might include stiffness, deformation, or energy indices, or a combination of these, cumulative or noncumulative indices, and so on [10], [11].

DI can include one or more vulnerability variables. Examples of vulnerability variables are deformations at the element and/or section level, ductility, dissipated energy, inter-story displacements, stiffness, etc.

DI, proposed by Morić et al. [12], is described as a linear combination of a structure's plastic deformations, stiffness deterioration, and energy dissipation during an earthquake:

$$DI = \frac{1}{30}\left[\mu + \Delta k + \sqrt[3]{\frac{N_Y E_H}{W}}\right] \quad (1)$$

where: $\mu = u_{max}/u_y$ is required ductility displacement; $\Delta k = K_{el}/K'$ is relative stiffness degradation at the end of the earthquake; $K' = BS_{max}/u_{max}$ is residual secant stiffness; K_{el} is initial stiffness; N_Y are the number of yield cycles; E_H is the hysteresis energy dissipated during an earthquake, and W is weight of structure.

On buildings affected by the earthquake, it is necessary to determine the damage so that the structures that have suffered damage can be repaired, and those that are not suitable for repair due to the extensive damage they have suffered are demolished. This is the main task of classifying structures into degrees of damage. The values of *DI* are related to the damage state and the classification is based on 5-category criteria similar to EMS-98 [13].

Table 2. Correlation of *DI* values with damage states of buildings

Value of *DI*	Damage description	Damage state defined in EMS-98
$1.0 < DI$	Extremely high level or collapse	Collapse
$0.8 < DI \leq 1.0$	Heavy	Extensive
$0.5 < DI \leq 0.8$	Severe	Moderate
$0.3 < DI \leq 0.5$	Moderate	Light
$DI \leq 0.3$	Insignificant	Slight

PROPOSED SEISMIC VULNERABILITY ASSESSMENT METHODOLOGY FOR MASONRY BUILDINGS

The initial step of the proposed methodology consists of representing the regular structure with an SDOF model. The SDOF model must have the following parameters defined: damping, weight, elastic stiffness, post elastic stiffness and elastic base shear capacity. Seismic response analysis for SDOF model may be conducted as a simplified non-linear dynamic analysis using the time history function of ground motion as input load. The proposed methodology involves the application of appropriate *DI* spectral functions in order to perform a quick seismic vulnerability assessment (plot of a number of SDOF models with different fundamental periods).

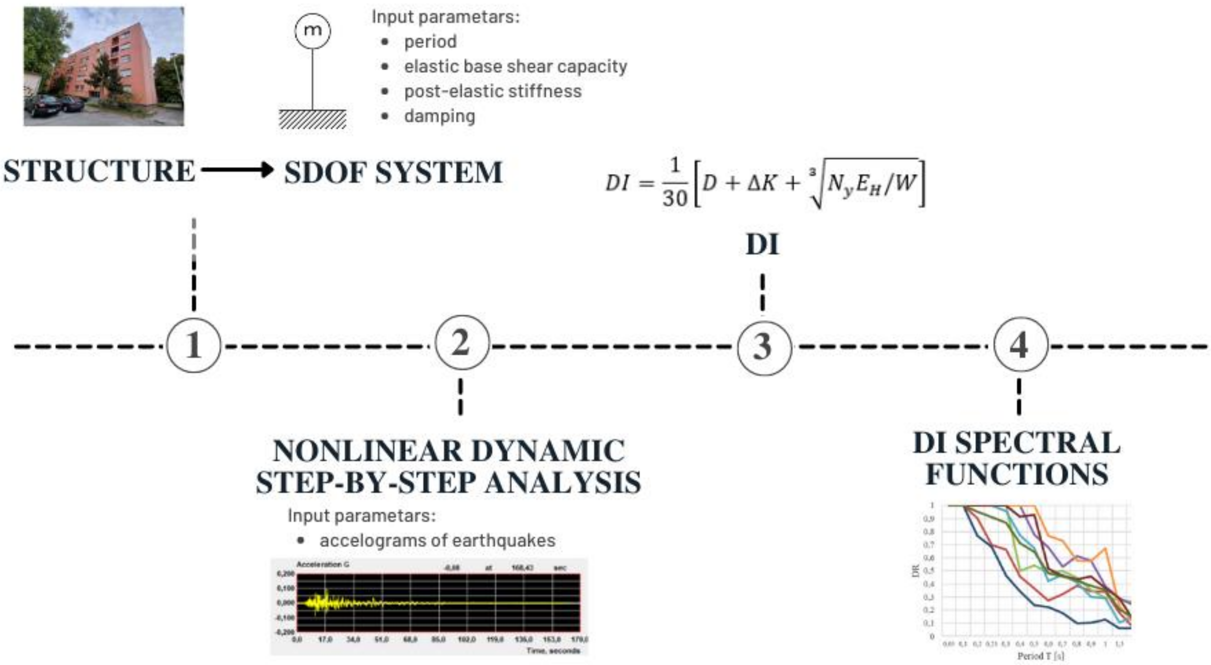


Fig. 1. Seismic vulnerability assessment methodology based on the calculation of *DI*

STUDY AREA

Knowledge of the structural system of the building and its behavior in the earthquakes that occurred in the area, the building codes that were adopted during construction, the location and distribution of vulnerable buildings in the earthquake area is very important for assessing the impact of earthquakes on the built-up area. The building inventory is a database of buildings and their typologies, thus exposure to specific hazards is defined according to them, and serves as input data for which losses are calculated. The building database consists of information about the building, including its purpose, year of construction, height, location, etc.

In this paper, one typical settlement in Osijek was selected (Fig. 2), consisting of five-story buildings built in 1975. The height of the buildings is 14.4 m. The average dimensions of the buildings are 10.9 m wide and 19.6 m long, while one building is 9.15 m wide and 27.54 m long, and one is 9.15 m wide. m and length 31.0 m. All buildings are confined masonry buildings. The thickness of the outer and inner walls is 30 cm. The floor structure is 12 cm thick. The roof structure is a flat roof system. The foundations are made of concrete with dimensions of 65 x 80 cm. Data on the buildings are presented in Table 3.

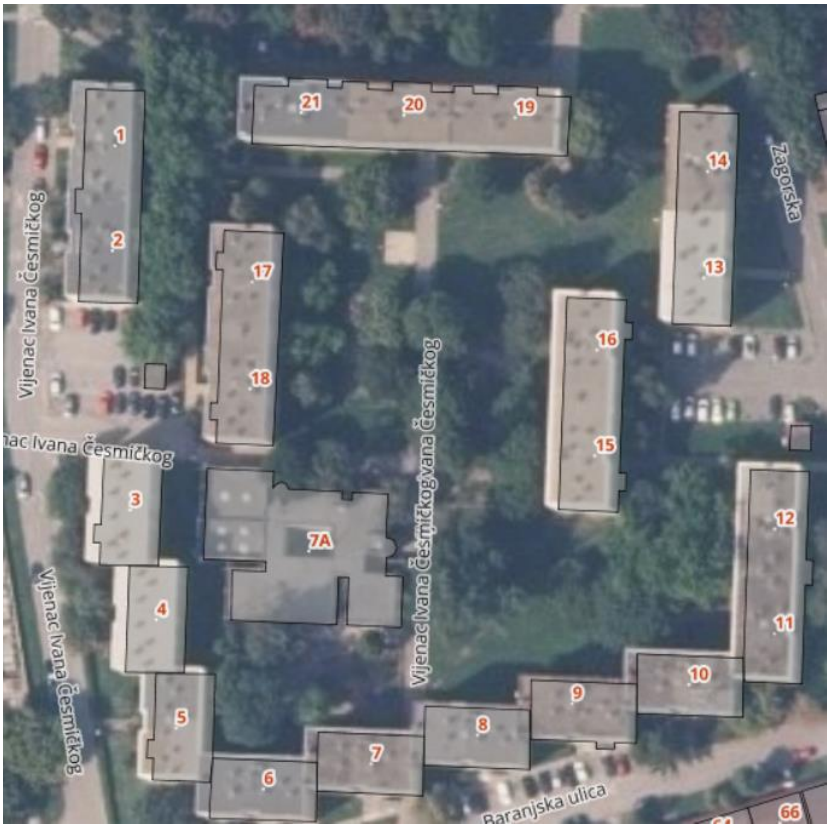


Fig. 2. Selected settlement of buildings in Osijek

Table 3. Collected data of selected buildings

Street and street number		Vijenac Ivana Česmičkog 1-18	Vijenac Ivana Česmičkog 19	Vijenac Ivana Česmičkog 20/21
Purpose of the building		Residential	Residential/Commercial	Residential/Commercial
Construction year		1975	1975	1975
Dimensions	**width [m]**	10.9	9.15	9.15
	length [m]	14.4	25.74	31.0
Brutto area of one storey [m^2]		213.4	251.99	283.65
Total brutto area [m^2]		1068.2	1259.96	1418.25
Number of storeys		5	5	5
Storey height [m]		2.8	2.8	2.8
Total height [m]		14.4	14.4	14.4
Material		Solid brick	Solid brick	Solid brick
Floor structure		Reinforced concrete slab	Reinforced concrete slab	Reinforced concrete slab
Structural system		Confined masonry	Confined masonry	Confined masonry

RESULTS AND DISCUSSION

For the selected building shown in Fig. 3, it is necessary to determine the parameters of the SDOF model that will represent it.

Fig. 3. Building type of the selected city block

Another important item must be defined, namely the parameters of the SDOF model that will describe the masonry building, specifically confined masonry. For post-elastic stiffness, it is assumed that K_2 = 0. This assumption is based on the following findings: due to the lack of post-elastic stiffness in masonry constructions, the elastic-perfectly plastic behavior is considered as a post-elastic branch. In Brzev [14], it is stated that in Chile since 1949, the construction of one- or two- storey confined masonry houses are quite stiff and they must resist a base shear of 10-22% of building weight. Therefore, in this study, we used two models, the first with BS_y=0.1W and the second with BS_y=0.2W. This was done to observe the effect of yield base shear on the level of structural damage of the building.

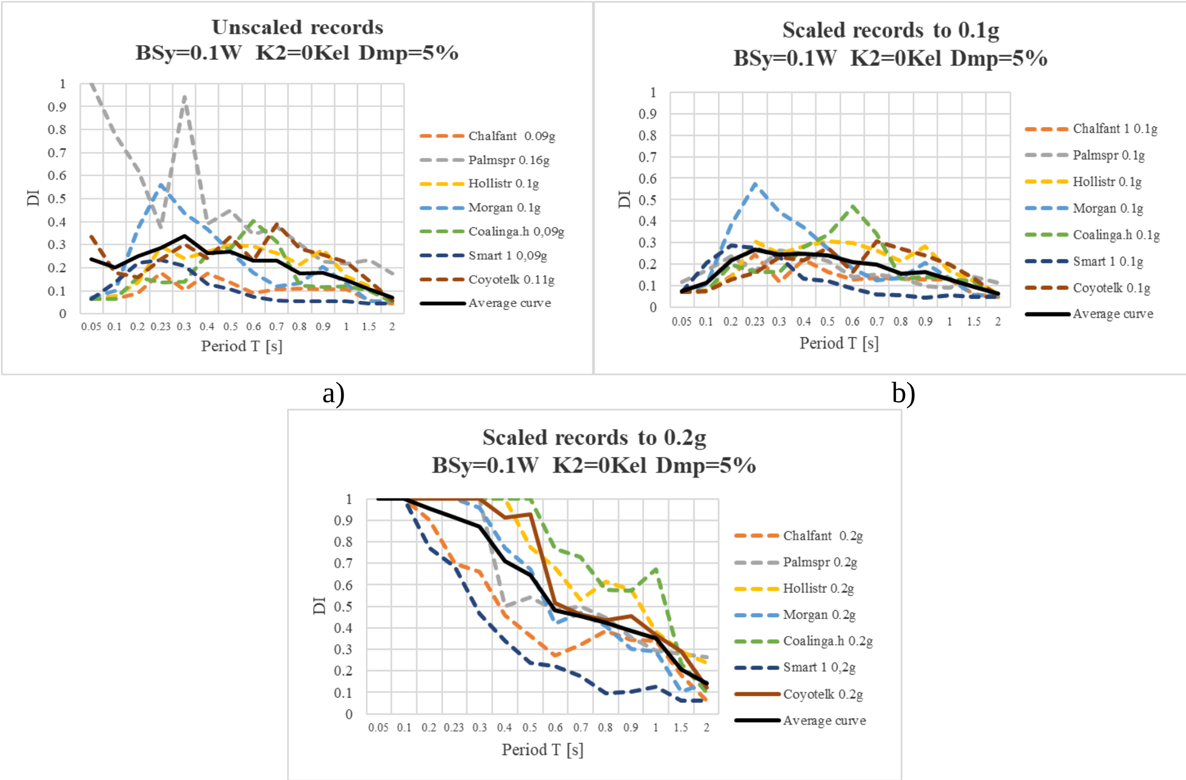
The fundamental period can be obtained using a simple formulation of the relationship fundamental period (T) and height (H), using the formula in the Croatian National Annex to Eurocode 8 [6]:

$$T = 0.016H \tag{2}$$

According to the Eq. (2), the fundamental period of the selected buildings is 0.23 sec.

For the defined parameters of the SDOF model and selected acceleration time-history records, a nonlinear dynamic time-history analysis was performed using the software NONLIN. After each stage of analysis, *DI* was calculated based on Eq (1). *DI* calculations were repeated for a set of SDOF systems with a wide range of fundamental periods from 0.05 sec to 2.0 sec in steps of ΔT = 0.1 sec.

Spectrum presented in Fig. 4. a) is determined by applying a set of original earthquake acceleration records, while spectra presented in Figs. 4.b) and 4.c) are created using the scaled acceleration records (i.e., PGA= 0.1g, 0.20g and 0.30g, respectively). Dashed lines show the damage indices of real earthquake records, while the black line is the average curve from all other seven spectra.



a) b) c)

Fig. 4. Spectral damage functions for SDOF with defined parameters for: a) unscaled earthquake records, b) earthquake records scaled to 0.1g, c) earthquake records scaled to 0.2g

For the observed confined masonry building, which is represented by the defined parameters of the SDOF model, for a fundamental period of 0.23 sec, possible damages can be read on the spectra shown in Figure 4. For a set of unscaled earthquakes, *DI* values range from 0.07 to 0.33, while the average value for all earthquakes is 0.16, which represents insignificant damage. For earthquakes scaled to 0.1g, *DI* values are very similar since the selected earthquakes have peak ground acceleration (*PGA*) from 0.09g to 0.16g. So, for earthquakes scaled to 0.1g, *DI* values range from 0.09 to 0.15, and the average value is 0.15. For earthquakes scaled to 0.2g, *DI* values range from 0.38 to 0.93, and the average value is 0.7, which represents severe damage. The results of obtained values for *DI* are shown in Table 4.

Table 4. *DI* values for SDOF with following parameters: K_2=0, T=0.23 sec, BS_y=0.1W and BS_y=0.1W

SDOF model	K_2=0, T=0.23 sec, BS_y=0.1W			K_2=0, T=0.23 sec, BS_y=0.2W		
Earthquake Name	**Unscaled records**	***PGA* 0.1g**	***PGA* 0.2g**	**Unscaled records**	***PGA* 0.1g**	***PGA* 0.2g**
Coyote Lake	0.24	0.16	1	0.06	0.06	0.17
Coalinga-01	0.14	0.17	1	0.06	0.06	0.18
Taiwan SMART1(5)	0.23	0.28	0.68	0.08	0.09	0.30
Chalfant Valley-03	0.18	0.24	0.70	0.06	0.07	0.26
Morgan Hill	0.56	0.57	1	0.11	0.11	0.62
Hollister-04	0.29	0.31	1	0.08	0.11	0.33
N. Palm Springs	0.37	0.17	1	0.13	0.06	0.18
Average curve	0.29	0.27	0.91	0.08	0.08	0.29

CONCLUSION

In this paper, an assessment of the seismic vulnerability of the confined masonry building was carried out. The assessment of seismic vulnerability is based on the calculation of the damage index (*DI*), which is based on a linear combination of a structure's plastic deformations, stiffness deterioration, and energy dissipation during an earthquake. A set of 7 earthquakes (with *PGA* ranging from 0.09g to 0.16g) was selected for the selected building located in the city of Osijek. For unscaled and scaled earthquakes at 0.1g and 0.2g, a series of nonlinear dynamic analysis of the SDOF system with defined input parameters were performed and spectral functions *DI* were constructed. The results show that the value of *DI* changes depending on the selected earthquake and depends both on the parameters of the SDOF model and on the earthquake frequency content. Based on the calculation of the average values for *DI* for all 7 earthquakes, the results show that the building would experience insignificant damage for a *PGA* of 0.1g. For a *PGA* value of 0.2g, the building would suffer heavy damage. In this study, the effect of yield base shear on the building damage degree was investigated. Thus, for a building with $BS_Y=0.2W$, it can be observed that in the event of an earthquake with *PGA* of 0.1g, the building would experience insignificant damage, as well as for *PGA* of 0.2g, but the average value of 0.29 is close to the moderate damage state. Further research needs to be carried out in order to determine the impact of the determination of the yield base shear on the *DI* values.

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UTILIZATION OF PM PREVENTION MEASURES ON CONSTRUCTION SITES IN NOVI SAD DURING 2021

Miljan Šunjević[1], Boris Obrovski[1], Vladimir Rajs[1], Milena Šunjević[2], Mirjana Vojinović Miloradov[1]
[1]University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
[2]University of Novi Sad, Faculty of Medicine, Novi Sad, Serbia
e-mail: msunjevic@uns.ac.rs

Abstract: Ambient air pollution is very problematic environmental issue, with Particulate matter (PM) as one of the key pollutants. The PM can peregrinate far away form place of origin due to particle diffusion dynamics. Construction industry is rapidly expanding transforming urban matrices in city of Novi Sad, Serbia. Numerous construction site allows production of high PM concentrations. This paper represents research on particulate matter emission from construction sites in Novi Sad. The research follows monitoring of 100 construction sites in Novi Sad during 2021. On construction sites selected available prevention measures were monitored.
Key words: PM emission, construction sites, prevention measures

INTRODUCTION

Nowadays, at the global level air pollution environmental challenges are considered crucial for population health. Anthropological effect on air pollution is caused by chemical molecules and suspended particles. Hazard effects on the environment and human health is inflicted by ambient air pollution [1–5]. There is high association of ambient air pollution with public health, biocenosis status, regional and global climate [6,7]. Particulate Matter – PM is considered to be basic omnipresent factor of air pollution. World Health Organization have marked fine suspended particles smaller than or equal to 10 µm to have a more direct impact on the environment [8].
Countries in development due to heavy industry have significant air pollution problem [9,10]. Economic trends in developed countries dictate need to compensate in various areas among which is environmental protection. PM pollution in developing countries could be considered as daily routine. High urban transformations processes follow development of areas, which results in numerous uncontrolled building sites. Amplified anthropogenic activities during processes of urban transformation and city development generates and emits high concentrations of suspended particles in surrounding built and natural environment [11–14]. Various researches have confirmed that building through its whole lifecycle emits increased PM concentrations [15–17]. Each construction process that follows urban transformations has different influence on particle emission and is often dependent on meteorological conditions. Distinctive construction activities during the building processes are important sources of PM in the ambient air:
- Site preparation (land clearing and demolition of existing buildings)
- Earth excavation and transport
- Moving equipment and moving machines
- Transport and storage processes (loading, unloading, transfer and storage)
- Specific activities in accordance with the position being performed
- Final activities

Construction origin of high PM concentrations in the ambient air pressured governments in developed countries to create mitigation measures and models [3,18–22]. The efficiency of created mitigation measures and models was ensured by introducing legislations and strict inspections.
Meteorological conditions have a great influence on the generation and emission of suspended particles. The used/worked materials are important elements in PM emission and generation processes. More humid material, the particles are strongly held together (statical tension occurs), which decelerate their emission into the ambient air. The Canadian Environment Agency annual reports estimated that construction processes account around 20% of total suspended particulate emissions [21]. Emitted particulate matter endangers both workers on construction sites and nearby residents

[12,23]. The long-range transport ability (effected by particulate size) allows PM to travel far from the source, creating hazard effect in the long run.

MATERIAL AND METHODS

Areas of urban transformations are constantly changing, progress and improving. Construction sites create specific system with determined expiration date and unseen effect on the total environment. Experiences from developed countries assert that construction processes need to be followed by adequate monitoring and prevention models and methods. Measures can be considered through prediction and detection phase. Prediction determines critical pollution spots in the planning sequence, while detection follows the works and give real time input. The research is based the detection phase, and implemented through monitoring of construction sites.

The research was implemented in the city of Novi Sad, Serbia. Monitoring was performed on 100 active construction sites during 2021. During research period the utilization of PM prevention measures was inspected (location are shown in the figure 1.).

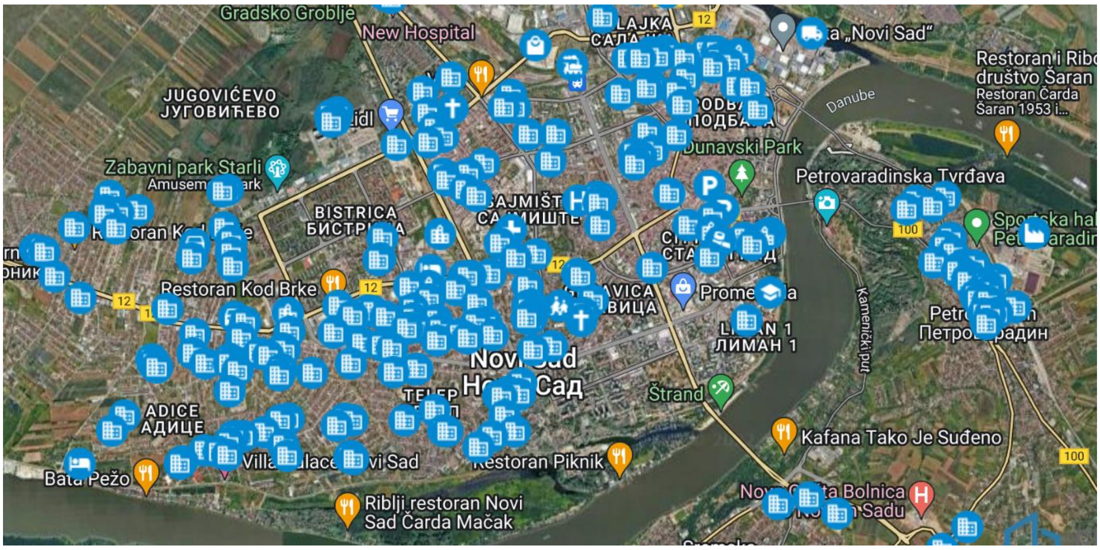

Fig. 1. List of active construction sites in Novi Sad during 2021[24].

The experience of the developed countries was observed through the construction manuals and guides. The presented measures given in the manuals were investigated and selected to fit the application in Serbia's building environment. Measures investigation and selection was performed during the authors PhD thesis research. Selected measures include:

- Keeping the existing vegetation
- Stabilization covers and geotextile
- Vegetation covering
- Mulching
- Adequate material handling
- Stored material covering
- Material transport covering
- Machine installation of powder materials
- Protective curtains
- Wind fences
- Controlled entrance
- Washing machine tires before exit (manual or automatic)
- Road paving
- Road definition and marking
- Speed limitation
- Transport road watering

- Maintenance
- Water spraying
- Use of suppressants

RESULTS AND DISCUSSION

The research and monitoring of construction sites is the consecutive part of first ever research based on following the utilization of PM emission mitigation measures on construction sites in Novi Sad. The results of the research are given in table 1. with goal to provide existing level of measure utilization and present the weak areas that needs to be addressed. On specific measure that was not included in the monitoring process was creation of green buffer zones. This measure could not be followed due to its previous incorporation into the urban zones core of Novi Sad.

Monitoring results show low level of PM prevention measures utilization for the most of the selected measures. The fully applied measures are setting up wind fences, controlled entrance, road definition and marking, and speed limitation. This can be seen through the legislations existence for given measures. All of the construction sites are required to have roads and entry point marked and organized, maximum speed limit inside should be 20 km/h, with fences installed around the site. Machine installation of powder materials have high percentage because it is more efficient, easier and cheaper measure. Road paving achieves high percentage for its economic reasons and it keeps moving on the construction site on efficient level.

Table 1. Results of measures utilization monitoring.

Monitored measures	**Application %**
Keeping the existing vegetation	5%
Stabilization covers and geotextile	0 %
Vegetation covering	4 %
Mulching	3%
Adequate material handling	20 %
Stored material covering	30 %
Material transport covering	35 %
Machine installation of powder materials	92 %
Protective curtains	40 %
Wind fences	100 %
Controlled entrance	100 %
Washing machine tires before exit (manual or automatic)	2 %
Road paving	75 %
Road definition and marking	100 %
Speed limitation	100 %
Transport road watering	30 %
Maintenance	10 %
Water spraying	30 %
Use of suppressants	0 %

Lower to medium usage of PM mitigation measures is seen in adequate material handling, covering of the stored material and material during transport, setting up the protective curtains, road watering and water spraying. Rising number of construction sites and small number of qualified workers has seen its tool in the quality of material handling, storing and transportation. Low numbers for water spraying can be explained through the lack of necessary equipment on the building sites and water savings.

Almost non existing measures on the construction sites in the city of Novi Sad are keeping the existing vegetation, different area covering including mulching, maintenance, use of suppressants and washing of the tires. The reason for these results can be found in the lack of care for the environment, high prices and absence of knowledge.

CONCLUSION

Research results of PM prevention and mitigation measures has shown that there are two main factors for application of selected measures: economic and legislations. In the results it is noticeable that the fully applied measures were the one determined by law. Measures that are defined by legislations mostly depends on the economic factor. Economic factor is one of the key drivers for measures utilization. Mechanization and material availability, efficiency, workers education and qualification level, time consumption and other are just some of the economic subfactors that needs to be taken into consideration. Most of the time application of the measures can be considered as good practice of the contractor companies and as part of the management experience of leading engineers. With the environmental protection, public and workers health in mind, it is imposed that new regulations will need to be created.

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MULTICRITERIA ANALYSIS OF PREVENTIVE MEASURES IN ORDER TO REDUCE THE RISK OF ACCIDENTS IN MINES WITH SURFACE OPERATIONS

Dejan Bogdanović[1]
[1]University of Belgrade, Technical Faculty in Bor, Bor, Serbia
e-mail: dbogdanovic@tfbor.bg.ac.rs

Abstract: Accident risk management in mining facilities includes measures to eliminate the possibility of accidents, which ensures that the risk of hazardous activities and hazardous substances is acceptable. Accident risk reduction takes place through accident prevention phases that are elaborated in detail separately for each mine and for each type of mining activity. In this paper, a multi-criteria analysis of the most important prevention measures is done in order to reduce the risk of accidents in mines with surface exploitation. The analysis was performed by AHP method. The results are used to develop an optimal plan for mine prevention from accidents, and the most important measures are the selection of those technologies and techniques that pollute the environment less and the determination of endangered zones and adequate spatial planning for new facilities, settlements and excavation dynamics.
Key words: mine, risk, accident, AHP

INTRODUCTION

Mines with surface exploitation must take into account the risks of accidents that may arise due to the natural disasters or some breakdowns in the process. They can cause damage both in the mine itself and in the environment – on private objects, land, water, air, flora and fauna, etc. For this reason, mines are obliged to make up annual plans for the occupation of land, the purchase or dislocation of buildings and the expansion of the sanitary protection zone around the mine where, in the event of a mine accident, environmental endangerment appears [1]. Along with the given plans, plans are being made for the recultivation of degraded land in and around the mine, too.
Also, a detailed analysis of the impact on the environment is made for open-pit mines. This analysis assesses the impact and determines measures of prevention, preparedness and response to accidents that would be caused by both natural disasters and malfunctions in the work process. The most risky accidents are related to objects containing dangerous substances (fuel and lubricant storages, tanks, landfills, mining slopes and machines in the production process). During an accident, these objects can be damaged, and this can lead to endangerment of the ecological factors of the environment, as well as the mine's facilities, including the employees [2].
Prevention includes a set of measures and procedures that are undertaken at the potential site of an accident at a surface mine. The aim of prevention is to prevent and reduce the probability of an accident and its possible consequences. Prevention measures and procedures are determined based on the risk assessment, with the probability of their effectiveness being adequate to the probability of an accident occurring. Also, prevention measures and procedures must take into account the specifics of each mine related to the applied technology, the type of mineral raw material, the size of the surface mine, the number of employees, etc. [3, 4].

MATERIAL AND METHODS

The appropriate work methodology is defined in order to obtain optimal results. An accident at a mine can cause significant problems, so prevention measures aimed at minimizing the risk of an accident are discussed here.

The unique work methodology, defined by the author, is shown in Fig. 1.

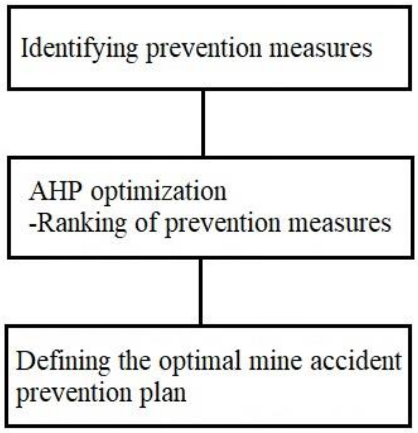

Fig. 1. Schematic presentation of the work methodology

Fig. 1 shows that research begins with the process of identifying prevention measures. The measures were identified on the basis of existing regulations in the field of mining, as well as on the basis of interviews with managers and experts of mining companies in our country. The questions are designed in such a way as to obtain the necessary data based on experiences and prevention measures that should be applied with the aim of optimal functioning of surface mines.
After the interviews, the author defined the final list of prevention measures with company managers. In doing so, it was concluded that the application of all identified measures is necessary, because this is the only way to reach an optimal prevention plan and reduce the risk of accidents in surface mines.
In the next phase, the prevention measures from the list were ranked in order to prioritize their implementation. The AHP method was used for the ranking, where the ratings were given by the group decision-making method (author with managers and experts from open surface mines).
After obtaining the ranking results, the optimal mine prevention plan was defined with the aim of minimizing the risk of accidents. Consequently, the plan contains the optimal sequence of defined prevention measures that are applied based on the defined priority.

AHP METHOD

AHP is a well-known quantitative method for ranking alternatives and it decomposes a complex decision problem into a multidimensional hierarchical structure consisting of objectives, criteria and alternatives. Using the AHP method, the influence of criteria is determined, alternatives are compared in relation to each criteria, and alternatives are finally ranked [5].

Table 1. Decision-making elements comparison scale

Dominance	
Description	**Mark**
Equal	1
Weak dominance	3
Strong dominance	5
Very strong dominance	7
Absolute dominance	9
2, 4, 6, 8 are intermediate values	

The comparison matrix is the basis for mutual comparison of criteria and comparison of alternatives in relation to criteria. The aim of the comparison is to obtain the size of the impact of the criteria on the ranking result, as well as the "strength" of each alternative. These quantities are called the weight coefficient. They are determined by means of appropriate grades that evaluate the criteria and alternatives. In doing so, the degree of consistency is also calculated and its value must be less than

10% (0.1) in order for the ranking result to be accepted. Comparison of criteria and alternatives is done using a scale with grades from 1 to 9 – Tab. 1.
Determination of the final ranking of alternatives is done by synthesizing the results obtained at all levels.

RESULTS AND DISCUSSION

Identification of prevention measures

Since the research was based on the results of interviews with managers and experts of mining companies, a list of accident prevention measures was obtained based on their assessment and existing regulations related to mining. When a list of all the proposed measures was obtained, an analysis of the given measures was carried out and a final list containing essential accident prevention measures at mining companies was made. This list includes the following measures:

- Selection of those technologies and techniques that pollute the environment less and provide a higher degree of protection (M1). This measure implies the selection of more modern available technologies and techniques that have a higher degree of reliability in operation and less pollute the environment and provide a higher degree of protection. This measure significantly reduces the risk of accidents in mines, but requires large investments. The solution is in a phased investment in the improvement of technologies and techniques.
- Maintenance of work technology discipline at the required level (M2). This measure implies the development and implementation of internal instructions for the operation and maintenance of devices based on the law and regulations given on technical norms and occupational safety during the surface exploitation of solid mineral raw materials and valid domestic and international standards. This measure is applied in all mining companies. The goal is to maintain work technology discipline at an appropriate level and ensure proper operation and handling of equipment by workers, as well as proper maintenance of equipment and proper maintenance of all roads and passages to and from dangerous installations, which can significantly reduce the risk of accidents at the mine .
- Application of technical means and equipment for detection and protection (automatic detection and extinguishing of fires, dilators for measuring the movement of the slope of the mine or tailings dump, etc.) (M3). This represents a set of measures aimed at timely detection of the danger of accidents in the mine, as well as the elimination of certain dangers. The specified set of measures implies the installation of appropriate measuring stations and other devices in and around the surface excavation.
- Control and supervision of monitoring in the security system, especially for the spread of chemical hazards (dust and gases in the environment, dangerous shocks, noise, etc.) (M4). This is a set of measures that experts say are gaining more and more importance due to increasing public pressure to protect the environment. Surface mines are a major source of environmental pollution, partly because the above measures have not been applied to a significant extent.
- Timely elimination of all observed technical and technological deficiencies (M5). The aforementioned preventive measures aim at constant control and elimination of all defects that may occur in the production process. In this way, many potential risks of accidents in surface mines can be avoided, because any deficiency can lead to a chain failure in the operation of many systems.
- Determining the zones of environmental threat (I, II, III) and adequate spatial planning for the construction of new buildings, settlements and excavation dynamics (M6). These preventive measures have the task of protecting and timely preparing the environment around the surface mine for future exploitation. The emphasis is primarily on the protection of buildings, settlements and the area around the mine, the purchase and relocation of buildings, the construction of the necessary mine buildings and facilities in accordance with the expected dynamics of mine development.

- Timely information and involvement of the public in decision-making on all issues important for the safety of the population (M7). The mining sector must create an effective system of communication with the public. The public, especially the population around surface mines, must be included in the decision-making process related to their safety, environmental protection, etc. In this way, good cooperation between all stakeholders can be achieved, which can significantly reduce the risks of accidents for them.

AHP optimization

After identifying all preventive measures aimed at reducing the risk of accidents at mining companies, the given measures are ranked using the AHP method. As it was said, the aim of the ranking is the prioritization of preventive measures against accidents, which will enable the development of an optimal mine accident prevention plan.
The ranking of the measures was carried out by managers and experts, as mentioned above – Tab. 2.

Table 2. Comparison marks of accident prevention measures

	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**
M1	1	2	3	4	3	1	3
M2		1	2	1	1	1/2	1
M3			1	1	1/3	1/3	1/2
M4				1	1/3	1/4	1/2
M5					1	1/2	1
M6						1	1
M7							1

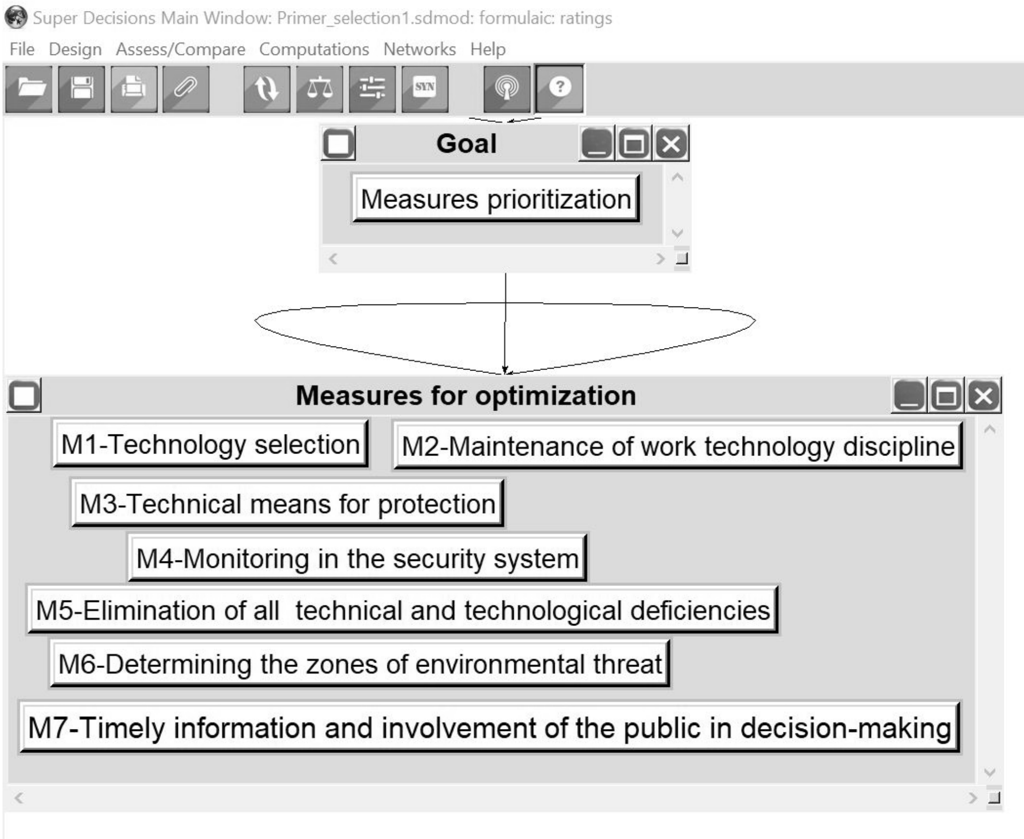

Fig. 2. Multidimensional hierarchical structures of goals and measures

After comparing the preventive measures, the Super Decisions software was used to obtain the results of the ranking of the measures. In doing so, a multidimensional hierarchical structure of goals and measures was determined – Fig. 2, and after that the weighting coefficients of the proposed measures were determined (the results are shown in Fig. 3).

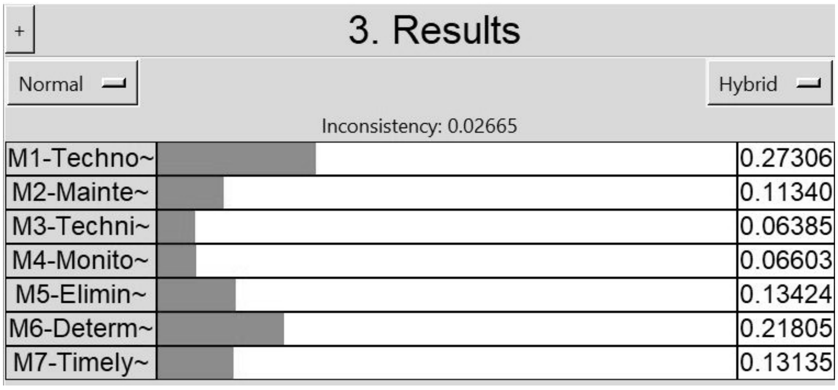

Fig. 3. Results of optimization

The degree of inconsistency is 0.02665, which is less than 0.1, so the results are consistent.

Defining the optimal mine accident prevention plan

The obtained results (Tab. 3) can be seen as very important guidelines for mines in terms of the priority in which the defined preventive measures should be applied when creating an optimal mine accident prevention plan.

Table 3. Ranking result with weight coefficients

No.	Proposed measures	Result
1.	M1 (Selection of those technologies and techniques that pollute the environment less and provide a higher degree of protection)	0,27306
2.	M6 (Determining the zones of environmental danger (I, II, III) and adequate spatial planning for the construction of new buildings, settlements and excavation dynamics)	0,21805
3.	M5 (Timely removal of all observed technical-technological deficiencies)	0,13424
4.	M7 (Timely informing and involving the public in decision-making on all issues important for the safety of the population)	0,13135
5.	M2 (Maintaining labor and technological discipline at the required level)	0,11340
6.	M4 (Control and supervision of monitoring in the security system, especially for the spread of chemical hazards)	0,06603
7.	M3 (Application of technical means and equipment for detection and protection)	0,06385

The results show that it is possible to divide preventive measures into three groups in terms of the priority of their application. The first group includes measures M1 (Selection of those technologies and techniques that pollute the environment less and provide a higher degree of protection) and M6 (Determining the zones of environmental danger (I, II, III) and adequate spatial planning for the construction of new buildings, settlements and excavation dynamics) . Their weight coefficients are the highest. In general, these are preventive measures that have the long-term task of reducing the risk of accidents. The choice of those technologies and techniques that less pollute the environment and ensure a greater degree of protection and the determination of environmental risk zones and adequate spatial planning for the construction of new buildings, settlements and the dynamics of excavation represent a long-term solution both for surface mines and for the local community that exists in the immediate vicinity of mine. Therefore, these preventive measures must be a priority during the development of a mine accident prevention plan. The disadvantage of these measures is that they require a large initial investment of the mine, but later obtain much better financial results with a large reduction in the risk of accidents.

The second group includes measures M5 (Timely removal of all observed technical-technological deficiencies), M7 (Timely informing and involving the public in decision-making on all issues important for the safety of the population) and M2 (Maintaining labor and technological discipline at the required level). These preventive measures have lower weight coefficients compared to measures from the first group. The reason for this is because the mentioned measures refer to medium-term tasks aimed at reducing risk and they represent a supplement to the preventive measures from the first group.

The third group includes measures M4 (Control and supervision of monitoring in the security system, especially for the spread of chemical hazards) and M3 (Application of technical means and equipment for detection and protection). These preventive measures have the lowest weight coefficients. Preventive measures of the third group refer to operational tasks in the daily performance of work in order to collect data and apply certain means for detecting the risk of accidents. These measures play a significant role in risk reduction and they also complement the preventive measures from the first and second groups.

Based on the obtained ranking results, the optimal mine accident prevention plan should rely on defined preventive measures, which are ranked by importance. As can be seen from Fig. 4, at the top are the most important, long-term measures that are systemic and as such reduce the risk of accidents at surface mines to the greatest extent. These are the measures from the first group – M1 (Selection of those technologies and techniques that pollute the environment less and provide a higher degree of protection) and M6 (Determining the zones of environmental threat (I, II, III) and adequate spatial planning of the construction of new buildings, settlements and dynamics excavations). Below are the measures from the second group (medium-term measures) – M5 (Timely removal of all observed technical and technological deficiencies), M7 (Timely informing and involving the public in decision-making on all issues important for the safety of the population) and M2 (Maintaining labor and technological discipline at the required level)). At the bottom are measures from the third group (operational measures) – M4 (Control and supervision of monitoring in the security system, especially for the spread of chemical hazards) and M3 (Application of technical means and equipment for detection and protection). The lines connecting these measures indicate the need to supplement and combine them during application, because this is the only way to achieve their maximum effect – minimizing the risk of accidents.

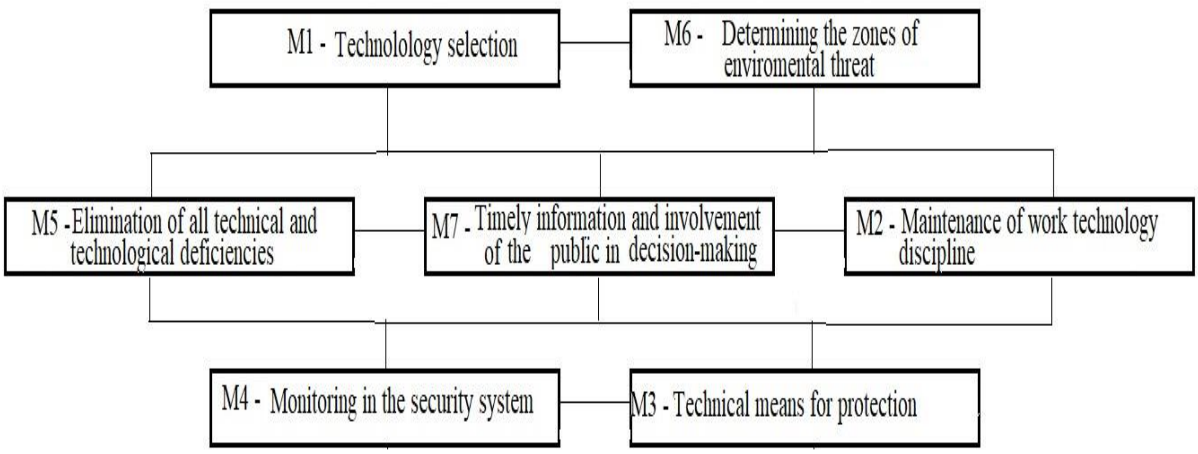

Fig. 4. Scheme of measures for creating an optimal mine accident prevention plan

CONCLUSION

In this paper, the AHP method was applied to rank the necessary preventive measures with the aim of creating an optimal plan for the prevention of accidents in surface mines. Seven measures were considered – M1 (choosing those technologies and techniques that less pollute the environment and provide a higher degree of protection), M2 (maintenance of labor and technological discipline at the required level), M3 (application of technical means and equipment for detection and protection), M4 (control and supervision of monitoring in the safety system, especially for the spread of chemical hazards), M5 (timely elimination of all observed technical and technological deficiencies), M6 (determination of environmental danger zones (I, II, III) and adequate spatial planning of the construction of new buildings, settlements and dynamics excavations) and M7 (timely information and involvement of the public in decision-making on all issues important for the safety of the population).
Based on the results obtained using the AHP method, prevention measures can be divided into three groups – the first group represents long-term measures (M1 and M6), the second group represents medium-term measures (M5, M7 and M2) and the third group represents operational (short-term) measures (M4 and M3).
The optimal mine accident prevention plan must implement all measures, with the priority of the given measures defined by the results of the AHP ranking.

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Oral/Poster Presentation

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Session 1

Mechanical Engineering

EXAMINING THE VALIDITY OF THE ES-EVT MODEL

Nenad Novaković[1]
[1]University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia
e-mail: novaković.ftn@gmail.com

Abstract: The paper is dedicated to the application of extreme value theory in quantifying and forecasting extreme market risk. More specifically, the paper is devoted to testing the validity of the Expected Shortall model for extreme risk assessment presented by (Radivojevic et al. 2016) [1]. The aim of the paper is to examine whether the model can be used reliably in terms of the Basel III standard. The obtained results suggest that the model can be used reliably to estimate extreme market risk.
Key words: value at risk, expected shortfall, extreme value theory, market risk

1. INTRODUCTION

The transition from Basel II to the Basel III standard also meant the transition from Value at risk measurement to Expected Shortfall measurement. Although at first glance, this seems like a small change, because the ES represents the average value of var for a certain level of confidence, this change has far-reaching consequences. First, the application of the EC provides a risk measure that meets the requirements of a coherent risk measure. Since VaR does not fulfil all the characteristics of coherent risk measures, the Basel Committee has proposed fundamental changes in the regulatory treatment of financial institutions' trading book positions [2]. Among other things, the replacement of 99% VaR with the 97.5% expected shortfall (ES) or conditional VaR (CVaR) for the quantification of market risk is recommended. The ES estimations were also calculated for a one-day-ahead horizon for the confidence level of 97.5%. According to the Basel Committee (2014, 2017), this confidence level provides a broadly similar level of risk capture as the existing 99% VaR threshold, while simultaneously providing a number of benefits, including a generally more stable model output and an often-lesser sensitivity to extreme outlier observations [3].
However, the problem that arises when applying a new risk measure is how to determine the validity of banking models for risk assessment. With the application of VaR, the Basel Committee clearly prescribes the manner in which the validity of risk models is examined. However, Unlike VaR backtesting, ES backtesting is significantly more complex. This is the reason why the Basel III standard is not the prescribed manner of backtesting the validity of ES assessments. Numerous authors, such as [4], recommended different methods for ES backtesting, and the majority agreed that the first step in testing the validity of risk models implied VaR backtesting.
Group of authors [1] have developed a new model for assessing market risk. Theoretically, the model eliminates a number of shortcomings of traditional VaR and ES estimation models. However, the model has not been sufficiently tested in the context of meeting the validity conditions of the ES model. Therefore, the aim of this paper is to examine its validity in the assessment of extreme risk in terms of the Bazel III standard.

2. ES-EVT MODEL

Starting from the extreme value theory, ie Pareto distribution (GPD) (see [5]):

$$G_{\xi,\sigma,\mu}(x) = \begin{cases} 1-(1+\xi\dfrac{x-\mu}{\sigma})^{-\frac{1}{\xi}} & \text{за } \xi \neq 0 \\ 1-e^{-(x-\mu)/\sigma} & \text{за } \xi = 0 \end{cases} \tag{1}$$

where are:

x - random variable for which the condition applies $x \geq 0$ for $\xi \geq 0$,

μ - location parameter;
σ - scale parameter;
ξ - tail index

Group of authors [1] have developed a new model for estimating ES which needs to meet the backtesting rules defined by Bazel Committee.
Depending on the tail of distribution (ξ), three special cases are distinguished:

1) when is $\xi > 0$,
2) when is $\xi = 0$ and
3) when is $\xi < 0$.

For financial data, the most relevant Pareto distribution is with $\xi > 0$, since it corresponds to fat tails. This type of distribution is known in the literature as an Fréchet distribution.
In the context of market risk management, previously it means that it is possible to estimate the distribution of extreme portfolios returns, without the need to make assumptions about the entire distribution of portfolio returns. In other words, EVT allows to assess the market risk associated with extreme events, or to determine the likelihood of extreme losses exceeding the defined threshold, using the following function:

$$F_u(y) = \Pr(x-u \leq y \mid X>u) \tag{2}$$

The estimation of market risk, which is associated with extreme losses with limited market data, is extremely difficult. It is becoming more and more difficult as extreme events are becoming increasingly rare. So one solution for risk estimation under these conditions is the use of an VaR models based on EVT. The advantage of these models in comparison with standard VaR models is precisely that they work directly with extreme losses and do not require assumptions about the entire distribution of portfolio returns. However, when using these models, one should bear in mind the constraints that the EVT paradigm imply. The EVT models are built on asymptotic arguments, so their application is limited when applied to a finite sample. In order to estimate the extreme risk, it use the result from asymptotic theory that for a sufficiently high threshold (u), $F_u(y) \approx G_{\xi,\sigma(u)}(y)$, where is $y = (x-u)$. An approximation of F(x), for x > u can be obtained as:

$$F(x) = [1 - F(u)]G_{\xi,\sigma(u)}(y) + F(u) \tag{3}$$

An estimate of F(u) can be obtained non-parametrically by means of the empirical cumulative distribution function:

$$\hat{F}(u) = (N-k)/N \tag{4}$$

where are: k is the number of exceedances over the threshold *(u) and (N) the* number of observations.
By substituting equation (3) into equation (4) the following estimate for F(x) is obtained:

$$\hat{F}(u) = 1/\frac{k}{N}(1 + \hat{\xi}\frac{x-\mu}{\hat{\sigma}})^{-\frac{1}{\hat{\xi}}} \tag{5}$$

where ($\hat{\xi}$) and ($\hat{\sigma}$) are the maximum likelihood estimators of (ξ) and (σ). This equation can be inverted to obtain a quantile of the underlying distribution, which is actually VaR. So, for $cl \geq F(u)$ the VaR is calculated using the following expression:

$$VaR_{cl} = u + \frac{\sigma}{\xi}\left[\left(\frac{1-cl}{k/n}\right)^{-\xi} - 1\right] \tag{6}$$

where (*k*) represents the number of exceeding over the defined threshold (*u*), (σ) is the scale parameter and (*n*) the number of observations, or

$$VaR_{cl} = x_{(n-k)}\left(\frac{n}{k}(1-cl)\right)^{-1/\hat{\alpha}^H} \tag{7}$$

when the tail index (ξ) is estimated by the Hill estimator.
Assuming that tail index (ξ) is less than 1, authors [1,6] developed a formula for calculating ES and thus obtained a new model known in the literature as the ES model based on extreme value theory. Hence, this model markes in the literature as ES-EVT.

$$ES - EVT = \frac{VaR_{cl}}{1-\xi} + \frac{\sigma - \xi u}{1-\xi} \tag{8}$$

Drawback of this model is that the tail size, through the assessment of the tail index, affects the validity of the risk assessment. When the tail is increased, the threshold is moved to the middle of the distribution and a larger number of data is obtained. This increases the accuracy and reduces the variation in tail estimation, but at the same time increases its bias because greater importance is attributed to the central observations in relation to the tail events. Conversely, when the tail size decreases. When the size of the tail decreases, the bias decreases, but the variance increases as the number of observations decreases [7].

3. DATA, METHODOLOGY AND BACKTESTING RESULTS

In order to test the validity of the model, a simulation was conducted. Data is generated using a data generation process. For this purpose, Monte Carlo simulations were used. In the Monte Carlo simulations, we consider a GARCH (1,1) -t model:

$$r_t = \sqrt{\sigma_t^2}[v/(v-2)]^{-1/2}\varepsilon_t \quad \varepsilon \sim t_5 \tag{9}$$

$$\sigma_t^2 = 0.004 + 0.03\varepsilon_{t-1}^2 + 0.95\sigma_{t-1}^2 \tag{10}$$

where r_t denotes the simulated returns, σ_t denotes the conditional standard deviation and ε_t denotes an innovation drawn from a student t distribution with $\nu = 5$ degrees of freedom. This model is a standard model for financial returns. It implies fat tailed student t distributed density forecasts and produces the volatility clustering often observed in financial return series [8-10].
It generated 5000 simulations for samples of 1000 observations. The first 1000 observations were used to calibrate the ES-EVT model and to calibrate the volatility model (GARCH (1.1), which Radivojevic et al., (2016) used in the ES-EVT model. The rest observations were used to test the validity of the ES-EVT model.
The calculated ES figures are for one-day ahead horizon, according to the Basel III standard.
In Table 1. was presented the estimated parameters of the GARCH (1,1).

For estimating the tail index, we used the Hill estimator:

$$\hat{\alpha}^H = \frac{1}{k}\sum_{i=1}^{k} ln(x_{n-k+1}) - ln(x_{n-k}) \tag{11}$$

Table 1. The estimates of the parameters of garch (1,1) model - source: authors' calculations

Parameters	
α	0,092 (0,001)
β	0,901 (0,000)

ω	0,000 (0,000)

In Table 2 are presented a threshold value, values of the sigma and tail indexes.

Table 2. The maximum likelihood estimates of the tail index and sigma, threshold value - Source: Authors ‘calculations

Parameters	**ES-EVT**
Threshold value	-1,374
The tail index (ξ)	0,128
Sigma	0,699

3.1. Validation of the backtesting results

To examining validity of the ES-EVT model in the paper was used the Acerbi and Szekely's first method. Testing the model validity was performed according to the procedure described [11,12]. Namely, [13] described the procedure for testing ES models using Acerbi and Szekely's first method. Starting with the null and alternative hypotheses, which were defined by Acerbi and Szekely:

$$H_0: P_t^{\alpha}=F_t^{\alpha} for\ \forall(t) \quad (12)$$

against the alternatives

$$H_1: \widehat{ES_{\alpha,t}}(R) \geq ES_{\alpha.t}(R)\ for\ \forall(t) and\ > for\ some\ (t) \quad (13)$$

$$\widehat{VaR_{\alpha,t}}(R) \geq VaR_{\alpha.t}(R) \qquad for\ \forall(t)$$

(14)

where F_t is the realized distribution of returns, $P_t^{\alpha}$is the conditional distribution tail of the distribution of P_t below the quantile α, $\widehat{ES_{\alpha,t}}(R)$and $\widehat{VaR_{\alpha,t}}(R)$ are the sample ES and VaR from the realized returns;
as well as their test:

$$Z_1(R) = \frac{\sum_{t=1}^{T}(R_t I_t / ES_{\alpha,t})}{N_t} + 1 \qquad (6) \quad (15)$$

where R denotes the vector of realized returns $(R_1, R_2, \ldots, R_t)$, I_t – the indicator function $I_T = \mathbb{I}_{(R_T < VaR_\alpha(R))}$ that indicates the backtesting exceedance of VaR for the realized return R_t in the period t, and $N_T = \sum_{t=1}^{T} I_t$ is the number of the exceedances, Doncic et al. (2022) described procedure for testing ES models in the next way:

1) The first step involves simulating R_t^i from P_t for all t and $i = 1,2\ldots, M;$
2) The second step involves that for every i, computes $Z_i = Z(R_i)$, i.e. compute the value of Z_1 using the simulations from the first step;
3) The third step implies that estimates the p-value as $p = \sum_{i=1}^{M} \frac{Z^i < Z(R)}{M}$, where $Z(x)$ is the observed value on Z_1.

The backtesting results were presented in Table 3.

Table 3. The backtesting results - Source: Authors' calculations

	ES-EVT model
Z_1	0.128

Based on the results shown in Table 3, it is possible to conclude that the model can be used reliably to assess extreme risk in financial markets. The model satisfied rules defined by the Basel Committee for determining a valid risk model.

4. CONCLUSION

In the paper, the possibility of applying the ES models based on EVT for the assessment of extreme risk on a financial market is examined. More specifically, the paper is devoted to testing the validity of the Expected Shortall model for extreme risk assessment presented by (Radivojevic et al. 2016) [1]. The paper was aimed at answering to question of whether this model can reliably be applied to the financial market in compliance with the rules for the validity of risk assessment models that are defined by the rules of the Basel Committee or not. The results of the backtesting procedure performed according to the standards of the Basel Committee show that the model can reliably be used for estimating ES. The backtesting procedure was performed according to Acerbi and Szekely's first method.

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DETERMINATION OF THE CRITICAL VELOCITY OF A FLUID FLOWING IN A NANOTUBE RESTING ON VISCOELASTIC FOUNDATION

Dimitar Lolov [1], Svetlana Lilkova-Markova [2]
[1]University of Architecture, Civil Engineering and Geodesy, Faculty of Hydraulic Engineering, Sofia, Bulgaria
[2]University of Architecture, Civil Engineering and Geodesy, Faculty of Hydraulic Engineering, Sofia, Bulgaria
e-mail: dlolov@yahoo.com, lilkovasvetlana@gmail.com

Abstract: This paper investigates the stability of a simply supported nanotube conveying fluid and resting on a viscoelastic foundation. The Euler elastic beam model is employed in order to study the dynamic stability behavior of the system. The aim is to analyze the influence of the parameters of the viscoelastic foundation on the critical flow velocity of the fluid in the nanotube under consideration and to draw conclusions about the stability of the system. The viscoelastic foundation is represented through the standard linear solid model (Maxwell representation). This problem is approached numerically using the spectral Galerkin method. Results reveal that all above mentioned parameters have a significant effect on the stability of the nanotube.
Key words: stability, critical velocity, viscoelastic foundation, nanotube

INTRODUCTION

Carbon nanotubes (CNTs) are widely used in nanophysics, nanobiology and nanomechanics in nanofluidic devices, nanocontainers for gas storage and nanopipes conveying fluid. They are with perfect hollow cylindrical geometry and superior mechanical strength. The flows inside carbon nanotubes are attractive research topic in recent years.
In [1] the problem of fluid-structure interaction is considered in the case of nanoscale. However, the experiments at the nanoscale are difficult and expensive. That is why the continuum elastic models have been used to study the fluid-structure interaction. The carbon nanotubes are considered with Euler- and Timoshenko-beam models.
Yoon et al. in [2] applied the Euler beam model for investigation of a cantilevered carbon nanotube conveying fluid, with or without being embedded into an elastic medium such as polymer. The same authors in [3] investigated carbon nanotubes, this time simply supported or clamped at both ends. They obtained the critical flow velocity of the transported fluid in the case of loss of stability of the pipe. The numerical results indicate that the flowing fluid has a substantial effect on vibrational frequencies of the system. On the other hand, their results showed that surrounding elastic medium influence on the effect of internal moving fluid on the vibration of the system.

VIBRATION OF A FLUID-FLOWING NANOTUBE RESTING ON VISCOELASTIC FOUNDATION

The transverse vibration of a straight pipe, with length l, conveying inviscid fluid and lying on a viscoelastic foundation is governed by the following differential equation

$$EI\frac{\partial^4 w}{\partial x^4}+m_f V^2\frac{\partial^2 w}{\partial x^2}+2m_f V\frac{\partial^2 w}{\partial x \partial t}+\left(m_f+m_p\right)\frac{\partial^2 w}{\partial t^2}=-q(x,t). \tag{1}$$

where t is the time, $w(x,t)$ is the lateral displacement of the pipe axis, x is the coordinate along the axis, EI is the rigidity of the pipe. The mass of the pipe per unit length is denoted by m_p and the

mass of the fluid per unit length of the pipe by m_f. V is the flow velocity of the fluid in the pipe. $q(x,t)$ is the soil reaction.
For the standard linear solid model (Maxwell representation) (Fig.1), the following holds [4]

$$q + \frac{d}{k_2}\frac{\partial q}{\partial t} = k_1 w + \frac{d(k_1 + k_2)}{k_2}\frac{\partial w}{\partial t}. \tag{2}$$

k_1, k_2 and d are respectively the rigidities of the springs and the damping coefficient in the Maxwell model.

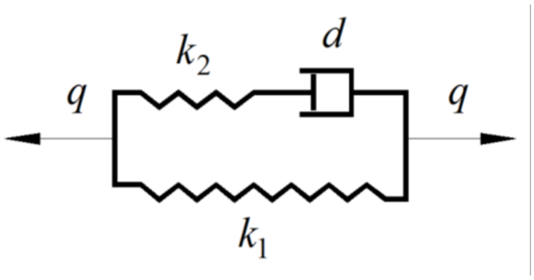

Figure 1. The standard linear solid model (Maxwell representation)

The following differential equation is obtained from equations (1) and (2)

$$\frac{dEI}{k_2}\frac{\partial^5 w}{\partial x^4 \partial t} + EI\frac{\partial^4 w}{\partial x^4} + \frac{dm_f V^2}{k_2}\frac{\partial^3 w}{\partial x^2 \partial t} + \frac{2dm_f V}{k_2}\frac{\partial^3 w}{\partial t^2 \partial x} + \frac{d}{k_2}\left(m_f + m_p\right)\frac{\partial^3 w}{\partial x^3} +$$
$$+ m_f V^2 \frac{\partial^2 w}{\partial x^2} + 2m_f V\frac{\partial^2 w}{\partial x \partial t} + \left(m_f + m_p\right)\frac{\partial^2 w}{\partial t^2} + \frac{d(k_1 + k_2)}{k_2}\frac{\partial w}{\partial t} + k_1 w = 0 \tag{3}$$

The spectral Galerkin method is applied to approximate the solution of differential equation (3). The solution is sought in the following form:

$$w(x,t) = \sum_{i=1}^{n} y_i(x) z_i(t) \tag{4}$$

where:
$z_i(t)$ - are unknown functions;
$y_i(x)$ - are basic functions that satisfy the boundary conditions of the nanotube. Such functions are the functions describing the *i*-th mode of vibration of a beam with the same static scheme as the nanotube, but without viscoelastic foundation.
On the basis of the differential equation, describing the lateral vibrations of a tubular beam, filled with stationary fluid ($V = 0$) is obtained [5]:

$$y_i^{IV}(x) = \gamma_i^4\, y_i(x) \tag{5}$$

where:

$$\gamma_i = \sqrt[4]{\frac{\left(m_f + m_p\right)\omega_i^2}{EI}} \tag{6}$$

where ω_i is the circular frequency of the beam.
Substituting equation (4) into equation (3), one obtains the residual function:

$$R(x,t) = \sum_{i=1}^{n}\left\{\frac{d}{k_2}\left(m_f + m_p\right)y_i\dddot{z}_i + \left[\frac{2dm_f V}{k_2}y_i^I + \left(m_f + m_p\right)y_i\right]\ddot{z}_i + \right.$$
$$\left. + \left[\frac{dEI}{k_2}y_i^{IV} + \frac{dm_f V^2}{k_2}y_i^{II} + 2m_f V y_i^I + \frac{d\left(k_1 + k_2\right)}{k_2}y_i\right]\dot{z}_i + \left[EIy_i^{IV} + m_f V^2 y_i^{II} + k_1 y_i\right]z_i\right\} \tag{7}$$

In (7) and in the sequel, primes denote derivatives with respect to x and dots with respect to the time t.
The Galerkin method requires the residual function $R(x,t)$ to be orthogonal to the basic functions in the interval $x \in [0;l]$:

$$\int_0^l R\left(x,t\right)y_k\left(x\right)dx = 0, \text{ for } k = 1,...,n \tag{8}$$

Equation (8) is rewritten in the following form:

$$\sum_{i=1}^{n}\int_0^l\left\{\frac{d}{k_2}\left(m_f + m_p\right)y_i\dddot{z}_i + \left[\frac{2dm_f V}{k_2}y_i^I + \left(m_f + m_p\right)y_i\right]\ddot{z}_i + \right.$$
$$+ \left[\frac{dEI}{k_2}\gamma^4 y_i + \frac{dm_f V^2}{k_2}y_i^{II} + 2m_f V y_i^I + \frac{d\left(k_1 + k_2\right)}{k_2}y\right]\dot{z} +$$
$$\left. + \left[EI\gamma^4 y_i + m_f V^2 y_i^{II} + k_1 y_i\right]z_i\right\}y_k\, dx = 0 \text{ , for } k = 1,...,n \tag{9}$$

Equation (9) represents a system of n differential equations with n unknown functions $z_i(t)$. In order to solve the system, the described in [5] method is applied. According to it the nanotube is divided to sections with length Δx. The following relationships are taken into account:

$$\int_0^l y_i\, y_k\, dx = \{y_i\}^T\{y_k\}\Delta x \tag{10}$$

$$\int_0^l y_i'\, y_k\, dx = \{y_i'\}^T\{y_k\}\Delta x \tag{11}$$

$$\int_0^l y_i''\, y_k\, dx = \frac{1}{EI}\{M_i\}^T\{y_k\}\Delta x \tag{12}$$

where in (10),(11) and (12):

$\{y_i\}$ - is a column vector consisting of the lateral displacements of the stations on the axis of the tube, corresponding to the i-th eigen form in the case of stationary fluid ($V = 0$);
$\{y_i'\}$ - is a column vector consisting of the rotations of the cross-sections in the stations on the axis of the tube, corresponding to the i-th eigen form in the case of stationary fluid ($V = 0$);
$\{M_i\}$ - is a column vector consisting of the bending moments in the stations on the axis of the tube, corresponding to the i-th eigen form in the case of stationary fluid ($V = 0$).
Substituting (10),(11) and (12) in (9) the following system of n differential equations with n unknown functions $z_i(t)$ is obtained:

$$\sum_{i=1}^{n}\left\{\frac{d}{k_2}\left(m_f+m_p\right)\{y_i\}^T\{y_k\}\dddot{z}_i+\left[\frac{2dm_fV}{k_2}\{y_i^I\}^T\{y_k\}+\left(m_f+m_p\right)\{y_i\}^T\{y_k\}\right]\ddot{z}_i+\right.$$
$$+\left[\frac{dEI}{k_2}\gamma^4\{y_i\}^T\{y_k\}+\frac{dm_fV^2}{k_2}\frac{1}{EI}\{M_i\}^T\{y_k\}+2m_fV\{y_i^I\}^T\{y_k\}+\frac{d\left(k_1+k_2\right)}{k_2}\{y_i\}^T\{y_k\}\right]\dot{z}_i+$$
$$\left.+\left[EI\gamma^4\{y_i\}^T\{y_k\}+m_fV^2\frac{1}{EI}\{M_i\}^T\{y_k\}+k_1\{y_i\}^T\{y_k\}\right]z_i\right\}\Delta x=0 \qquad (13)$$

The system (13) could be rewritten in matrix form:

$$A\dddot{z}+B\ddot{z}+C\dot{z}+Dz=0 \qquad (14)$$

The general solution of the system (14) is expressed through the roots ($\lambda_1,...,\lambda_{2n}$) of the equation:

$$\det X=0 \qquad (15)$$

The elements of the matrix X are given by:

$$X_{ik}=\lambda^3 A_{ik}+\lambda^2 B_{ik}+\lambda C_{ik}+D_{ik} \qquad (16)$$

On the basis of obtained roots ($\lambda_1,...,\lambda_{2n}$) could be drawn conclusions about the stability of the system. The system is stable if the real part of all the roots of the characteristic equation (15) is negative.
The roots ($\lambda_1,...,\lambda_{2n}$) depend on all the parameters of the system. If all of them are fixed except the velocity of the conveyed fluid V, one could obtain the corresponding critical velocities.

RESULTS AND DISCUSSION

Numerical studies have been carried out for the fluid conveying nanotube in Fig. 2.

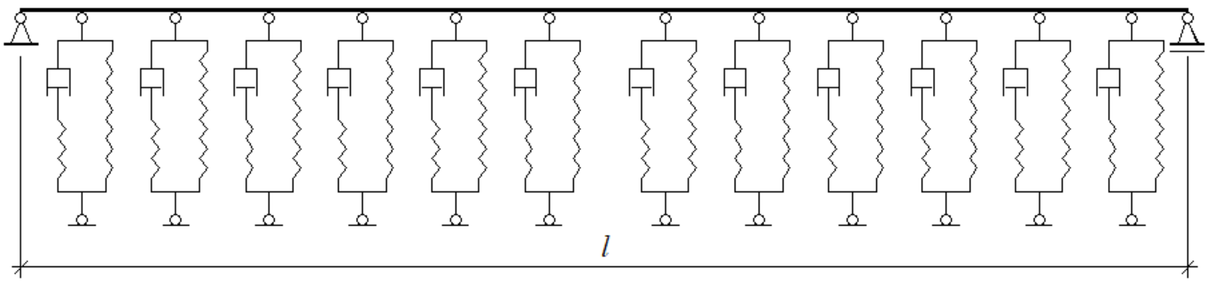

Figure 2. Static scheme of the investigated nanotube conveying fluid

The characteristics of the material of the tube are: modulus of linear elasticity $EI = 1\,TPa$, density $2{,}3\,g/m^3$. The flowing fluid in the tube is with density $1\,g/m^3$. The length of the beam is $l = 2000nm$ and the cross-section is with a inner radius $R = 55nm$ and thickness $10\,nm$.
The results obtained show the relationship between the damping coefficient d of the viscoelastic foundation and the critical velocity V_{cr} for different rigidities of the springs k_1 and k_2 in the Maxell model.

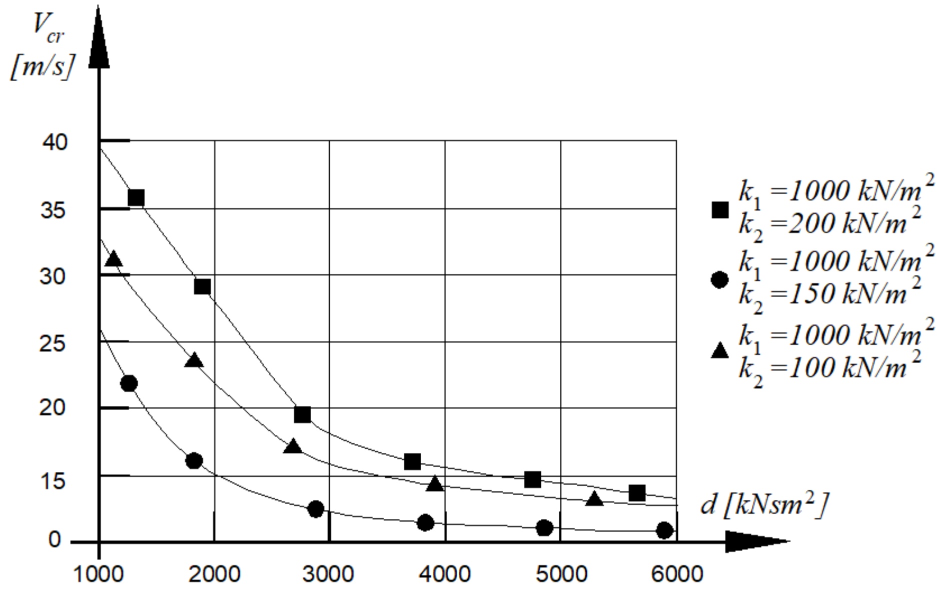

Figure 3. Dependence of the damping coefficient d of the viscoelastic foundation and the critical velocity V_{cr} for different rigidities of the springs k_1 and k_2 in the Maxell model

CONCLUSION

In the present paper is studied the influence of the parameters of a viscoelastic foundation, modelled with the Maxwell model, on the stability of a nanotube conveying fluid.
The results obtained in the study could be summarized as follows:

1. For the investigated system the damping of the viscoelastic foundation has a destabilizing effect. The bigger the damping parameter d the smaller is the critical velocity V_{cr}.
2. The rigidities of the springs k_1 and k_2 in the Maxwell model have stabilizing effect on the system. With the increase of the coefficients, increases the critical velocity V_{cr}.

The results obtained contribute to the safety of nanotubes conveying fluid. In order to avoid damages, it shouldn't be allowed transportation of the fluid with higher velocities than the critical velocity of the system. The critical velocity depends on many parameters of the system, among them the parameters of the viscoelastic medium in which the tube is embedded. For modeling of this medium are used several recognized among researchers models. One of them is the Maxwell model. The present study shows that the damping of the foundation has a significant effect on the stability of the system.

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METHODOLOGY FOR DETERMINING DIFFERENCES OSE IMPPELER SHAFT TURBINE UNI

Slobodan Juric[1], Slavica Prvulovic[2], Jasna Tolmac[2], Milos Josimovic[2], Milica Josimovic[2]
[1] High school "CEPS-Center for Business Studies" Kiseljak, Bosnia and Herzegovina
[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: prvulovicslavica@yahoo.com

Abstract: The research work was aimed to perform: assessment of dynamic conditions, sensitivities and preferences hydrogenerator rotating elements, to the imbalance, as well as the assessment of the security of the shaft and the turbine rotor of the drive HE, in terms of the minimum risk of downtime. Evaluating the above condition is estimated that if the above mentioned devices eligible for long-term trouble-free operation. Timely knowledge of damage to mechanical parts allow the user to replace these parts or assemblies during overhaul of emergency as soon as you can avoid unplanned and often costly delays due to sudden failures or breakdowns in the worst case.
Key words: hydroelectric generator, turbine, generator, vibration, shaft.

INTRODUCTION

The vibrations are measured on bearings, bearing housing or other parts that are transmitted vibration [1, 2]. The direction of the measured vibration to be the same as the direction of the load (radial to the guide bearing and an axial bearing for load-bearing). Measurement points may vary depending on the type of device with the range in accordance with the relevant standards and recommendations. For the measurement using the accelerometers, capable of measuring the frequency over a wide range with uniform frequency response. The dynamic characteristics of the turbine system, ie special measures. instruments for each point [3, 4]. Dynamically oscillating signals can not always be treated as a sum of two types of signals: periodic and random fluctuations. Methods of signal processing based on the selected measuring method and purpose of the testing [5-7]. Common methods for dynamic signal processing are as follows:
- peak-to-peak or peak analysis (analysis of the maximum amplitude)
- the analysis of the rms value (Vrms or standard deviation)
- statistically processing signals
- the spectral analysis of the signal (spectral density of the amplitude or power of the signal)

On the other way can methods to process the signals divided in the method that are based on signal processing in the time domain (amplitude) and those based in the frequency domain (frequency) [1, 3, 7].

MATERIAL AND METHODS

Measuring equipment used

The equipment used for testing in HE "Jajce I" is a system of continuous control of vibration in the turbine bearings implemented using oneprod MVX measurement acquisition system supported OneproD VIO (View) software [8, 9]. As the vibration velocity sensors 16 are used ICP accelerometers (piezo-electric accelerometers integrated preamplifiers with the charge). Assist the cables through the connection boxes are connected to 16 channel oneprod MVX measurement data acquisition system, which is located in a dedicated cabinet. OneproD MVX measurement data acquisition system via Ethernet-connected to a central computer, which is located in a separate control room, where the software is installed OneproD VIO for current status display at each measurement point. In case of Internet communication, the data is stored in the Flash memory card of 512 Mb, which is an integral part of OneproD MVX measurement acquisition system [10].

Measuring axis deviation back in the hydropower

Radial vibration relative shaft axis deviation were measured by the main carrier bearing. Were used inductive sensors without direct contact. Their sensitivity is sufficient to accurately capture the smallest deviations of the shaft axis of micrometers, and thus cover the whole frequency range of vibration of the shaft (usually at least two times to the BPF - blade passing- frequency upon the number of rotor blades and speed of rotation). The installation is performed using the two sensors in a single plane. The sensors are mutually turned through an angle of 90°, to give the motion vector the shaft in relation to the measuring plane.
For the measurement deviation of the axle shaft to the HE "eggs and" were used in inductive sensors Telemecanique XS1 M12AB120, with the range of 0.2 ... 2 mm and an output strength of 4 ... 20 mA. Positioned at the top of the main carrier bearing (Fig. 1).

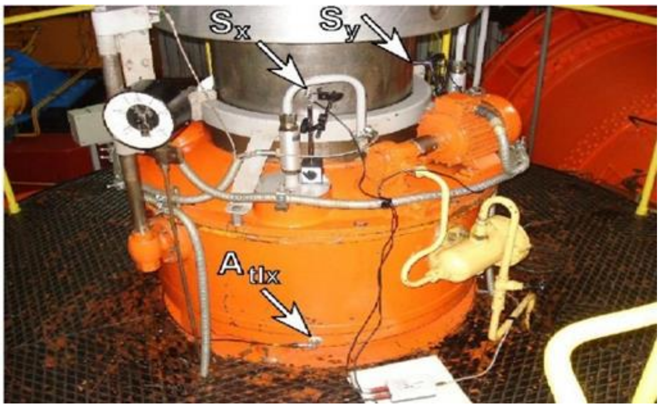

Fig. 1. Sensors for measuring the deviation from the axis of the shaft and the turbine bearing vibration

Analog signals are monitored in the measurement in real time digitized and stored as binary files directly to your hard disk. Positions dynamic transducer during the measurement are shown in Fig. 2:

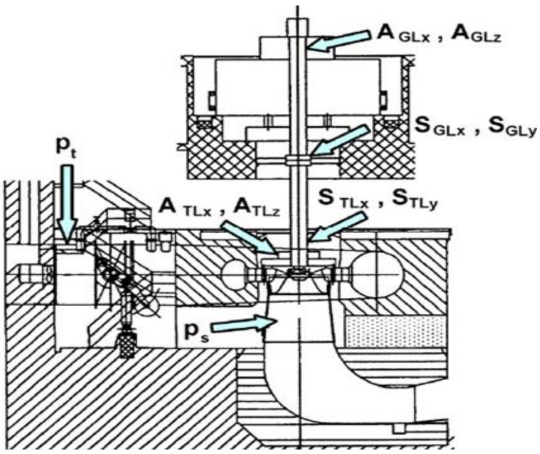

Fig. 2. Positions on the measurement of dynamic size HE „Jajce I“

Review of regulations for research results

Radial relative vibration of the shaft (axis deviation) were measured at the main bracket bearing. Rotating the shaft, the path is displayed in the measuring level of the combined signal by means of two different encoders, shifted by 90°. The maximum peak-to-peak, with (pp) max and the current deviation Smax axle shaft can be based on time sampling converted. Both values can be used for the

calculation. In the case of HPP "Jajce I" Smax is (pp) max are used to assess the relative vibration of the shaft. Maximum values over 10 consecutive rotation of the turbine shaft are average within one minute in order to obtain the appropriate size. The budget deviation value returned is similar budget vibration bearings, ie. is divided into four working zones A, B, C and D. These zones are shown in Table 1.
Areas AB and CD are according to ISO 7919-5 divided into two groups:

Table 1. The two main areas – ISO

Zone A-B	Machine with magnitudes of vibration in a part of this area are considered acceptable for an unlimited long duration of action.
Zone B-C	Machines in this area have increased vibration magnitude. It is necessary to check whether the measured values are allowable for long-term continuous operation due to the construction of the machine and the operating mode.

RESULTS AND DISCUSSION

Deviation axis turbine shaft

The dynamic characteristics of the turbine „Jajce I" measures specific system, ie. instruments for each point.

Bucket-wheel vibration level measured at HA no.1.

On the basis of assessment of variations of the turbine axis of the shaft (aggregate 2 is not working) of Table 2. See that the level Smax measured μmu 553 relative to the standard (ISO 7919, part 5) of the boundary C is 310 micrometers in the number of revolutions 300, means belongs to the area D. Condition turbine aggregate 1 is declared as not good or it is not acceptable for continuous operation. Based on ISO 7919, which assesses the state of the machine based on the rotor vibration condition of hydro units in the class D and is considered as not acceptable for long-term trouble-free operation.

Table 2. Deviations axis turbine shaft assembly 1 aggregate 2 is not working

Points	**Smax (μm)**	**Spp-x (μm)**	**Spp-y (μm)**
9	424	785	443
10	426	789	448
11	425	786	446
12	423	790	448
13	432	799	454
14	427	802	454
15	427	802	453
16	444	821	463
17	454	834	471
18	494	873	493
19	495	911	507
20	553	947	530
21	514	907	516

Table 3. Deviations axis turbine shaft aggregate 1 aggregate 2 with a maximum power

Points	**Smax (μm)**	**Spp-x (μm)**	**Spp-y (μm)**
2	411	728	387

3	405	743	401
4	416	759	416
5	425	775	430
6	422	774	432
7	433	782	439
8	435	780	440

Deviation axis turbine shaft

The diagrams of measured Smax and Sp-p values for all measuring points can be found in Fig. 3 and Fig. 4. Orbite travel speed of the turbine shaft 10 to the selected specific operating modes are plotted in Fig. 5. The values of Smax of the turbine 1 are very increased and can reach even more than 500 microns. This means that they are already in the D according to ISO 7919-5, where the machine is not working. Such increased vibrations are visible throughout the entire range of measured flow. Aggregate 2 has a much smaller relative vibration of the turbine shaft, most Smax values in zones A and B of appropriate for unrestricted long-term operation. Increasing the path back in the flow between 16.5 and 22 m³/s (power between 13 and 18 MW) due to the influence of vortices in the suction pipe. In this area, the amplitude in the zone C according to the ISO standard, which means that aggregate in this area can only work temporarily.
The basic frequency is 5 Hz, the path, plus the low frequency component from the partial flow at the frequency of the vortex (1,2 - 1,4 Hz)

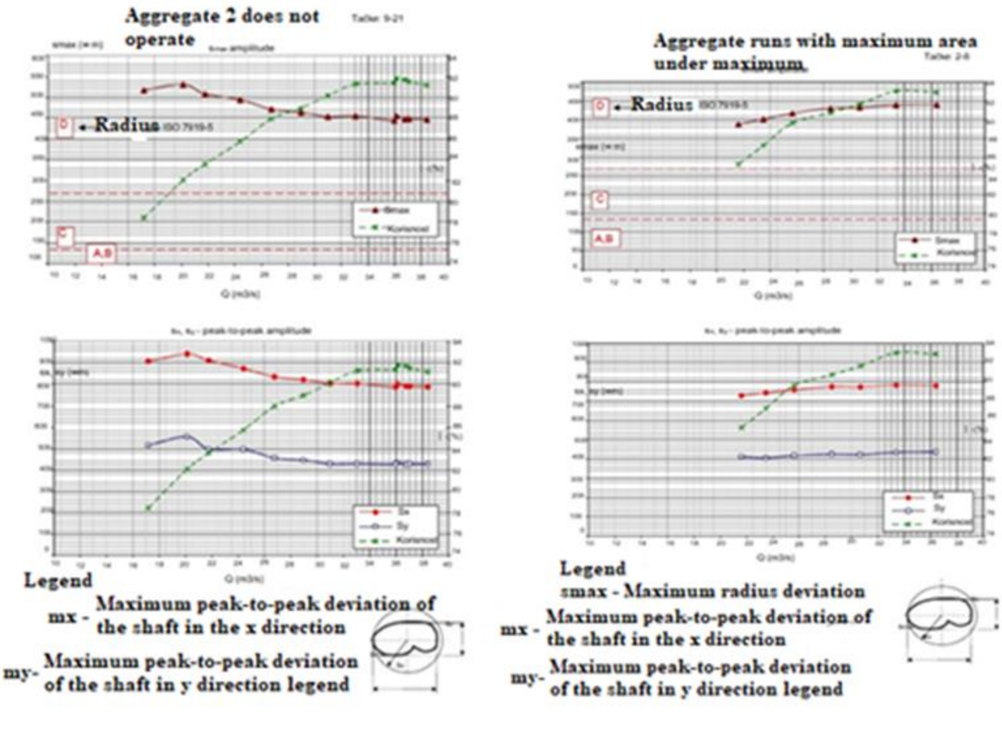

Fig. 3. Deviation axis turbine shaft agragat 1- HE JAJCE I

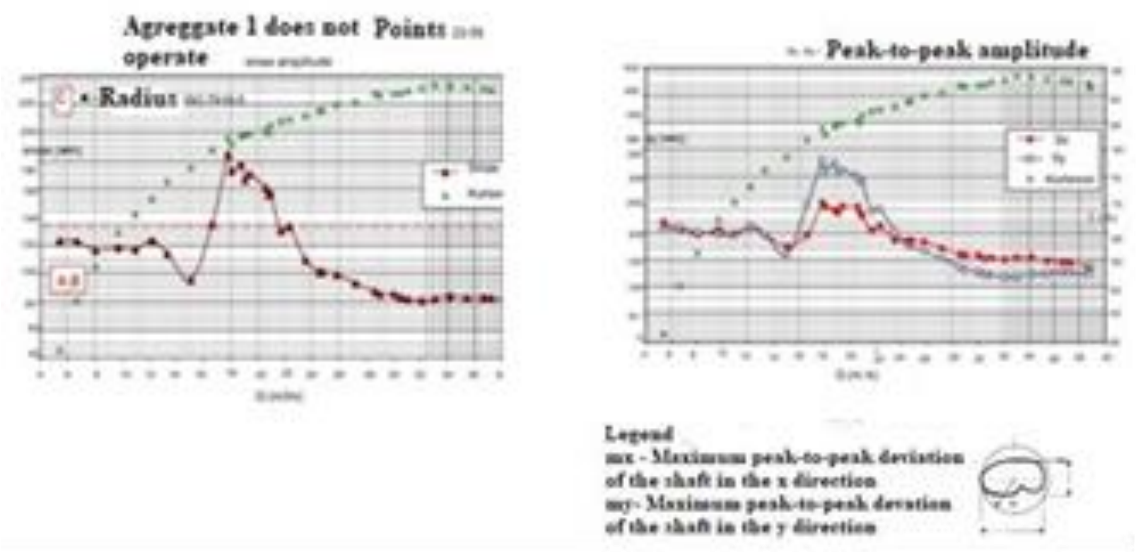

Fig. 4. Deviation axis turbine shaft aggregate 2- HE JAJCE I

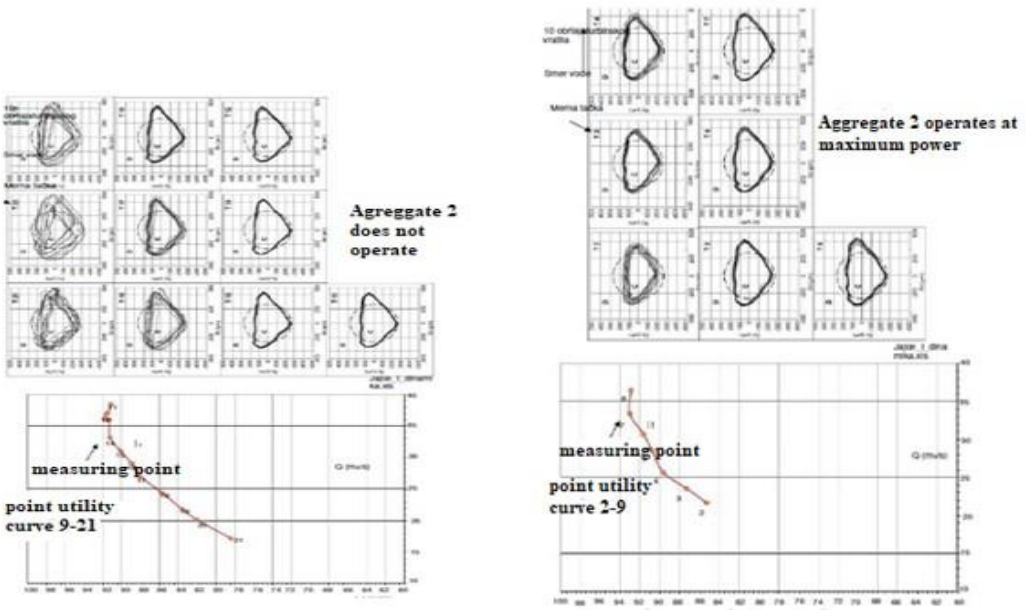

Fig. 5. Deviation axis turbine shaft-orbit agragat 1 - HE JAJCE I

Discussion of research results

Dynamic characteristics unit 1 are significantly deteriorated, in particular a deviation of the turbine shaft axis. The results confirm that the vibration of the engine compared to 2 several times higher, and particularly worrying that are in the area D. It was found that the unit 1 of the mechanical deterioration due to a breakdown of the carrier bearing. Rating of amplitude is made according to standard ISO 10816-5, with marked boundaries of the service areas in the diagrams. For unit 1 is specifically to be a little less vibration when unit 2 are parallel.
Dynamic state unit 2 is normal. Aggregate can work permanently and continuously. The only complaint is that it is good to avoid long-term work in the field of partial flow16,5 i 22 m^3/s (forces between 13 and 18 MW) due to the increase of the relative vibration of the impeller shaft (deviation axis) as a consequence of hydraulic instability and oscillation of pressure (turbulence) in the suction pipe.

CONCLUSION

Conducted research can be applied to all other technical systems or elements which have a vibration severity due to rotary motion of a mechanical element. The results showed that the incidence of vibration is very detrimental to the technical system, which indicates the need for structural improvement of technical systems at the initial stage of the life cycle and preventive removal of the cause of vibration. Those examples are hard to exhaust all the diversity of speed, the regime and contour characteristics. Proposed methods of detecting the causes of vibration are also not exhausted. Further theoretical elaboration of identifying the cause of the vibration will change and improve [1,2,10].
On the basis of the given values of all parameters as important elements in the process of forming a model for estimating the vibrations of the integral components of technical systems circuits according to the selected measurement points is carried out of the analysis of the security of functioning operation of the same.

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DEVELOPMENT OF THE MOLD DESIGN USING FRAME RULE REASONING

Ivan Matin, Branko Štrbac, Miloš Ranisavljev, Miodrag Hadžistević[1]
[1]University of Novi Sad, Technical Faculty Sciences, Novi Sad, Serbia
e-mail: matini@uns.ac.rs

Abstract: Based on a review on the conventional mold design process, a new procedure has been proposed for the development of molds. The procedure was implemented through an integrated, knowledge-based system. To enable the development of the system, some key technologies such as product modeling, frame-rule structures, were studied in detail. The system owns three main advantages: with product modeling, engineers' tasks can be focused on product design; being integrated with production rule based technology, the system sets up a design environment with field knowledge by which design efficiency can be improved significantly, and a new frame-rule structure for knowledge development has been incorporated into the knowledge-based system.
Key words: KBS, production rules, mold design

INTRODUCTION

The knowledge-based system (KBS) needs to to improve mold-design efficiency and shorten design time through implementing proposed design method. In general, a mold is often designed in these stages: detailed design of the mold; design of the mold-base and ordering the mold-base from other sources; and mold manufacturing. Firstly, the engineer designs mold-bases according to the dimensions of the product. Then the engineer begins to design the detail of the mold, while ordering the mold-base from other sources (D-M-E, HASCO, Strack, Meusburger etc). This process may enable shortening the product development cycle. The mold-base KBS was developed to enhance mold design. Matin et al. [1-3] build a CAD/CAE integrated mold design system based on PTC Creo Parametric, Pro/Plastic Adviser and Visual Basic module for calculation of parameters of injection molding, mold design calculation and mold plates selection. The feature contains design and analyses related data, called feature attributes. The authors presented a feature-based ontology consisting of a number of CAD/CAE features. The features represent not only geometric product information and specifications of the molded part, but also the design intents oriented to the injection simulation process. The feature-based frame rule ontology was used for analytical calculations, mold sizing, and its selection. Nowadays, the KBS has been widely used [1-6]. In this paper, the KBS is aditionally built on the frame rule method. Hentati et al. [7]. build a integrating CAE optimisation system of plastic injection molding process based on Taguchi method. The optimal injection parameter levels was tested via Taguchi were verified via CAE numerical simulation.

MATERIAL AND METHODS

The case library stores successful mold-design assemblies for insertation. The KBS modules can be divided into the following steps:

- ***Cavity calculation*:** calculating the shrink ratio in the part using PTC Pro/Mold Design software.
- ***Set-in calculation*:** calculating the dimensions of set-in and other factors (radii, chanfer, slope, thickening) for set-in.
- ***Slide calculation*:** considering the dimensions of the mold-base for the slide KBS subsystem.
- ***Determine cavity and core plate*:** determining the dimensions of the mold plates intention and rigid check.
- ***Calculating the number of plates*:** determining the numbers of the mold plates based on the gate and product information.
- ***Define mold-base*:** creating the mold-base model based on the information above.
- ***Mold-base check*:** checking the interference of additional structures.

- ***Injection mold machine selection*****:** checking interference between the mold-base and injection molding machine.

Mold-base design knowledge during different stages is different from one stage to another, in terms of the formal style and performance. Therefore, these cannot be represented just by one kind of knowledge representation method (e.g. just use one frame-rule, production rule, feature-based, etc.). In different subsystems (module), different kinds of knowledge processing technologies may be used. The KBS structure is shown in Fig. 1. Various cases of the mold-base's modeling are stored in the database. The mold-base library includes successful design cases. With a knowledge acquisition technology, the knowledge-based library presents application cases for the selection. The KBS is built on all these modules and linked to PTC Creo Parametric software. The complete process of executing the system is illustrated in Fig. 1.

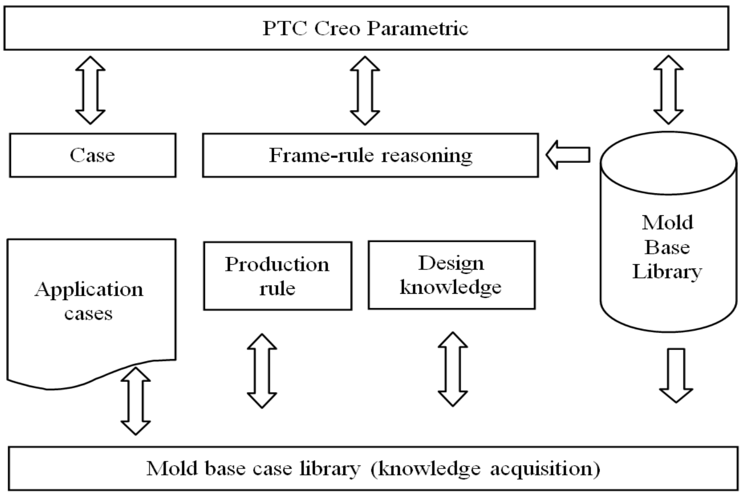

Fig. 1. Structure of the knowledge-based system

The key technologies in the KBS include: product modelling, knowledge representation with a frame-rule structure, production rules and simple reasoning. The KBS, that is based on can execute mold design, such as set-in design, interference check, selection the model of the mold-base assembly and other mold parts. Its field knowledge adopts few kinds of representation methods including frame-rule (gate design, sprue bushings), production rule (set-in and dimensions calculation), mold-based library and mathematical calculation (interference checking in mold). Modeling three of injection molding consists of production layer, subsystem layer and part layer. Product modeling is an assembly modeling of the sub-models or parts and represents the structure in detail (i.e. an injection molding process) can be represented by a modeling tree, as shown in Fig. 2.

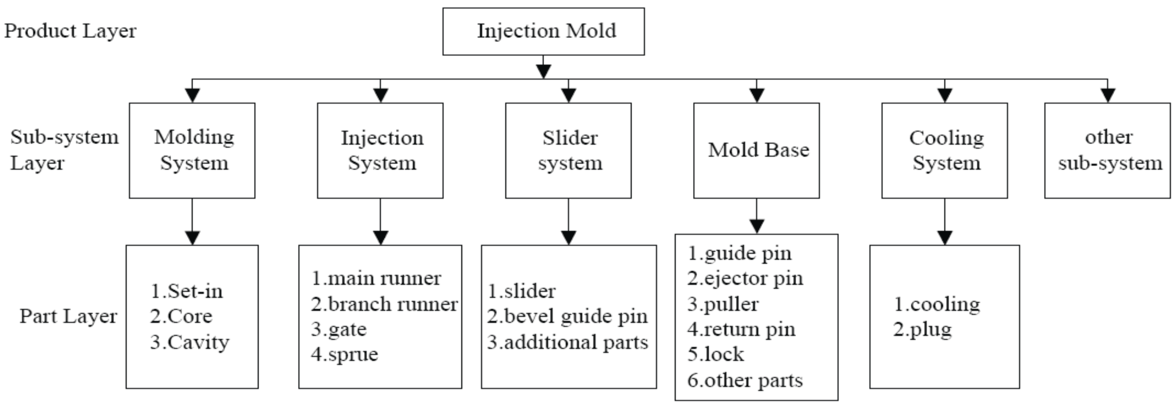

Fig. 2. Modeling tree of injection molding

The product information standard in a integrated CAD/CAE system has different types which deal with geometry representation, feature representation, etc. The integrated representation can incorporate some kinds of non-geometry information, such as expert experience and knowledge, into product modeling, resulting in an efficient way to realize intelligence and automation of product design and analysis. Rule structure is often used in knowledge representation and reasoning, but frame structure has an advantage in that it can group relational knowledge into blocks so that the knowledge system can manage knowledge conveniently. Therefore, a frame-rule structure is developed to process application knowledge in the KBS.

RESULTS AND DISCUSSION

In the frame-rule structure, a frame represents every object in project modeling (such as guide pin, ejector pin, return pin etc.) and rule represents field knowledge (such as equations and judgments in guide pin). The rules are, therefore, integrated into its related frame (objects in project modeling). According to an object's level and product modeling, frames are set up a frame tree of field knowledge through the key word framename. The formal description of the frame-rule structure is presented in Fig. 3. This language is used to represent design knowledge and experience, which belongs to the KBS. However, some sub-fields, such as set-in design, parameter calculation of the mold plate and selection the fit case of the classic mold-base, are not suitable for being represented by the frame-rule method. As a result, the function mode in variable mode is indicated in Fig. 3.

```
Knowledge = frame {frame}
Frame = framename variablearray rulearray objectarray father framename subframename
Framename = string
Fatherframename = string
Subframename = string
Variablearray = variable{variable}
Variable = variablename variableclass variablevalue variablemode
variablename = string
rulearray = rule{rule}
rule = IF equation {equation} THEN equation {equation} CF
equation = variable operator varialbevalue
operator = > | = | < | …
objectarray = variable {variable}
variablevalue = string | boolean | int | float | variable
variableclass = string | boolean | int | float | variable
variablemode = functionmode | askmode | rulemode
CF = float
end
```

Fig. 3. Backus representation of frame structure

The method of the frame-rule structure can represent and reason the knowledge in the white-box state, such as engineering theories and experience equations. For example, the number of mold plates is reasoned as below (partial): If a side gate is adopted and the number of the products in one mold is 2, then the number of the mold plates is 2; If a side gate is adopted and the number of the products in one mold is 1, then the number of the mold plates is 3; If a dot gate is adopted, then the number of the mold plates is 3.

These rules build a knowledge base for calculating the number of the mold plates. Using it, mold creators can avoid some unnecessary calculation and focus on the specific design of the molds. In the moldbase, some fields, such as the number of the plates and checking the interference of the mold are adopted in the frame-rule system to effect the reasoning. The few KBS windows (forms) are presented in Fig. 4.

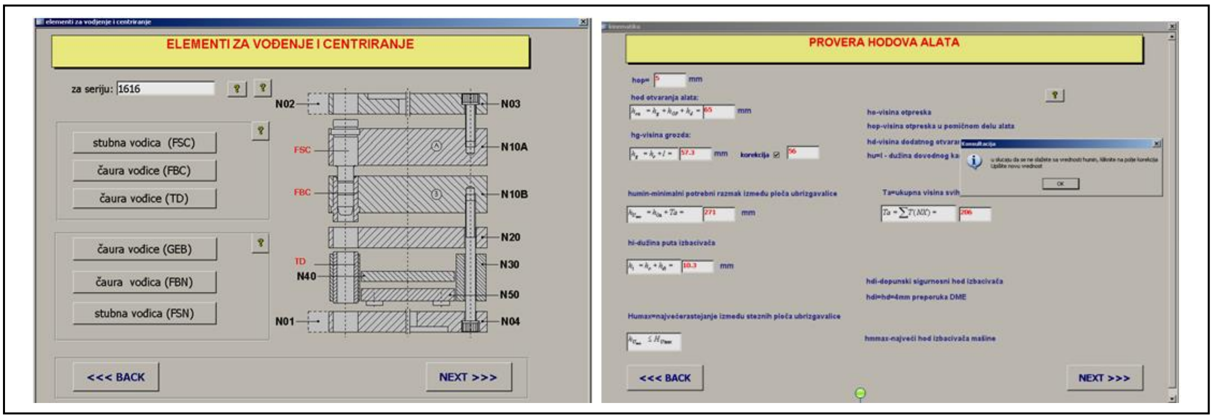

Fig 4. Two forms contained in KBS

The windows presents some calculus for main plate elements and injection molding machine parameters. Output information uses calculated parameters of stroke, machine, parameters for screw selection, guide pins and guide bushing selection.

CONCLUSION

Metasyntax notation (backus representation) of frame structure *is used to demonstrate the performance and simplicity of the proposed method.* The results of this study facilitate the knowledge integration and reduce development time. In this paper, a mold-base and its key technologies, such as product modeling, the frame-rule method, are presented in detail. The use of these technologies affords an efficient way to evolve a CAD/CAE system into KBS. The mold-base library includes successful design cases (four types) but frame base reasoning was observed only N-type. Further research will be based on other types.

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NEW DRYING SYSTEM CONCEPT OF SHELLED HAZELNUT

Mukrimin S. Guney[1], Musa Demir[1], Birkut Güler[1], Hakan Adatepe[1], Sertan Turan[2]
[1]University of Giresun, Engineering Faculty Giresun, Türkiye
[2]Kocaeli Health and Technology University
e-mail: guney80@gmail.com, ms.guney@giresun.edu.tr

Abstract: Around 1 million tons of in-shell hazelnuts are produced annually in the world. This constitutes a commercial amount of approximately 3 billion euros in the unprocessed state. 65% of the world hazelnut production is made in Turkey. 75% of this produced amount is exported. Hazelnuts are mainly used in the chocolate industry. Shelled hazelnut drying methods have a significant impact on product quality, lipid oxidation and overall flavor (total palatability). Fast harvesting and effective drying is gaining importance. In this study, suggestions and preliminary examinations of a greenhouse style drying system that farmers of all sizes can use in all climatic conditions, regardless of size, were made. In addition to effective and positive contributions to the total palatability of the product, it is expected to make significant contributions to the prevention of the formation of harmful structures such as aflatoxin.

INTRODUCTION

Hazelnut production on a global scale is approximately 1.000.000 tons/year. Approximately 65% of the world's total hazelnut production is carried out in Turkey. Hazelnut is important for our country with an annual export income of approximately 2 billion dollars. (Güney and Güner, 2018). In Turkey, approximately 440,000 farmers produce hazelnuts on an area of 700,000 hectares. Hazelnut, 80% in the chocolate industry, in the form of roasted, sliced, chopped, ground; 10-12% in the pastry-biscuit-bakery products sectors; 3-4% is used as nuts and snacks and the rest is used in the ice cream industry and oil industry (URL-1, 2019)

Hazelnut is mostly grown in the Black Sea region. Ordu, Giresun provinces hazelnuts are particularly preferred due to their suitability for chocolate sector and total palatability. Harvesting season is depends on altitude and hazelnut variety and realized in the second half of August and the first half of September. In summer, the relative humidity in this region is 70% and above. Little depending on the type of hazelnuts.

Although it varies depending on the variety, Turkish hazelnuts have an oil content of 60% and above. High oil content makes the product susceptible to lipid oxidation. One of the most important issues in the harvesting process is fast harvesting, minimum soil contact, and speed and effective drying (Guney 2020). According to the style and time of the harvest, as well as the type of product, the moisture content of the harvested products can vary about 25% during harvesting time. It is desired that the shelled hazelnuts with an average moisture content of 25% are quickly brought to the range of 6-7%, which is quite stable moisture content values.

Drying is based on simultaneous heat and mass transfer. Bringing the shelled hazelnuts from 30% moisture content to 6-7% moisture content is carried out by drying under the sun or in the shade with traditional methods. This is a method that is quickly affected by weather conditions, and it also causes labor intensive consumption in unsuitable weather conditions. In addition, it is very difficult to provide qualified and homogeneous drying. Hollow spherical body approach and modeling is appropriate for the analysis of the drying kinetics of in-shell and unshelled hazelnuts. Thermal energy is given to the product by radiation energy from the outer surface of the product or partially by contact with hot summer air and natural convection, and a temperature increase is created inside the product from the surface to the inside. The moisture in the product is directed towards the product surface from the inner point of the product and other regions and is removed from the product surface by means of hot air that provides thermal energy. During the process, the highest temperature occurs on the outer surface of the product and a temperature gradient develops within the product by decreasing in the radial direction. Moisture content analysis is a critical component of material quality (URL-2, 2020), (Brennan, 2008). It also directly affects the shelf life. In this study, a greenhouse-style tunnel-type portable tray-mounted fixed-bed drying system with natural air circulation is used. In the tunnel type drying system, the shelled hazelnuts are brought in trays and placed on top of each other and side by side. Rain and soil contact of shelled hazelnuts is prevented by covering the top and some side surfaces. Moisture analyzes and drying kinetics of in-shell hazelnuts during drying will be experimentally investigated and approaches to thin layer assuming and drying kinetics development curves will be determined by empirical equation.

MATERIAL AND METHODS

The opinion that the movement of the evaporated moisture to the product surface during drying is by diffusion is dominant. [Mjumdar, 2006) and hazelnut kernels can be considered as hollow spherical bodies.

2.1. Material

The hazelnuts used in this study were of the Tombul type and were obtained from the village of Öceli in Ordu province. The altitude in this region is between 110-160 meters. After the harvest, the hazelnuts with high moisture content, in shell form, separated from the outer husk by sorting the grain, will be placed in perforated style trays and placed in greenhouse style tunnel dryers. The diameter sizes of the products used were determined as 13-18 mm.

2.2. The experimental setup

Greenhouse-style tunnel dryers may be referred to as fixed bed drying ovens or assemblies. Trays are 100*50 cm in size. The trays are placed in 10 double rows on top of each other and 50 rows side by side. The schematic view of the greenhouse style tunnel dryer is given in Figure 1.

Fig. 1. Shelled hazelnut drying device

In Figure 2, the moisture meter device is given. My humidity measurement was carried out using a RADWAG brand MA 60.3Y model device. This device determines the humidity amount with infrared heating and thermogravimetric method.

Fig. 2. Moisture meter RADWAG MA 60.3Y

2.3. Experiment procedure

In the execution of the drying process, a tunnel-type fixed bed drying device similar to a greenhouse was used. Drying air temperature conditioning is not done. Ambient air was used and the process was applied for 72 hours between 22-25 August 2021. Ambient air temperature fluctuates between 18 and 26 C during 24 hours.

RESULTS AND DISCUSSION

Initial moisture content in shelled hazelnut drying is 25%. The final moisture amount to be reached is in the range of 6-7%. Considering the general developments of drying processes, they are divided into three parts as heating, constant drying rate, and decreasing drying rate periods. If a more detailed examination is desired, the decreasing drying fast period can also be considered as the first and second decreasing drying fast periods in itself. The moisture reduction in the heating period will be very small, so approximation of the relevant phase with the help of kinetic modeling equations will not be very meaningful in obtaining the targeted information. When the drying rate curve is examined, it is seen that the heating period will not last very long and it takes place within the first hour period. From this moment up, constant drying takes place in the first twelve hour period and the following periods. It is understood that the development of the second decreasing drying fast period will occur in deeper drying processes such as roasting.

CONCLUSION

It is important to limit the stack height in the trays to ensure homogeneity. In addition, it is necessary to pay attention to the distance between the tray stacks in order to establish homogeneous air distributions. At the end of the 72-hour drying process, it is observed that the desired 6-7% humidity can be easily reached with the right intervention natural methods. It is understood that the desired moisture contents can be obtained after 48 hours depending on the external weather conditions (wind, temperature, relative humidity). With this method, the desired moisture content in the products can be provided quickly and homogeneously. Since there is no soil and water contact, lipid oxidation formations are minimized. In addition, the fast and convenient drying process makes a positive contribution to the total taste of the product. As can be seen from the model curves, it is understood that it is appropriate to divide the drying periods as heating, constant drying speed, and first decreasing drying speed periods. All three periods show differentiated characteristics from each other. Approximating the entire process with a single model equation, including all three periods, may not be very successful. As a result of determining the durations of different drying periods, it would be more appropriate to take different models for each period and evaluate the whole process with the combination of these models.

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MODELLING AND ANALYZES THE CATENARY SUSPENSION IN RAILWAY ELECTRIC TRACTION

Cristina Miklos[1], **Imre Zsolt Miklos**[1]
[1]University Politehnica Timisoara, Faculty of Engineering Hunedoara, Romania
e-mail: cristina.miklos@fih.upt.ro; imrezs@fih.upt.ro

Abstract: Catenary suspension is a big complex structure, which can provoke incorrect function of trains, because of extern perturbation. In this paper, the authors present 3D catenary suspension modeling in Autodesk Inventor program. 3D model who result, is analyzed by finite element method in Ansys program, to have in view: equivalent stress distribution and deformations, respectively frequency modes in catenary suspension elements for different positions of contact force. Contact force is between pantograph and the catenary suspension. In the final part of paper, authors present the conclusions who results of this analyses.
Key words: catenary suspension, electric traction

INTRODUCTION

In electric traction, electric locomotives is moving on railway track because of a propulsion subassembly, made with rotative/linear electric motor who exert a contact force on train. In electric traction, contact line use catenary suspension (contact line sustained by a messenger through droppers). The assembly made this way, is named contact suspension [1], [2], [3], [4], [5].

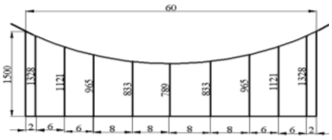
CATENARY MODEL DESCRIPTION

The equations governing the response of the catenary are obtained through each contact wire displacement as Fourier sine series expansion [2]. The displacement equations are extended then using the sine terms amplitudes and Lagrange's method, and are used to obtain catenary natural frequencies and natural modal shapes [3], [4].

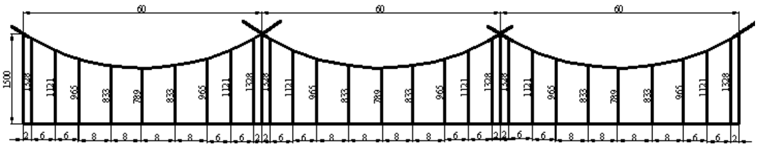
CATENARY SUSPENSION ANALYSIS

Catenary suspension modeling in Autodesk Inventor Professional [6]

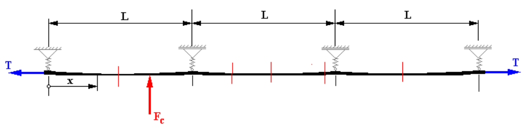
The study is made on a road section with the configuration shown in figure 1.



a) Road section



b) Geometric model in detail



c) Static scheme of the analyzed section

Fig. 1. Geometric and static diagram of the catenary suspension section assembly

Sectional characteristics and the element's material are:

- Contact wire section S=100mm^2 - copper; Messenger wire section S=70mm^2; mass m=610kg/km; sag f≅28cm; modulus of elasticity E=150000N/mm^2 – steel; droppers section S=28,26mm^2 – steel wire

The declaration of the general data of entry in the calculation program is detailed in the reports generated by the program following the running of the required analyzes. The discretization of the structure, respectively the "mesh", followed by the automatic identification of the number of finite elements and the number of connection nodes between them, led to the determination of a number of 65509 nodes and 34428 elements.

In the calculations the own weight of the structure was taken into account, considering:

- gravitational acceleration value: 9806,65mm/s^2; weight vector components: [0,0x; -9806,65y; 0,0z] in the Oxyz coordinate system

Catenary suspension static analysis

First, the contact force F_c=90N action to the middle of the first catenary span, as a verified, concentrated force applied on inferior contact wire. Figure 2–4 show the catenary behavior (deformation, unit stress and safety factor).

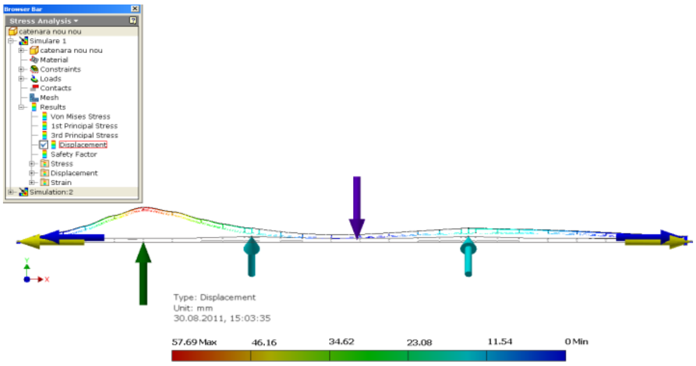


Fig. 2. The distribution of the values of the displacements and the deformed allure along the catenary

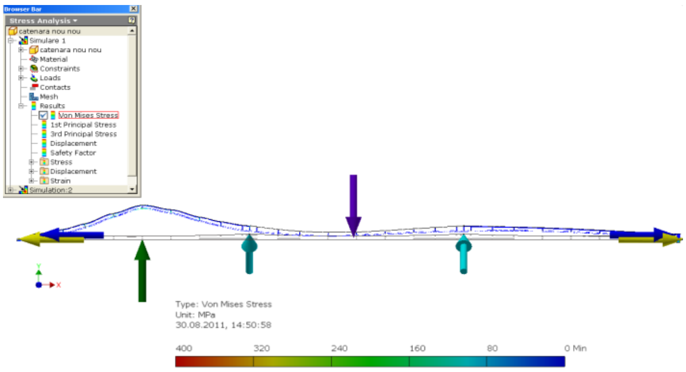


Fig. 3. Distribution of equivalent unit stress along the deformed catenary

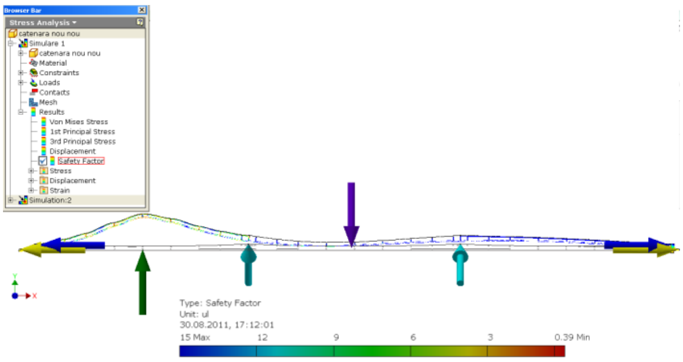


Fig. 4. Distribution of the safety factor along the deformed catenary

In the first step, it is observed that the contact wire moves vertically upwards, as the contact force transmitted by the pantograph advances along the catenary. The displacement increases monotonously and linearly due to the fact that the stiffness of the suspension decreases towards the areas located in the catenary field, and the contact point of the concentrated force moves in the same direction with the decrease of the stiffness, respectively towards the middle of the first opening. After the catenary displacement reaches a maximum, it begins to decrease. Because the structure of the catenary is stiffer in the areas near the poles than in those in the middle of an opening, the displacement of the contact wire is also lower as it approaches a pole. Next to the poles, it is noticed that the wire does not move significantly, due to the local rigidity of the suspension. In the area at the right end of the first opening, the deformed shape of the wire is steeper. Therefore, in order to follow the catenary, the pantograph will be forced to move downwards, and its inertia and the faster decrease of the wire slope will lead to the increase of the contact force. As the pantograph goes through the first opening disturbing the catenary, it causes the contact wire to vibrate after its passage. The first opening has decreasing positive value shifts, showing oscillations similar to the first natural mode. Although these oscillations dampen over time, they can cause problems for trains that use more than one pantograph, because after passing the first pantograph that affects the catenary, the second raised pantograph will enter an already disturbed area of the catenary.
In the second part of analysis, contact force F_c=90N action to the middle of the second catenary span. Figure 5–7 show the catenary behavior (deformation, unit stress and safety factor).

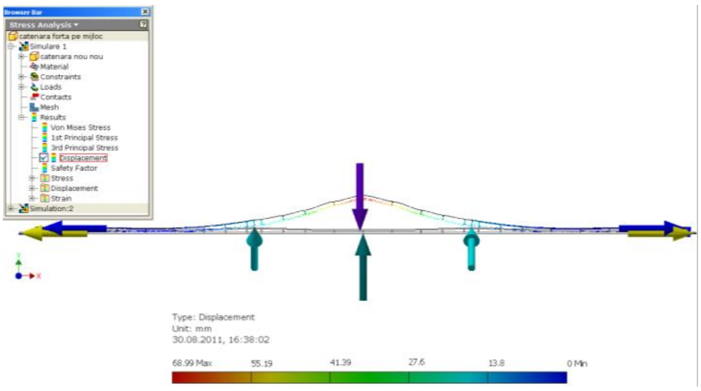


Fig. 5. The distribution of the values of the displacements and the deformed allure along the catenary

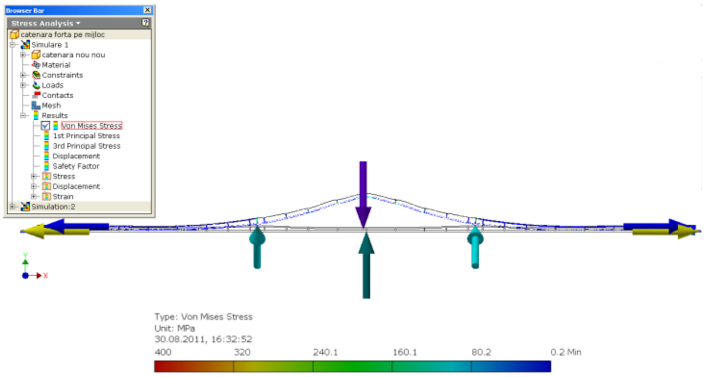


Fig. 6. Distribution of equivalent unit stress along the deformed catenary

Analyzing the obtained diagrams, it is found that the response of the loaded catenary in the middle of the second opening is similar to that of the first opening: the displacement of the wire increases sharply, approximately linearly, in the less rigid region of the catenary located in the opening field support, where the rigidity of the structure is higher, the slope of the deformity decreases. This consistent behavior in consecutive openings may justify the consideration in calculations of a catenary having a finite length. From the analysis of the evolution of the mechanical phenomena subject to the study, the following conclusions can be formulated: the movements of the catenary increase almost linearly until a peak is reached, then decrease rapidly as one approaches a pillar.

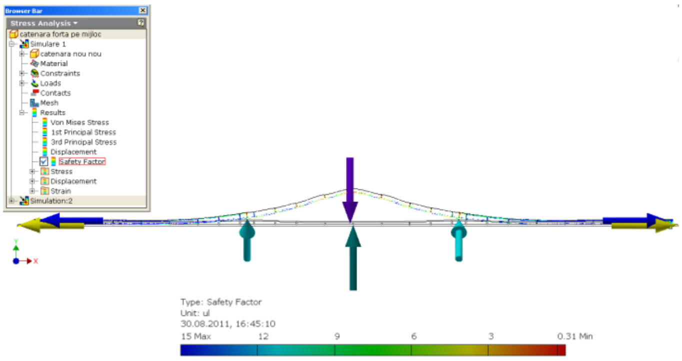


Fig. 7. Distribution of the safety factor along the deformed catenary

The maximum displacement of the catenary occurs immediately after the pantograph has exceeded the middle of the opening, and the value peak of the displacement is offset from this section. Then, the tendency of the contact wire to rise, coupled with the constraint imposed by the higher stiffness of the catenary in the areas of the support poles, leads to a decrease in vertical displacements as one pole approaches, and the next peak of displacement can occur only in the area towards the middle of the next opening. Changing the shape of the catenary next to the support pillars, from a steep slope to a more moderate inclination, can have a significant effect on the performance of the pantograph. The hypothesis is confirmed by the findings from the operation, which reveals that in these areas there are the most frequent losses of contact between the pantograph and the catenary.

Catenary suspension modal analysis

The third part of the simulation aimed at determining its own vibration modes for the catenary configuration described above. The simulations were conducted on the section consisting of the three openings previously considered (fig. 8 – 15).

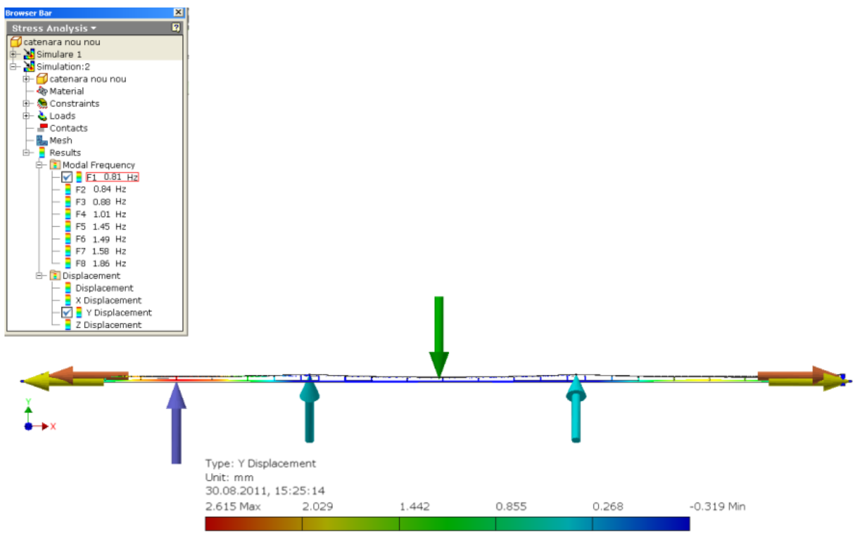


Fig. 8. First frequency mode in range

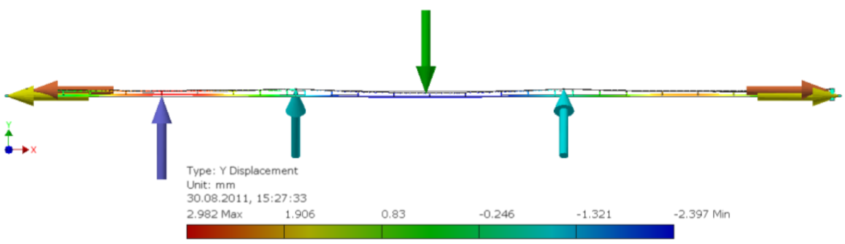


Fig. 9. Second frequency mode in range

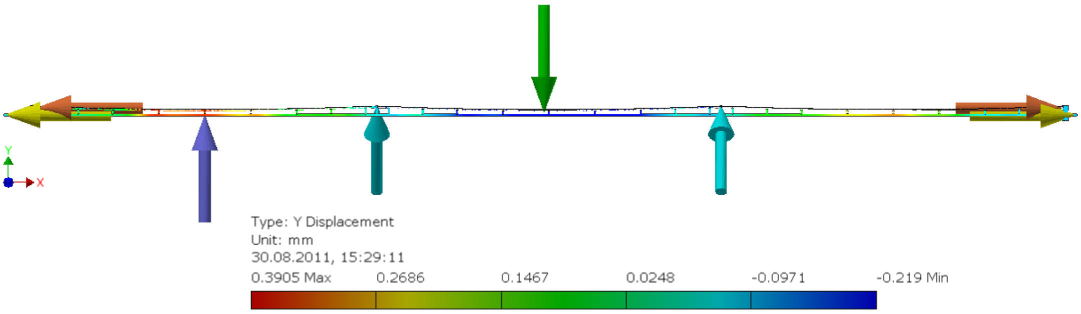


Fig. 10. Third frequency mode in range

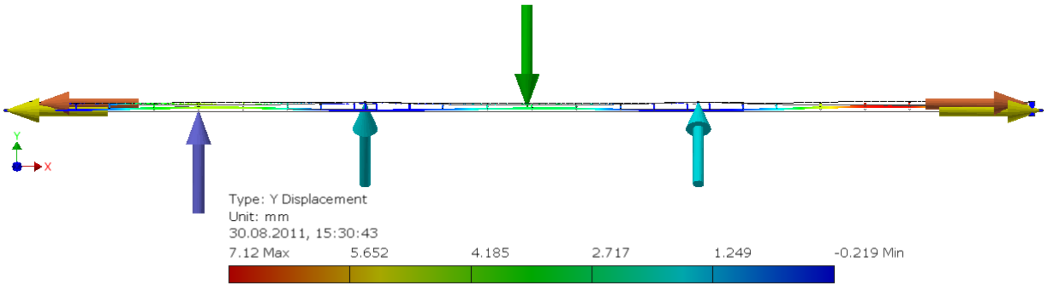


Fig. 11. Forth frequency mode in range

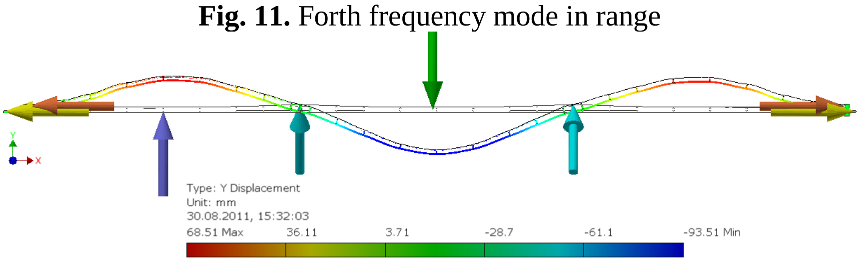


Fig. 12. Fifth frequency mode in range

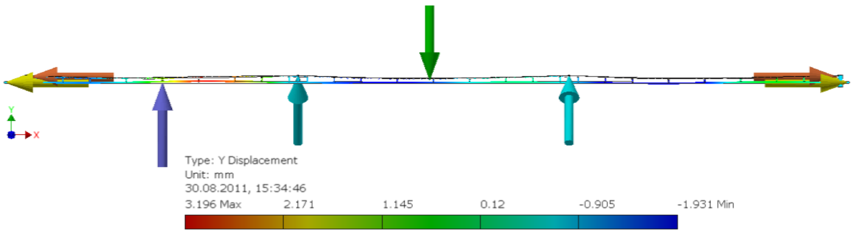


Fig. 13. Sixth frequency mode in range

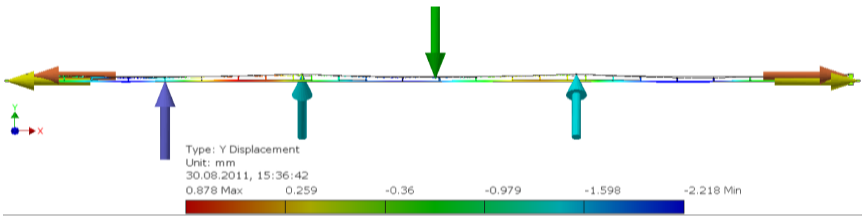


Fig. 14. Seventh frequency mode in range

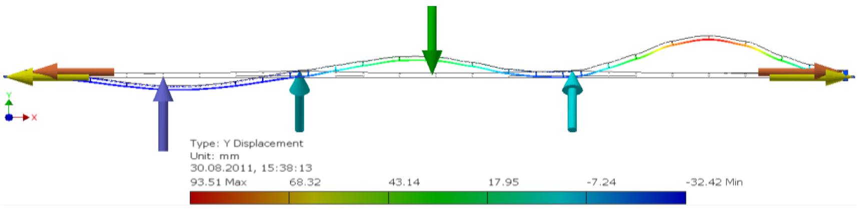


Fig. 15. Eighth frequency mode in range

Next, are presented the sixth frequency mode in range for the case when contact force act in the second section of catenary. The obtained results are showed in figure 16 - 23.

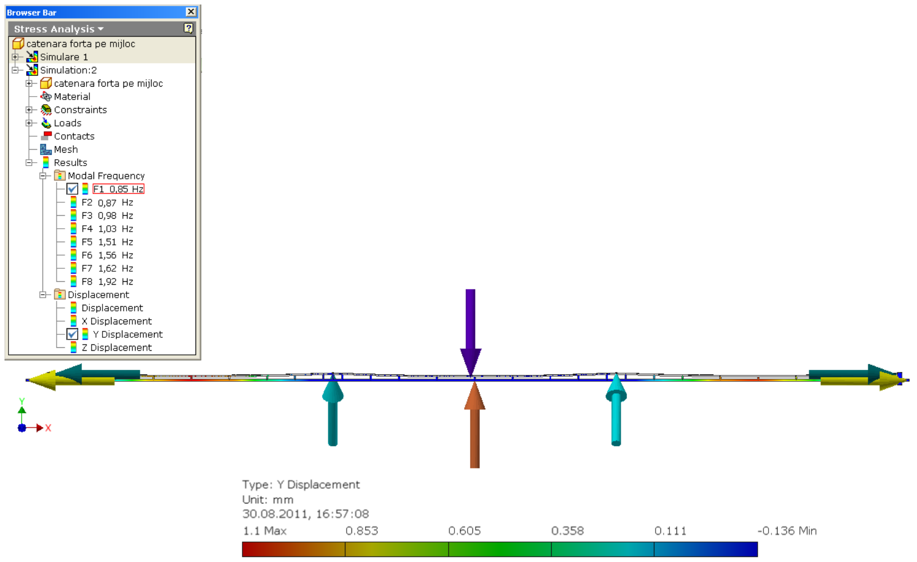


Fig. 16. First frequency mode in range

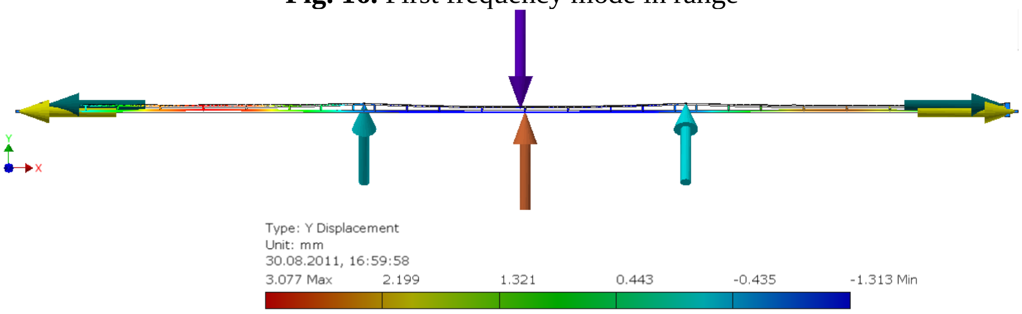


Fig. 17. Second frequency mode in range

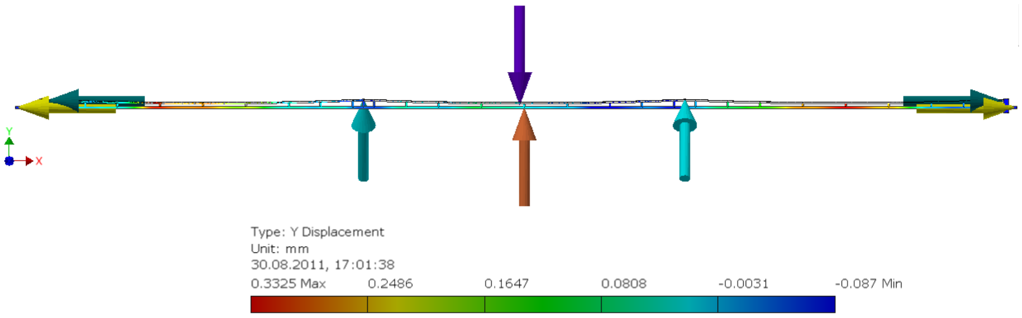


Fig. 18. Third frequency mode in range

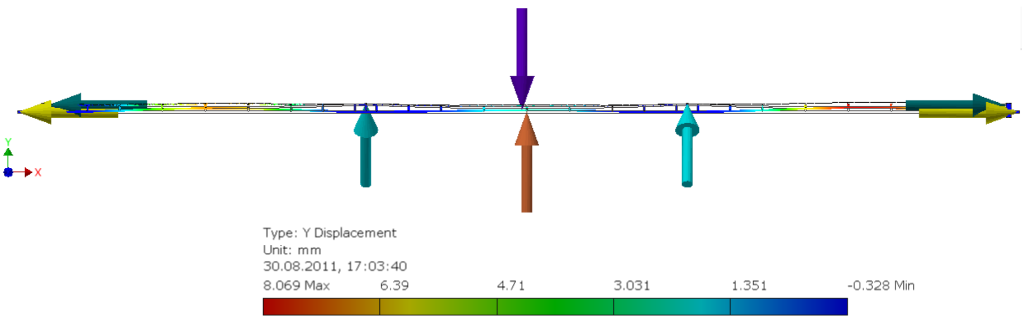


Fig. 19. Forth frequency mode in range

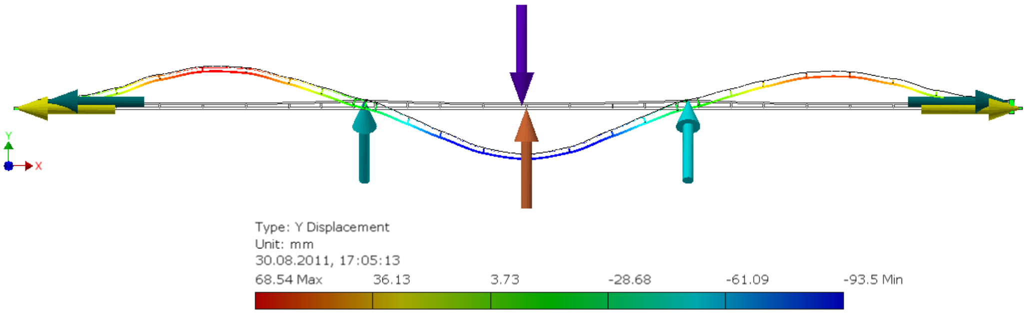


Fig. 20. Fifth frequency mode in range

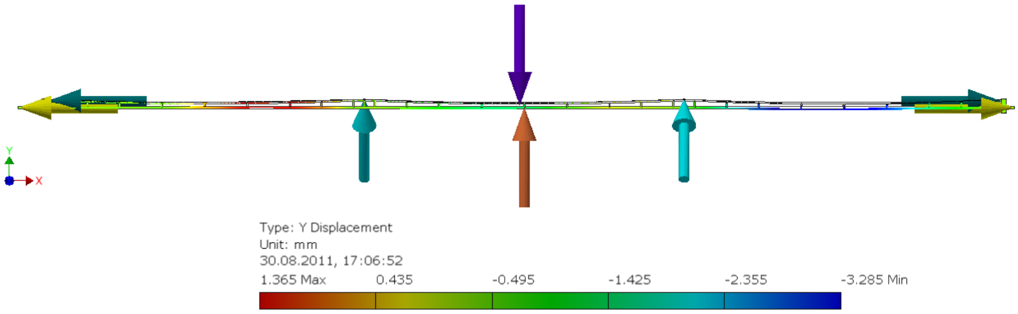


Fig. 21. Sixth frequency mode in range

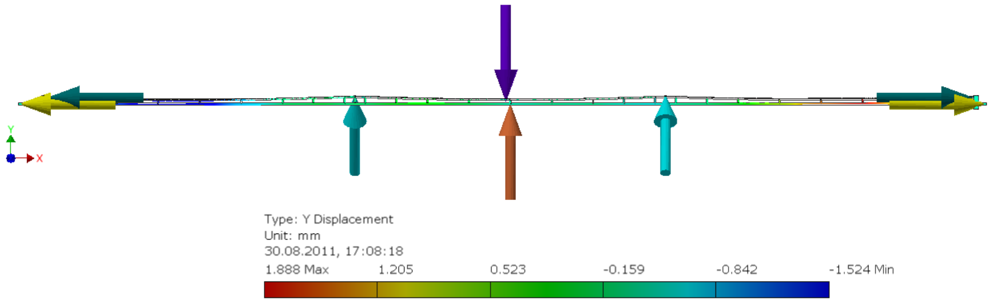


Fig. 22. Seventh frequency mode in range

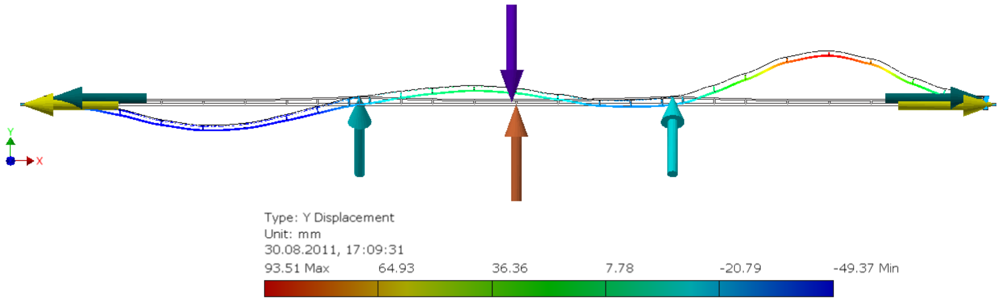


Fig. 23. Eighth frequency mode in range

CONCLUSION

In conclusion, the research carried out reveals that the catenary suspension always has a higher rigidity in the regions adjacent to the support pillars, compared to the areas located in the field of the openings. The rigidity of the poles and that of the pendulums significantly influences the natural modes of vibration. The pillars, with high rigidity, move much less with the vibratory movements of the catenary they support. The smaller displacement in the region of the pillars can be distinguished in each of the 3 openings, especially in the first natural ways, even the shape of the lower thread of the catenary being influenced by the local manifestation of the rigidity of the pillars. The pendulums, also showing a significant rigidity, move a little with the vibrational movements of the catenary. At low frequencies, the difference between the behavior of the upper and lower wire is almost imperceptible, but at higher frequencies, the deformed shape of the two wires differs especially between the connecting pendulums. The bending stiffness of the catenary wires has less influence on the shapes of its own modes. However, next to the pillars, the shapes of the own modes present significant discontinuities, depending on the bending capacity of the catenary. In the absence of the pantograph, each aperture can vibrate freely relative to the adjacent aperture, and the frequencies have the same order of magnitude, whether or not the apertures vibrate together. In terms of vibratory movements, the described behavior reappears when the pantograph is in the second opening, the movement of the catenary wire increasing linearly; once the pantograph leaves the opening, the free vibration of the catenary occurs and, similar to those presented above, the vibration is dominated by the first vibration mode. Deviation of the peak deformation of the catenary is significantly influenced by the kinematics of the vibrational wave displacement of the suspension, the phenomenon becoming important at high train speeds or at low catenary wave speeds. However, changes in the shape of the catenary deformity near the pillars, from a steep slope to a steeper one, significantly affect the performance of the pantograph.

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[6] ***Autodesk Inventor Professional

HARDNESS TEST OF 3D PRINTED WORK PIECE FROM PLA PLASTIC

Dušan Jovanić[1], Valentina Mladenović [1], Dragan Halas[1]
[1]Technical College of Applied Sciences, Zrenjanin, Serbia
e-mail: dusan.jovanic@vts-zr.edu.rs

Abstract: The paper presents a hardness test of a 3D printed workpiece with a filament of polymeric material - polylactide (PLA) by Shore A scale method. One of the disadvantages of 3D printing is that the parts have much weaker mechanical characteristics and need to be tested to determine the functionality of the working part. Hardness testing of plastic materials is defined by the standard SRPS EN ISO 868: 2015 - Plastics and ebonite - Determination of hardness by indentation using a durometer (Shore hardness) and was performed with an analog durometer - hardness tester.
Key words: Hardness testing, Additive production, 3D printing, Polylactic acid (PLA)

INTRODUCTION

Due to the lower quality of the processed surface and weaker mechanical characteristics of polylactide (PLA) parts obtained by 3D printing, it is necessary to determine the mechanical characteristics: hardness, tensile strength, impact strength, compressive strength, bending strength, fatigue strength, creep, aging, friction coefficient, resistance to shear and crack propagation according to SRPS ISO 17296-3: Additive technologies - General principles - Part 3: Main characteristics and corresponding test methods. In addition, it also defines test categories for metal parts, plastic parts and ceramic parts and classifies them into three groups: group H (tests of functional parts that are highly safety-critical), group M (tests of functional parts that are not safety-critical) and group L: testing parts during construction or prototype parts. Hardness testing is provided for all these groups of plastic parts.
The goal of this work is to determine the hardness of the workpiece made of PLA plastic depending on the height of the applied layer in the shell and infill. In addition, it is necessary to determine the hardness for different filling methods (linear, zigzag and concentric) at the same layer height.
The hypotheses of the research are that the highest hardness of the workpiece made of PLA plastic is achieved at the lowest layer height both in the casing and in the filling, and that the hardness is the same for the same layer height, and different ways of filling.

ADDITIVE MANUFACTURING

Additive manufacturing can be divided according to SRPS ISO 17296-2:2017: Additive technologies - General principles - Part 2: Overview of process categories and filling, into: Bath photopolymerization - laser stereolithography (SLA) and full-layer illumination-based stereolithography (DLP - SLA, LCD -SLA), Powder substrate fusion - procedures using laser (SLS, SLM, DMLS) and procedures using electron beam (EBM), Material extrusion (FFF - Fused filament fabrication), direct printing (PolyJet, PolyJet Matrix) , Bonding printing (3D Print, 3D Print with suspension application), Lamination of foils (LOM - Laminated object manufacturing, PSL) and Deposition of materials using directed energy (DED - Directed energy deposition).
An overview of the types of additive manufacturing standards is shown in fig. 1 [10].

The process of extruding materials

The process of material extrusion (FFF - Fused filament fabrication or FDM - Fused Deposition Modeling, the trade name of the company Stratasys [11], uses solid thermoplastic material - filament, which is pushed through a heated nozzle, the temperature of which depends on the type of polymer, and in a doughy-melted state it is applied to a heated or unheated build plate, after which it hardens and forms the desired piece layer by layer.

The most important parameters that can be adjusted with a 3D printer for the process of extruding materials - FFF are: manufacturing speed, extrusion speed, the height of the applied layer in the shell and infill and the temperature of the nozzle and build plate.

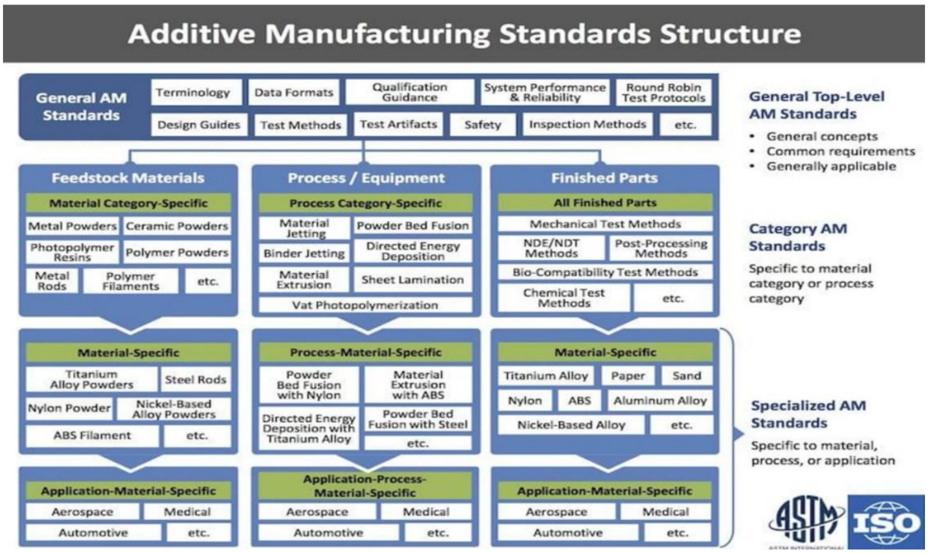


Fig. 1. Overview of types of additive manufacturing standards according to ISO/TC 261 and ASTM F42

POLYMERS - POLYLACTIC ACID (PLA)

There are a large number of polymers with different mechanical, physical, chemical, electrical, thermal and other characteristics, which have a wide range of applications.

PLA is a thermoplastic biodegradable plastic obtained from organic sources (corn starch, sugar cane or beet) - by fermentation of plant starch and has similar characteristics as polypropylene (PP), polyethylene (PE) or polystyrene (PS). It is used to produce food containers, foils and medical implants and has a high surface energy that makes it ideal for 3D printing. The disadvantages of PLA are low heat resistance and relatively low strength. The characteristics of PLA are given in Table 1 [8].

Table 1. Characteristics of polylactide acid - PLA

The parameters	Values
Heat Deflection Temparature- EN ISO 75	52 °C
Density	1,24 g/cm³
Tensile Strength EN ISO 527-1	50 MPa
Flexural Strength EN ISO 178	80 MPa
Impact Strength (IZOD) - EN ISO 180	96,1 (J/m)
Shrinkage rates	0,37-0,41%

The chemical formula of polylactide acid is H-[OCH(CH3)CO]n-OH, and the PLA polymer for this type of 3D printing is in filament form.

EXPERIMENTAL PART

In a series of experiments, a blind flange was used as a working object. These elements are used, during the construction of pipelines, to close the ends of pipelines or forks, as well as when testing pipe closures. They are connected with screws and nuts to pipeline flanges, forks or pipe closures with a mandatory seal between the elements. The blind flange, whose structural shape and dimensions were used in this work, was made according to the EN 1092-1 Type 11 / DIN 2632 PN6 standard. The outer dimensions of the flange are ϕ80 x 12 and it has four M10 holes spaced on a ϕ55 diameter.

The 3D model of the flange (Fig. 2) was realized in the software package SOLIDWORKS 2016, and then it was formed into a suitable STL file with the maximum resolution allowed by the software.

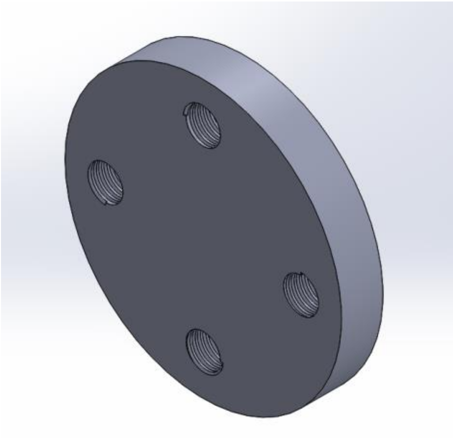


Fig. 2. 3D CAD model of blind flange

The STL file of the flange was imported via Ultimaker open source Cura software and is shown in Fig. 3.

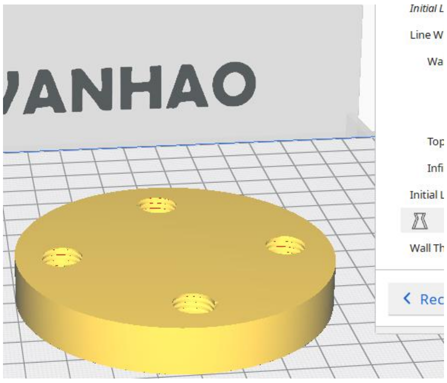


Fig. 3. Imported STL file of blind flange

After that, the corresponding parameters were varied according to the experimental plan and a series of flanges with the same external appearance (Fig. 4) but different characteristics was produced.

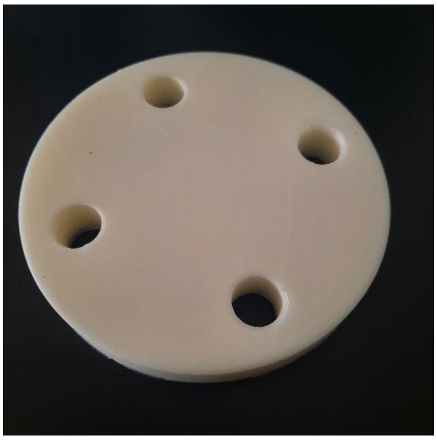


Fig. 4. Appearance of the 3D printed object

As measuring instrumentation, a durometer - hardness meter (hardness meter) BAREISS, Germany, according to Shore, scale A with a conical shape of the needle at an angle of 350, shown in Fig. 5, with a minimum sample thickness of 4 mm and an accuracy of 0.5 HS A [6].

Fig. 5. Device for measuring the hardness of PLA parts

The characteristics of Wanhao PLA filament are shown in Table 2.

Table 2. Features of Wanhao PLA filament

The parameters	Values
Filament type	PLA
Diameter (mm)	1.75
Melting point (ºC)	190 - 210
Build plate temperature (ºC)	0 - 60

In Fig. 6 is shown the 3D printer Wanhao Duplicator 6 on which the elements for the experiment were printed, and its technical characteristics are given in Table 3 [7].

Table 3. Wanhao Duplicator 6 3D Printer Technical Features

The parameters	Values
Additive technology	Material extrusion (FFF)
Materials	PVA, PLA, ABS, PEVA, HIPS
Max. part dimensions (mm)	200 x 200 x 180
Layer thickness (μm)	20 - 200
Filament diameter (mm)	1.75
Nozzle outlet diameter (mm)	0.4
3D printing speed (mm/s)	30 - 150
Working temperature (ºC)	180 - 260
Build plate temperature (ºC)	50 - 100

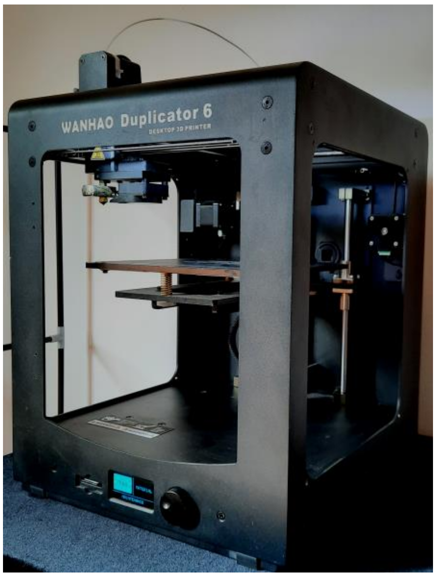


Fig. 6. 3D printer Wanhao Duplicator 6

RESULTS AND DISCUSSION

The surface quality of the workpiece made of PLA plastic depends on the height of the applied layer in the shell and infill. The lower the height of the applied layer, the higher the quality of the object and the greater the ability to perform details, but the production time is nonlinearly longer.
The hardness values depending on the height of the applied layer and the type of filling, as well as the temperature of the build plate, are shown in Table 4, and the hardness values for different types of filling (pattern), with an unheated work plate, are shown in Table 5.

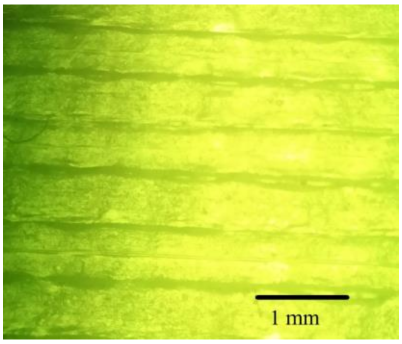
Tabela 4. Hardness values for different heights of the applied layer and heating of the build plate at the same linear filling

Pattern	Build plate temperature (ºC)	Layer height (mm)	Hardness HS (A)
Lines	55	0.1	98
	20	0.1	99
	20	0.2	98
	20	0.4	96

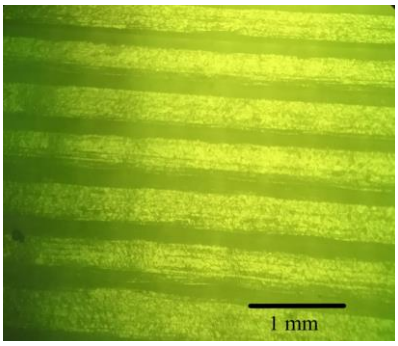
Tabela 5. Hardness values for different types of fillings (patterns)

Pattern	The length of the filament used (m)	Layer height (mm)	Build time (min)	Hardness HS (A)
Lines	0.52	0.1	13	99
Zig Zag	0.52	0.1	13	99
Concentric	0.52	0.1	12	99

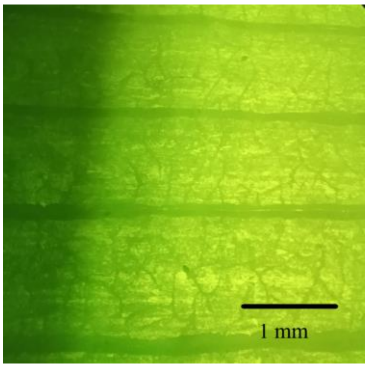
Macroscopic images of PLA objects with a layer height of 100, 200 and 400 microns at x5 magnification are shown in Fig.7.



a)



b)



c)

Fig. 7. Macroscopic image of a PLA object with a layer of 100, 200 and 400 microns high at x5 magnification and a cross-section of a layer with a layer height of 100 microns

In Fig. 7a, the darker lines represent the furrows between the layers, which are places of stress concentration, and the wider they are, the rougher the surface. Macroscopic inspection revealed that the width of the applied layer (layer) is the largest at the highest height of the applied layer (Fig. 7c) and that it is twice as large in relation to the height of the applied layer of 0.2 mm (Fig. 7b). It can also be seen that the width of the groove (unfilled), almost twice as large at the height of the applied layer of 0.2 mm (fig. 7b) compared to the height of the applied layer of 0.1 mm (Fig. 7a).
A cross section of flange and the number of layers for an application height of 0.1 mm is shown in Fig.8.

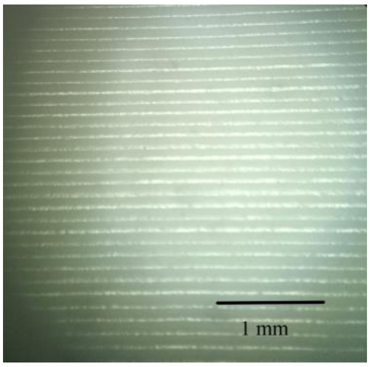


Fig. 8. A cross-section of a layer with a layer height of 100 microns

The hardness (HS-A) of the PLA plastic part depending on the height of the applied layer (h) is shown in Fig. 8.

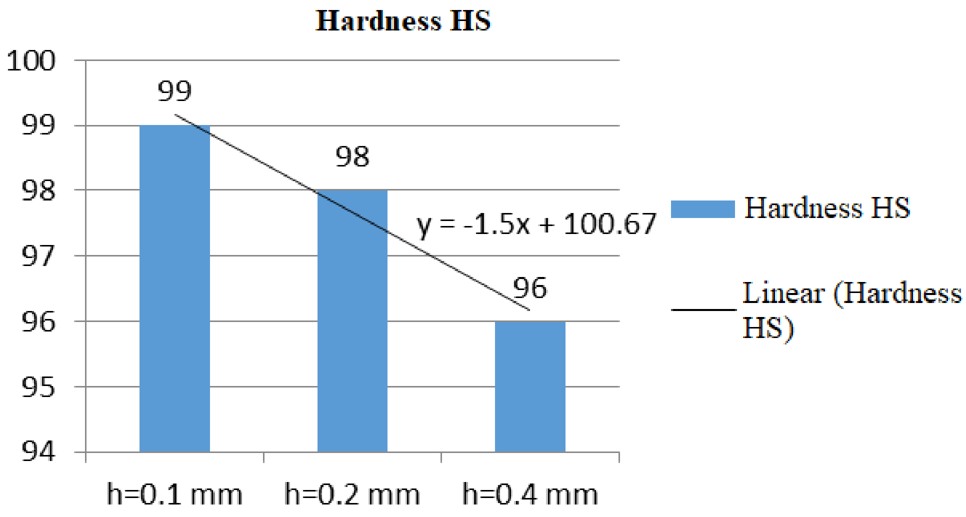


Fig. 8. Hardness depending on the height of the applied layer

The hardness of PLA samples made by 3D printing with FFF technology depends on the height of the applied layer, so that it is maximum for the smallest height and decreases almost linearly according to the smallest hardness to the largest height during linear filling.
The heating of the board at the same filling and height of the applied layer has a slight effect, so that the hardness is lower by 1%.
The hardness is the same for the same layer height, with different filling methods (linear, zigzag and concentric).

CONCLUSION

3D printing with the process of extruding material with FFF technology has a low quality of the processed surface, and from the point of view of hardness, the hypotheses is confirmed that the highest hardness of the workpiece made of PLA plastic is achieved at the lowest layer height of 0.1 mm, with complete filling in the shell and filling (infill) and decreases almost linearly according to the lowest hardness for the highest height at linear filling.
The filling (pattern) does not significantly affect the hardness values because for all three types of filling (linear, zigzag and concentric) the hardness value is the same.
At the same filling and height of the applied layer, the heating of the plate only slightly affects the hardness of the workpiece, reducing it by 1%.

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INVESTIGATION OF SHAPE ACCURACY OF SELECTIVE LASER MELTED TI6AL4V LATTICE STRUCTURE BY COMPUTER TOMOGRAPHY

Gergely Dezső[1], Ferenc Szigeti[1]
[1]University of Nyíregyháza, Institute of Engineering and Agriculture, Department of Physics and Production Engineering, Nyíregyháza, Hungary
e-mail: dezso.gergely@nye.hu

Abstract: Selective laser melting is a widely applied additive manufacturing technology for metals, especially Ti6Al4V alloy today. Manufacturing of lattice structures stands in focus of scientific research, because of special technological advantages of those, like production of lightweight parts, opportunity of combination with other materials utilizing pores, biomedical applications, several scenarios of production resulting in tuned mechanical properties.
In our experiments tensile test specimens were produced with periodic trabecular structure. Pore size of structure were varied. Shape accuracy of test specimens were measured by computer tomography. Size accuracy of the total specimen, size and shape accuracy of pores, places of material defects and excesses were identified and described quantitatively.
Our experiments showed that most part of test specimens were precise enough. However special areas were identified with high inaccuracies. Moreover most dangerous errors, material absence and cracks also observed.
Key words: lattice structure, Ti6Al4V, selective laser melting, shape accuracy, dimensional accuracy

INTRODUCTION

In 20th century manufacturing technologies went through the most extraordinary advancement in history of mankind [1–3]. Beside several areas of technological development additive manufacturing (AM) brought a revolutionary change opening up new doors of integration of production with other systems of economy like remanufacturing, informatics, robotics [4], logistics [5], commerce, construction [6] and medicine [7–9]. Flexibility of AM strongly contributes to mass customization production emerging in the frame of industry 4.0 [10]. Number of research publications related to AM increase exponentially since 2000 [11]. AM with its new opportunities and challenges [12] also transforms even way of thinking in engineering design [13–15]. AM today is applicable for composing new materials with designed and tuned properties, like composites [16, 17] and special microscopic-level mixtures [18].
Standard ISO/ASTM 52900 introduces a nomenclature for AM technologies and concepts connected with AM [19]. This standard specifies seven class of AM technologies: binder jetting (BJT), directed energy deposition (DED), material extrusion (MEX), material jetting (MJT), powder bed fusion (PBF), sheet lamination (SHL) and vat photo polymerization (VPP).
Distinctive feature of PBF technology is that during the process thermal energy fuses a part of a powder bed. PBF technologies can be applied to many different materials, most frequent ones are plastics and metals. In the followings we deal with metals
Fusion comes true in two main ways, sintering and melting. The process is called sintering if original powder particles do not completely melt. When all powder particles are melted, it is called melting. Source of thermal energy is usually laser beam or electron beam.
Selective laser melting (SLM) is a PBF method which uses laser beam for full melting of material to be fused [20]. When it is applied for metals it is often called direct metal selective laser melting (DMSLM). This paper presents result of DMSLM applied on Ti6Al4V material, and we refer to this briefly as SLM, because there is no risk of ambiguity.
Feedstock material of SLM is metal powder. Such kind of powders differ from base materials of powder metallurgy. Today a complete industrial background exists to supply AM market with powders of several metals and alloys. Most important properties of AM metal powders are particle size distribution, average size, particle shape, nominal chemical composition, and level of accuracy of

chemical composition. Quality of metallic parts produced by AM depends of quality of metal powder which it is made of [21, 22].
SLM is a production method with several process parameters. Significant part of scientific literature treats how properties of parts produced depends of SLM process parameters [23–26].
Dimensional and shape accuracy are also dependent from SLM process parameters [27–32].
AM technologies in themselves are rarely able to produce ready to use parts. Commonly so-called postprocessing methods are used to achieve required quality of the product. Aims of postprocessing are surface modification in order to improve shape accuracy , wear resistance [33, 34], surface roughness [35–37].
Computer tomography first gained ground in biomedicine is a cost and expertise demanding method, at the same time it is increasingly applied also in other fields of industry for three-dimensional imaging of complex structures. This is especially true for inspection of additively manufactured lattice structures which form a new and promising class of parts [38, 39].
In this paper we introduce an experimental study on shape and size accuracy of a lattice structure produced by SLM from Ti6Al4V alloy. Since a lattice structure has numerous details inside, where those can not be observed by optical methods, computer tomography (CT) has been applied as imaging procedure. Aim of this study was to show out dimensional and shape deviations, material excess and lack, as well as cracks and fractures originated from manufacturing procedure.

MATERIAL AND METHODS

Material Ti6Al4V

Samples were produced from Ti6Al4V ELI powder by SLM.
Ti6Al4V is known as a widely applied metal alloy in industry, which is also intensively studied in science. In our experiments we used a special form of Ti6Al4V containing extra low interstitials (ELI). Chemical composition of Ti6Al4V ELI in weight% is 5.5-6.75% Al, 3.5-4.5% V, C $\leq$ 0.08%, O $\leq$ 0.2%, N $\leq$ 0.05%, H $\leq$ 0.015%, Fe $\leq$ 0.4%. All other elements must be present in less than 0.1%, and total amount of other elements must be less than 0.4% [40].
This metal alloy has remarkable advantages like low mass density, good mass-strength ratio, chemical endurance and biocompatibility. It is applied in biomedical, pharmaceutical, vehicle, nuclear industries and several other fields [41, 42].

Sample production

The shape of the sample is identical to a standard tensile test specimen with rectangular cross section expected that active zone (which part is used to break away) of it has lattice structure. Lattice is periodical. Unit cell is cubic with 2.5 mm edge length. Figure 1 shows overall shape of the test specimen and middle part with lattice structure magnified.

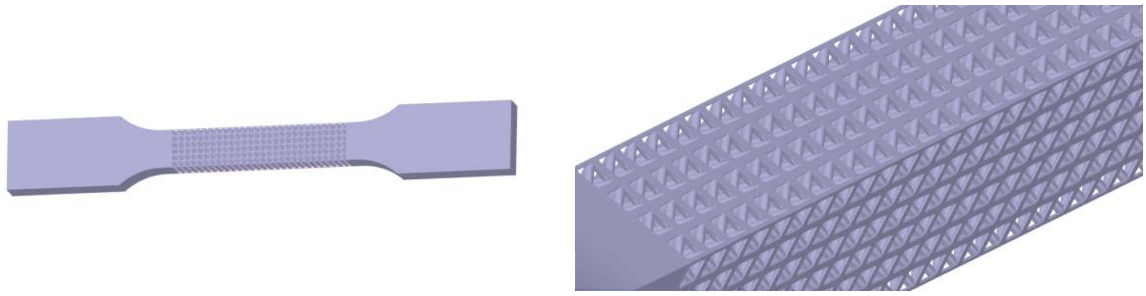

Fig. 1. A standard tensile test specimen with modified active zone. It has lattice structure built up from cubic unit cells

This sample was produced in horizontal orientation with its smallest faces down as left side of Figure 1 sows. Manufacturing machine was an EOS M290 400W. Production parameters were set to default values.

Computer tomography

Computer tomography is often applied for inspection of additively manufactured metallic parts [38] [39].

Computer tomography may be known for most people from medical practice. Aim of such a measurement is to gain a 3D representation of internal structure of a body, which is not observable by optical methods. In industry aim is the same. Difference from medical machines is that specimen rotates and X-ray source stands, and usually it applies stronger X-ray for inspection.

A computer tomograph uses X-ray to radiograph the sample. By this way a projection of internal structure is captured like a shadowed plane image. As the sample rotates several such an image are taken. Spatial representation of internal structure is gained by numerical mathematical methods in digital form, usually as an STL (standard triangulation/tessellation language) model. Resolution is characterized with so-called voxel size, which depends on acceleration voltage, size of sample and distance of sample and source.

In our experiment a Werth industrial computer tomograph (CT) machine was applied with maximum 225 kV accelerating voltage.

In this study shape of the lattice was imaged, which is really the surface of the solid body. Now microstructure inside the material was not revealed.

RESULTS AND DISCUSSION

After CT measurement we had two electronic body representation of the specimen in STL format. First is the CAD body model which was the base of manufacturing. This is the ideal shape of the specimen. Second body model was resulted from CT inspection by processing software of the measurement system. This represents the realized shape of the body. The two STL file were compared with each other.

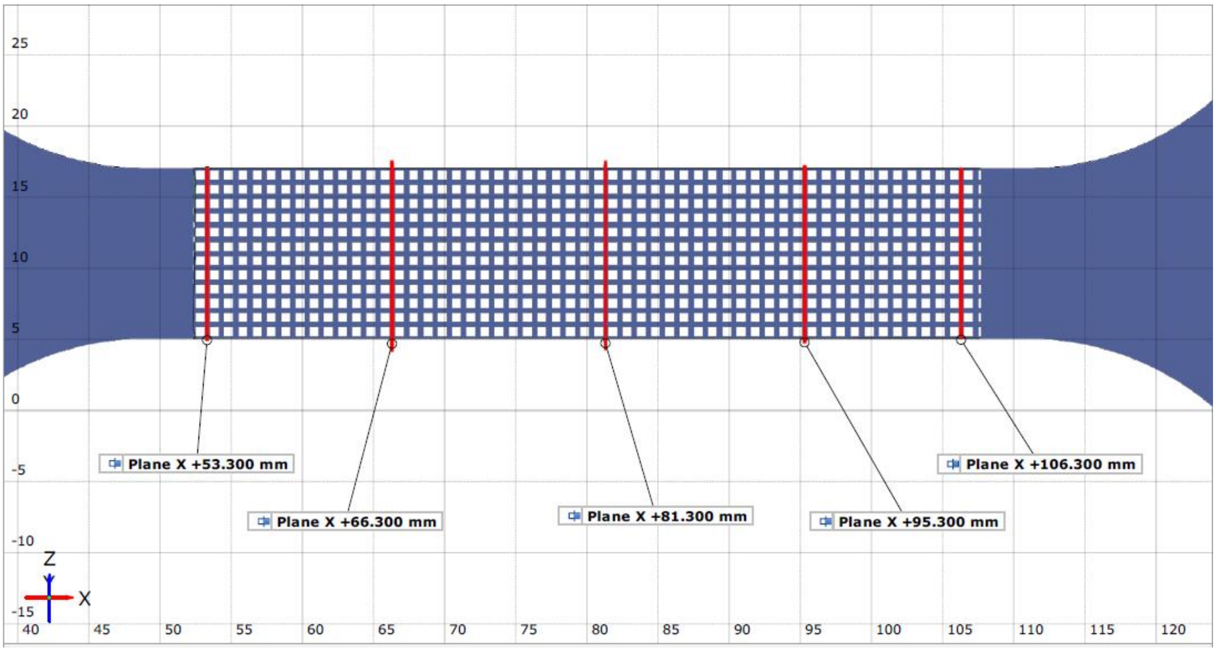

Fig. 2. Section planes of CT generated STL body model for measurements and observations

Figure 2 shows planes in which measured STL file was sliced and digital dimensional measurements and observations was taken.

Two STL files were fit to each other by least squares method. Figure 3 shows deviations of measured shape from designed (ideal) shape. This image represent absolute value of deviations with color code. It is observable that maximum deviation on the flags is +0.213 mm. Compared to classical manufacturing technologies this is a bad value. However we must not forget that there are biomedical applications where this accuracy is sufficient. For example a bone implant needs not higher accuracy since bone grows around it.

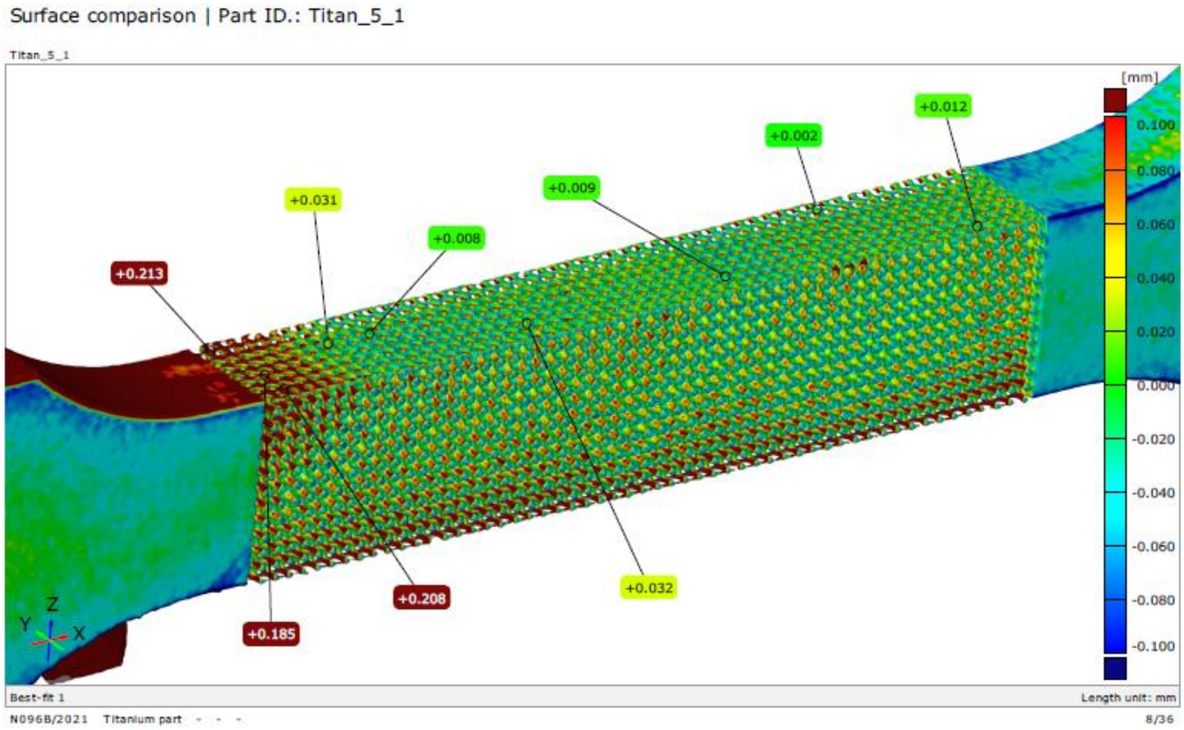

Fig. 3. Deviations of measured shape from ideal shape of test specimen. On this image z coordinate is represented in mm units

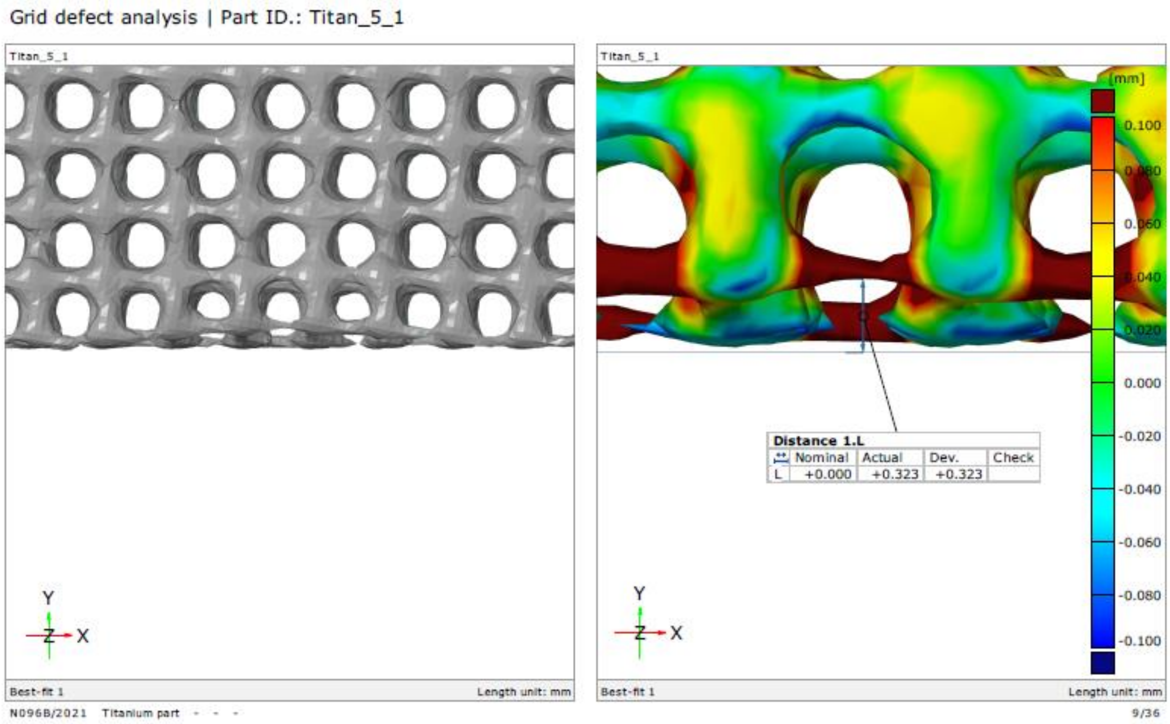

Fig. 4. Pores of the lattice structure, and deviation from designed shape by color code

On Figure 4 we can see a highly important phenomenon. Original designed shape is rectangular with plane faces and sharp corners. In contrast to it, manufactured (realized) shape is quite rounded. This follows from principle of SLM. When particles of metal powder are melted those moves as fluid drops and their movement is determined by two factors: surface tension and wetting the underneath not melted metal part. Both effects makes the material arrange along rounded shapes and will never form either sharp corners or plane faces. Manufactured shape seems as it was designed from unit cells with spherical holes. SLM will never create sharp corners in micro scale.

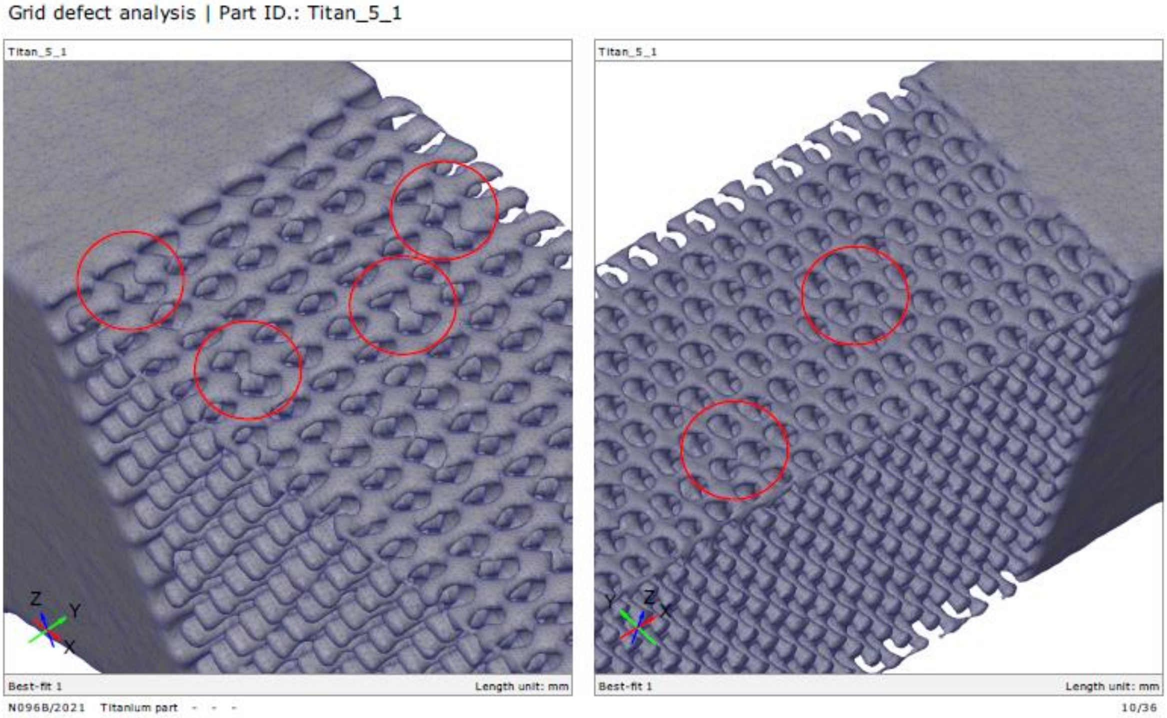

Fig. 5. Red circles show material defects and excesses

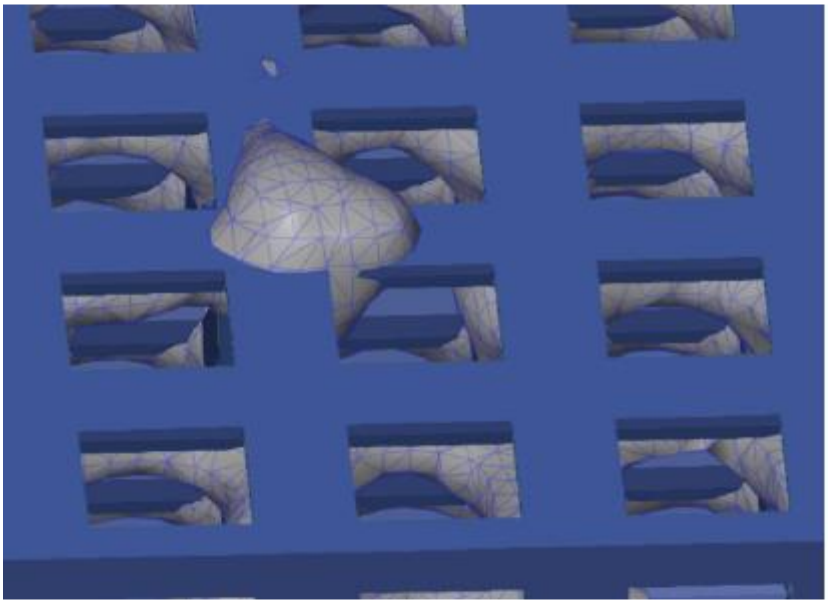

Fig. 6. A special region with material excess. Blue color shows designed ideal shape, and measured shape is visible in grey

On Figure 5 several material defects are demonstrated. This may come from contractile effect of surface tension. The higher is the temperature the stronger is this effect. It means that overheating is to be considered and corrected if we can see high number of such material defects.
Figure 6 shows a material excess. This may come from uneven powder spreading or splatter phenomena, which is similar to what is well known in case of welding.

SUMMARY AND CONCLUSIONS

In this study a tensile test specimen with lattice structure in the middle was investigated. The test specimen was produced by SLM in horizontal direction. Material of the specimen is Ti6Al4V. Shape and dimensional accuracy of the specimen was studied by CT inspection. Both designed and measured shape was available in STL files. Two body model were fit to each other and deviations were visualized and characterized numerically.
The following conclusions can be stated:

- Largest dimensional deviation of manufactured specimen from designed shape is in the magnitude of 0.2-0.3 mm. This is not sufficient in most mechanical engineering applications, but may be eligible for biomedical purposes.
- In macro scale the shape of the specimen stands close to the design.
- In micro scale shape of lattice details are rounded even if the original design was rectangular, brick-like with plane faces and sharp corners. Shape of pores is not cubic, indeed spherical or circular.
- Material defects can be observed at several locations of the model in the lattice structure. Thin rod-like fractions and fine details tend to be rounded by fluid behavior during the SLM process. This is valid for details with size under 1 mm.
- Material excess can also be observed. This may come from inaccuracies of powder spreading of splatter.

ACKNOWLEDGEMENTS

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DESIGN PROCESS, OPTIMIZATION, AND LIFE-CYCLE ASSESSMENT OF THE MULTIPURPOSE BAG CLIP

Ivan Grgić[1], Jure Marijić[1], Marko Vilić[1], Mirko Karakašić[1], Eleonora Desnica[2], Jurica Semenić[3]

[1]University of Slavonski Brod, Mechanical Engineering Faculty in Slavonski Brod, Slavonski Brod, Croatia

[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia

[3]University North, University Center Varaždin, Varaždin, Croatia

e-mail: igrgic@unisb.hr

Abstract: With the aim to preserve food freshness and prevent it from further microbial contamination after bag opening, the multipurpose bag clips were designed and various designs of the bag clips can be found on the market. Once the plastic bag is open, it is not possible to close it again without an additional tool. A review of the market and available literature has identified the potential for the redesign of the existed bag clip in terms of geometry optimization concerning the technological design guidelines of polymers and recyclability and to show the design process of such products. Applying the design theory guidelines, Autodesk Fusion 360 and SolidWorks as tools, and product life cycle assessment (LCA), a polymeric multi-purpose bag clip was designed to the level of a functional prototype. The bag clip consists of four parts, two frames, an insert, and a closure. It is intended for closing and opening candy bags, snacks, and freezer bags. The prototype of the bag clip was 3D printed and functionality was successfully tested. The final product has a mass of 32% less than the initial and it is fully recyclable. According to the LCA, the disadvantage of the proposed bag clip is the high energy consumption for its production.

Keywords: bag clip, design theory, life-cycle assessment, optimization, 3D printing

INTRODUCTION

Polymers are ubiquitous materials in everyday human life. There are various types of polymer products such as various plastic parts in cars, aircraft, insulation materials, various packaging, various medical aids, parts of electrical devices, etc. [1]

Closures belong to the group of packaging, and their main function is food and beverage safety and reducing food and beverage waste. The most commonly used closures are bottle closures, as shown in Fig. 1. [2]. Polymer products are usually produced in large quantities, ie in serial or mass production. This method of production requires a minimum amount of waste, maximum productivity, minimum production time, optimal production conditions, and ultimately full product functionality. The design process can have a significant impact on all of these conditions. Concerning the design process of products from non-plastic materials, the design of polymer products has certain specifics. It is important to provide basic information about the type of material before starting the process to help determine the right guidelines for the design. The choice of material is often based on the mechanical properties of the material. Such information is commonly available in the material specifications provided by the material manufacturers. Polymer closures are made by injection molding, which is also the most common production process by which polymer products are made. Injection molding of polymeric materials is the injection of polymeric substances of certain shear viscosity from the preparation unit (the funnel) in a tempered mold cavity. Injection molding produces a mold that, after the cooling, can be removed from the mold cavity, whereby the mold takes the shape of mold cavities. In the process of polymer products design, it is important to pay attention to the basic strategies of molding, and these are:

- Maximum functionality
- Optimal material
- Minimum mass

Having in mind the maximum functionality, one of the goals of polymer products design is to eliminate as many assemblies and parts as possible by combining components and at the same time achieving as many functions of construction as possible [4]. In this paper, the construction is represented by a bag clip. An analysis of the available literature did not show any work on this topic, however, an analysis of the products available on the market showed that there are different designs of bag clips. The idea for the design came from the polymer bag clip shown in Fig. 2. [5]. A 3D model of the bag clip was generated, respecting the set of the requirements and the process of technological design of polymer products. Numerical analysis, optimization, and life-cycle assessment of the newly created product were performed, and the functionality was analyzed using a prototype made by 3D printing.

Fig. 1. Plastic closures

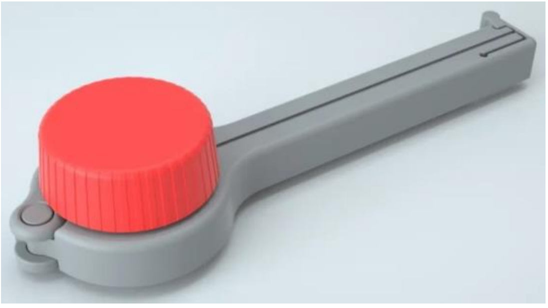

Fig. 2. Plastic bag clip

MATERIAL AND METHODS

Conceptual design of the multipurpose bag clip

After setting the list of requirements and creating a morphological matrix and combining different principles of the solution to perform partial functions for a multipurpose polymer bag clip, four variants were selected. The evaluation procedure determined the optimal solution shown in Fig. 3. It should be mentioned that all solutions meet the requirements prescribed in the requirements list.

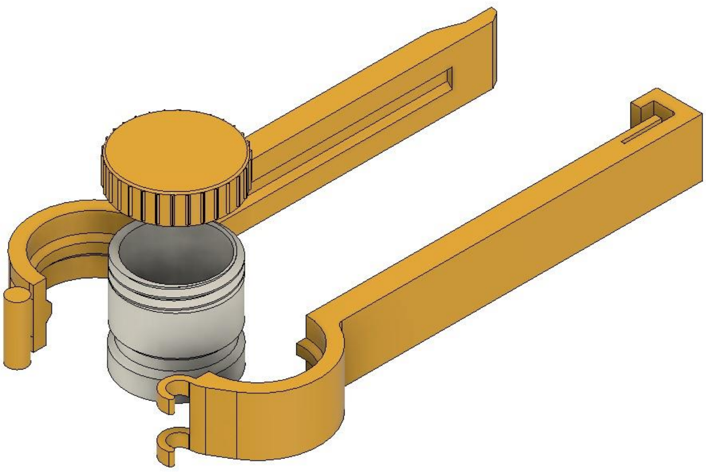

Fig. 3. Optimal conceptual design

Technological design of the multipurpose bag clip

The application of basic design strategies also has a significant impact on the technological design of the mold and these are the maximum molding functionality, optimal material, and the minimum weight. Polypropylene(PP) was selected as the optimal material in accordance with the requirements list. It must be polymeric, recyclable, safe for use in the food industry, have a low density, corrosion-resistant, and deformable. Furthermore, the different color shades of the selected material are welcome.

The review of the design characteristics is given in below:

- The wall thickness of the parts of the bag clip was kept in the range of 1 to 3 mm (Fig. 4.).
- The transitions between different wall thicknesses are shaped in a way to prevent the formation of stress concentrations.
- Accumulation of masses on all parts of the structure was avoided
- The optimal value of the radius is set to be 0.5 mm
- The parts of the structure are shaped so that they are symmetrical on at least one axis (Fig. 5.)
- A buttress thread SP400-M-8 was chosen as the optimal solution which allows high thread loading forces, while also providing fewer capability deformations during mold cooling.

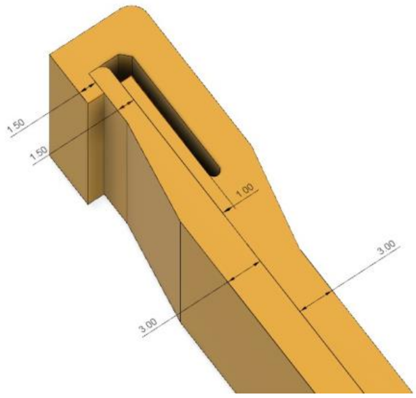

Fig. 4. Wall thickness

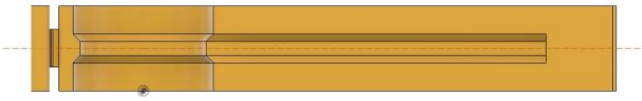

Fig. 5. The symmetry of the part

Numerical analysis of critical points

First of all, it is necessary to simplify the design to facilitate the creation of the initial stress and displacement calculations of the structure. It is assumed that the critical place of the construction is on the first part of the frame in the area on the inside of the buckle. Namely, in order to open the bag clip frame, it is necessary to move the buckle with a finger, which can be physically described as the action of the force of the finger at the beginning of the buckle (Fig. 6.) whereby the buckle deformation of the part occurs.

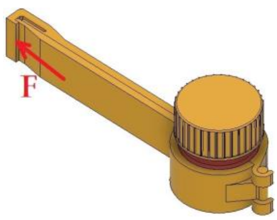

Fig. 6. The acting force of the finger

Due to easier analysis, part of the construction has been simplified according to Fig. 7., where only the longitudinal part of the frame with the hinged buckle and the rounded part for the insert was taken into account. Furthermore, it was assumed that the part of the frame with the buckle is fixed, and on the part where the buckle acts the finger force of 25 N [6] was applied.

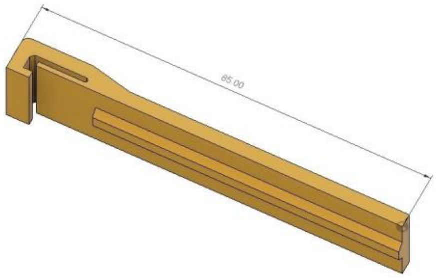

Fig. 7. The simplified structure

The main parameters of the numerical analysis are given in Table 1. The finite element mesh is presented in Figure 8. The fine mesh was set on the critical side of the part.

Table 1. Parameters of the numerical analysis

The parameters	Values
Mesh type (element)	tetrahedron
Force	25 N
Material	Polypropylene
Element size (fine mesh)	0,6 mm
Element size (coars mesh)	1,7 mm
Nodes	25.781
Elements	24.285
Boundary condition	Fixed support

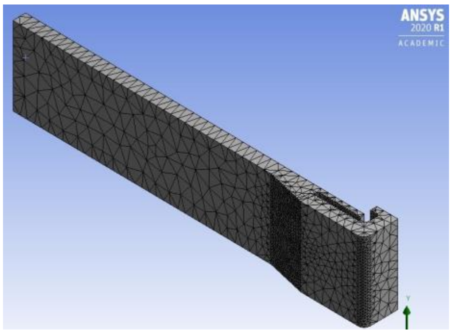

Fig. 8. Tetrahedron mesh (fine and coarse)

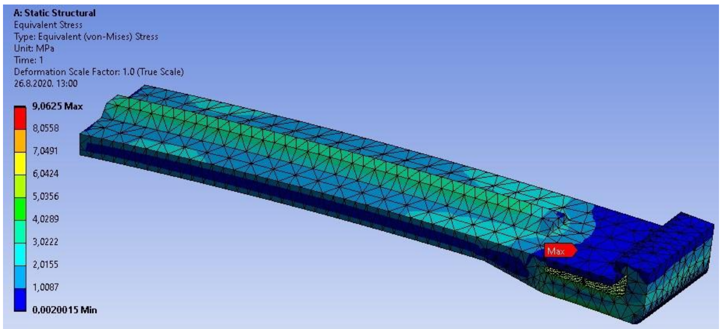

Fig. 9. The Von-Mises Stress distribution

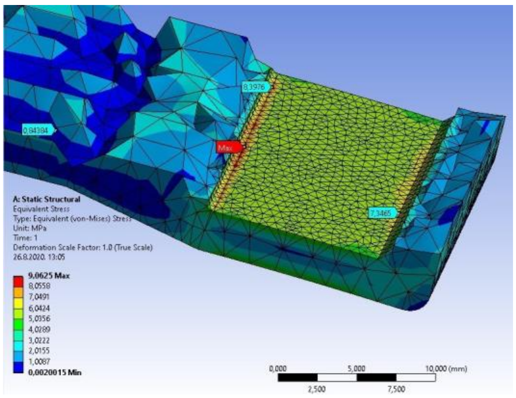

Fig. 10. The Von-Mises Stress distribution

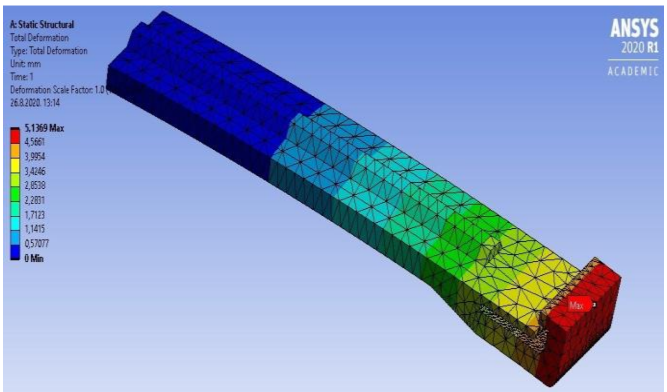

Fig. 11. The total deformation

on the inside of the buckle
The results of the numerical calculation are satisfactory. The criterion according to which the value of the maximum equivalent stress must be less than the allowable stress value of the material, which in this case is 9,0625 MPa < 26,2 MPa is satisfied. A total displacement of 5,1369 mm is acceptable for polypropylene polymer construction. In comparison with steel structures, this is a significant shift, however, the modulus of elasticity of selected polypropylene is 200 times smaller than the modulus of elasticity of steel which provides it a significantly higher possibility of deformation. The results of this calculation confirmed that this construction can take over the set load within the specified limits of allowable stress and displacement. In other words, during the opening, the frame will not break or permanently deform. The mass of the whole construction is 0,022502 kg or 22,502 g, while the mass of the simplified part for calculation is 0,0051473 kg or 5,1473 g.

Bag clip optimization

The production of polymer products is unprofitable for small batches due to high mold prices. It was assumed that hundreds of thousands of pieces will be produced. Therefore it is necessary to minimize production costs as much as possible. Since the costs can be directly associated with the surface of the product, it is reasonable to minimize the amount of material required for its production. Hence, it is necessary to determine the minimum mass of the product with optimization compliance with the set of the limits, and then according to the obtained results (optimized parameters) proceed with the final design of the entire multipurpose bag clip.
The geometry consists of four parts, namely frame, buckle, frame amplification, and groove. The frame is the biggest part whose dimensions of the rectangular profile (width and height) will be optimized. The second part is the buckle, looking at the profile of the buckle the width remains fixed (1,5 mm) and the height of the profile was optimized. The value of the buckle height is equal to the height of the frame profile. The third is a fixed part of the amplification of the frame that was not optimized but the length of that part is equal to the height of the profile.
The fourth part is a groove that has fixed dimensions and has not changed during the optimization.
In Fig. 12. an overview of the input and output optimization parameters is given. Input parameters were the width of the rectangular frame profile (3 mm) and the height of the profile (18 mm). The output parameters were the mass (5,1473 g), maximum equivalent stress (9,0625 MPa), and total displacement (5.1369 mm). The constraints of the input parameters (Fig. 13.) for this structure are geometric and arise from a profile of the structure which is rectangular. The width (thickness) of the structure must not be less than 1 mm and more than 3 mm according to Fig. 4., therefore, a profile width limit of 1 to 3 mm was set. The profile height limit is in the range of 10 to 20 mm. Furthermore, Fig. 14 shows the optimization constraints related to the equivalent stress and total deformation. For the process of direct optimization to optimize the bag clip, the software was selected to generate 100 different samples according to given constraints. Then, from these samples, select the three most acceptable results in accordance with the objective function (minimum mass) and set limits.

Outline of All Parameters

	A	B	C	D
1	ID	Parameter Name	Value	Unit
2	Input Parameters			
3	Static Structural (A1)			
4	P11	profile_height	18	mm
5	P15	profile_width	3	mm
*	New input parameter	New name	New expression	
7	Output Parameters			
8	Static Structural (A1)			
9	P6	Geometry Mass	0,0051473	kg
10	P13	Equivalent Stress Maximum	9,0625	MPa
11	P14	Total Deformation Maximum	5,1369	mm
*	New output parameter		New expression	
13	Charts			

Fig. 12. Outline of the parameters

Table of Schematic B2: Optimization

	A	B	C	D
1	Input Parameters			
2	Name	Lower Bound	Upper Bound	
3	P11 - profile_height (mm)	10	20	
4	P15 -profile_width (mm)	1	3	
5	Parameter Relationships			
6	Name	Left Expression	Operator	Right Expression
*	New Parameter Relationship	New Expression	<=	New Expression

Fig. 13. The constraints of input parameters

Table of Schematic B2: Optimization

	A	B	C	D	E	F	G
1	Name	Parameter	Objective		Constraint		
2			Type	Target	Type	Lower Bound	Upper Bound
3	Minimize P6	P6 - Geometry Mass	Minimize		No Constraint		
4	P13 <= 26,2 MPa	P13 - Equivalent Stress Maximum	No Objective		Values <= Upper Bound		26,2
5	P14 <= 10 mm	P14 - Total Deformation Maximum	No Objective		Values <= Upper Bound		10
*		Select a Parameter					

Fig. 14. Stress and deformation constraints

In Fig. 15., the change of the goal function during the optimization process is shown, the diagram shows that the mass of the structure gradually increases as the values of input parameters grow. Thus, by increasing the geometric parameters of the structure, the mass of the structure grows, and the values of the maximum equivalent stresses and the total displacement are declining. The results of the optimization process are given in Fig. 16.

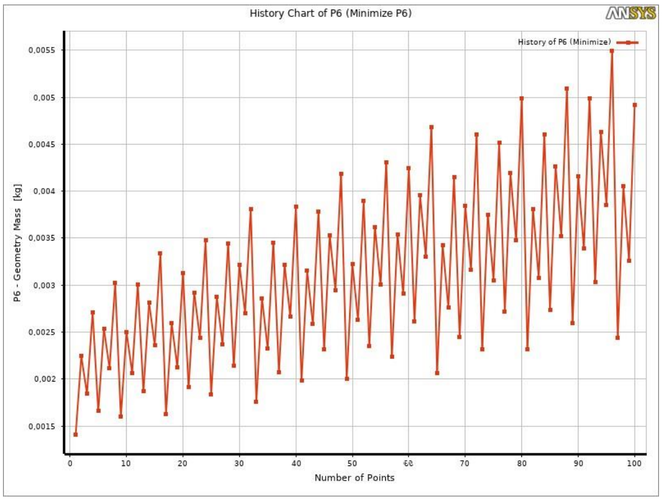

Fig. 15. The mass change

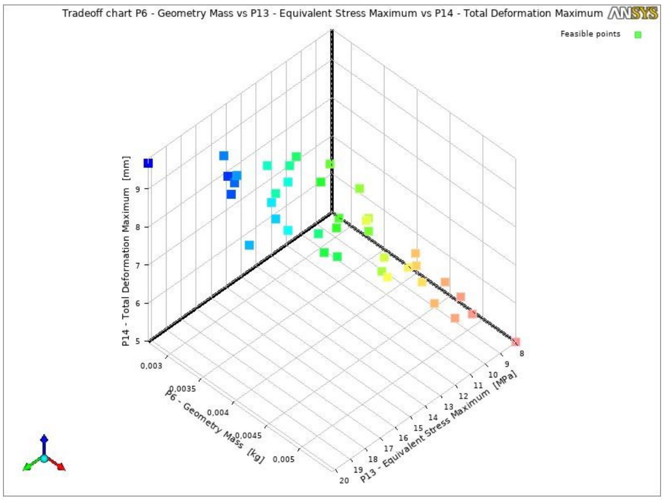

Fig. 16. The results of the optimization

Out of all one hundred generated samples, the software singled out the three best solutions characteristics shown in Fig. 17. According to the goal function (mass reduction), the first solution is the best, it gives the smallest mass. However, the first solution has the maximum value of the maximum equivalent stress and the total displacement. The third solution has a maximum mass and total displacement. Out of the three offered solutions, the variant under number two was chosen as the optimal solution. Although the chosen variant does not have the least mass concerning other solutions, due to the acceptable weight of the structure and the lowest values of stress and a total displacement of all the offered variants, this solution was chosen. The function of the optimization goal is fulfilled, the initial mass was reduced from 5,1473 g to 3,1268 g which is a 40% reduction in weight! A ton of polypropylene whose price is approx. € 1400, there is approx. € 560 in savings. The final design of a bag clip is shown in Fig. 18.

Candidate Points	Candidate Point 1	Candidate Point 2	Candidate Point 3
P11 - profile_height (mm)	10,35	11,95	13,75
P15 - profile_width (mm)	2,51	2,5725	2,2913
P6 - Geometry Mass (kg)	★ 0,0027089	– 0,0031268	– 0,0032151
P13 - Equivalent Stress Maximum (MPa)	★★★ 20,203	★★★ 16,284	★★★ 17,354
P14 - Total Deformation Maximum (mm)	★★★ 9,6827	★★★ 8,5966	★★★ 9,714

Fig. 17. The three best solutions

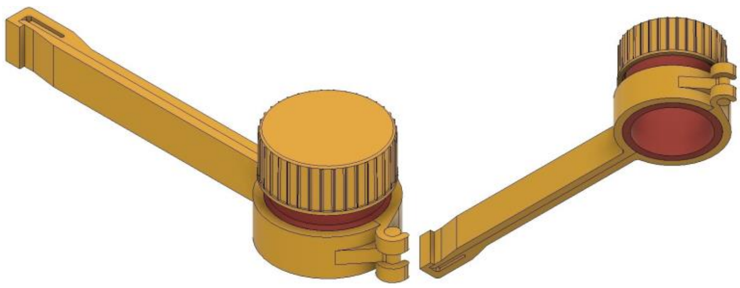

Fig. 18. The final optimal design of the bag clip

To test the product functionality, the bag clip prototype was 3D printed using the hobby-grade 3D printer Creality Ender 3. No functionality issues were found.

Qualitative life-cycle assessment of the bag clip

ECODESIGN Assistant Pilot [7] was used only for qualitative LCA analysis due to the extensiveness of quantitative analysis, i.e. collection and processing of large amounts of data. The purpose of the qualitative analysis was to show the environmental impact of this polymeric bag clip during its life cycle.
The LCA analysis aimed to:

- determine the type of product (A-E)
- suggest at least 3 proposed strategies to increase sustainability

Table 2 presents the set of estimated parameters used for the LCA analysis. The results can be divided into two parts, product classification, and recommendations for strategic improvements. The results of the analysis (Fig. 19) show that the multipurpose bag clip is a B type of product. These are the products that require high production requirements, and they are characterized by the following [8]:

- production requires large amounts of energy,
- parts are transported over long distances,
- the product is difficult to repair, i.e. it requires new production.

Table 2. Parameters of the numerical analysis

The parameters	**Values**
Product Life Time	5 years
Material	Polypropylene
Energy input	50 kWh
Waste per unit	5% of the mass
Production per year	100.000
Means of transportation (Truck)	1.000 km
Frequency of use	300 uses/year

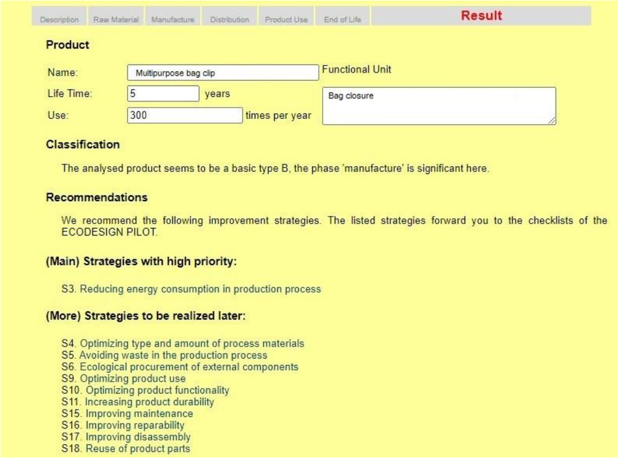

Fig. 19. The recommendations and strategies for bag clip improvement

CONCLUSION

The construction of polymer products has its specifics. First of all, it is important to pay attention to the basic design strategies of molding: maximum functionality, optimal material, and minimum weight. The basic rules of technological design are also important, e.g. design as thin walls as possible, anticipate bevels, avoid undercuts, etc. Applying design recommendations for assembly (DFA) for polymer products can significantly reduce the cost of materials, mold making, etc. Namely, due to increasing competition in the market and the development of the technology, the application of the DFA principles is not a possibility but a need. Due to the reduction of plastic waste generation, already in the process of construction of polymer products, it is important to take into account the method of reuse of plastic waste. LCA analysis has shown that the selected material ensures the reuse of the product, which means that at the end of exploitation does not end up in nature as garbage but is completely recycled and used for the new processing. Finally, the initial mass of a product was reduced by 32 %. In the case of the production process, the high priority should be to reduce energy consumption.

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COMPARISON OF FAILURE DURATION AND FAILURE FREQUENCY OF MINING MACHINES USING THE KRUSKAL-WALLIS H TEST (ONE-WAY ANOVA ON RANKS) - PRELIMINARY RESEARCH

Martina Perišić[1], Neda Papić[1], Mirjana Misita[1], Vesna Spasojević Brkić[1], Nemanja Janev[1]
[1]University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia
e-mail: npapic@mas.bg.ac.rs

Abstract: Mining is considered one of the most risky industrial operations. Development and application of risk assessment methods has the greatest impact on improvements in terms of safety in mining equipment. Risk is analyzed in many aspects i.e. human factor, environmental impact and operational aspects. Analyzing the mining machinery is a way to determine which ones have the greatest tendency to fail. The aim of this research is to compare data on failures obtained from 348 mining machines. All machines are arranged in 7 groups, namely 50 excavators, 50 bulldozers, 48 drills, 50 dumpers, 50 backhoe loaders, 50 bucket wheel excavators and 50 loaders. In order to compare the data, it is necessary to first determine the distribution under which the data belong. That is achieved by using Kolmogorov-Smirnov test. After that the Kruskal-Wallis test was used to determine whether there is a relationship between the machines, viewed from the aspects of failure duration and failure frequency.
Key words: risk assessment, mining machinery, Kolmogorov – Smirnov normality test, Kruskal - Wallis H Test (one-way ANOVA on ranks)

INTRODUCTION

Mining is considered one of the most risky industrial operations, and the accidents that occur leave great consequences, namely economic, operational, as well as environmental and health and safety consequences. Development and application of risk assessment methods has the greatest impact on improvements in terms of safety in mining equipment. Recognizing the need for risk analysis leads to the realization of the necessary efficiency and effectiveness of the system [1]. Recently, interest in risk assessment and management in the mining industry has a growing path, and this is confirmed by the increasing number of reports dealing with this topic. Risk is analyzed in many aspects i.e. human factor, environmental impact and operational aspects. Systematic maintenance is one of the basic factors for the normal functioning of the system, and this can be achieved by analyzing the mining machinery to determine which ones have the greatest tendency to fail [2].

LITERATURE REVIEW

Tubis et al. [3] proposed a systematic review of risk assessment methods in mining industry. They selected 94 papers in that area. Based on the results obtained from different databases, they identified the biggest gaps in research in this area. Groves et al. [4] used Mine Safety and Health Administration (MSHA) and Current Population Survey (CPS) to examine injuries which are equipment-related in mining industry and came to conclusion that off-road ore haulage was the most common source of injuries and fatalities. Petrovic et al. [2] used fuzzy sets theory, fuzzy logic and min–max composition to show risk assessment of coal mine technical system. They compared these methods to FMEA method with standard RPN calculating, showing that fuzzy methodology has more advantages. Joy [5] in addition to risk assessment methodology, also considered incident and accident aspects of risk in mining industry. Badri et al. [6] presented new practical approach to risk management using Analytic Hierarchy Process (AHP) and discussed importance of taking occupational health and safety (OHS) into account when talking about all mining activities. Md-Nor et al. [7] presented the results of research which characterized risks of fatal incidents in US mining. Mikhailov et al. [8] considered the environmental aspect of risk management and came up with a package of ecological risk reduction measures. Nawrocki et al. [9] used fuzzy logic to compare operational risk in mining enterprises in Central and Eastern Europe from two perspectives: internal and industrial.

METHODOLOGY

The aim of this research is to compare data on failures obtained from 348 mining machines. All machines are arranged in 7 groups, namely 50 excavators, 50 bulldozers, 48 drills, 50 dumpers, 50 backhoe loaders, 50 bucket wheel excavators and 50 loaders. In order to compare the data, it is necessary to first determine the distribution under which the data belong. For determining the distribution, when processing more than 50 data, the Kolmogorov - Smirnov test is used. With this test, if the level of significance is $p>0.05$, we can say that the data belong to the Gaussian distribution, while in the case of $p<0.05$, the data do not behave according to it [10]. When it is determined which distribution the data belong to, it is necessary to use parametric or non-parametric tests. When the data behave according to the normal distribution, parametric tests can be used, while in the case when the data do not behave according to the same, non-parametric tests must be used. Some of them are Mann-Whitney U test or Kruskal-Wallis test. Given that more than 2 samples are taken into account in this paper, the Kruskal-Wallis test was used.

RESULTS

Kolmogorov – Smirnov normality test

The conducted research included the collected data of 7 different types of mining machines, namely 50 excavators, 50 bulldozers, 48 drills, 50 dumpers, 50 backhoe loaders, 50 bucket wheel excavators and 50 loaders. The aim of the research was to determine whether there is a relationship between the machines, viewed from the aspects of failure duration and failure frequency. In order to be able to approach the comparison of machines, that is, to choose an adequate test, descriptive statistics were first determined, in order to determine whether the data are subject to a Gaussian distribution. For samples greater than 50, the Komologorov-Smirnov test is used [10]. If the level of significance is $p>0.05$, it can be said that the data follows a normal distribution [10]. The normality test was performed using SPSS software. The results of the Komologorov-Smirnov test are given in table 1 for the criteria of duration of failure and frequency of failure.

Table 1. Normality test results

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
Failure Duration	0.278	298	0.000
Failure Frequency	0.278	298	0.000

Given that the level of significance p in both criteria is less than 0.05, it can be concluded that the data do not follow a normal distribution, and this is also shown on the histograms (figures 1 and 2).

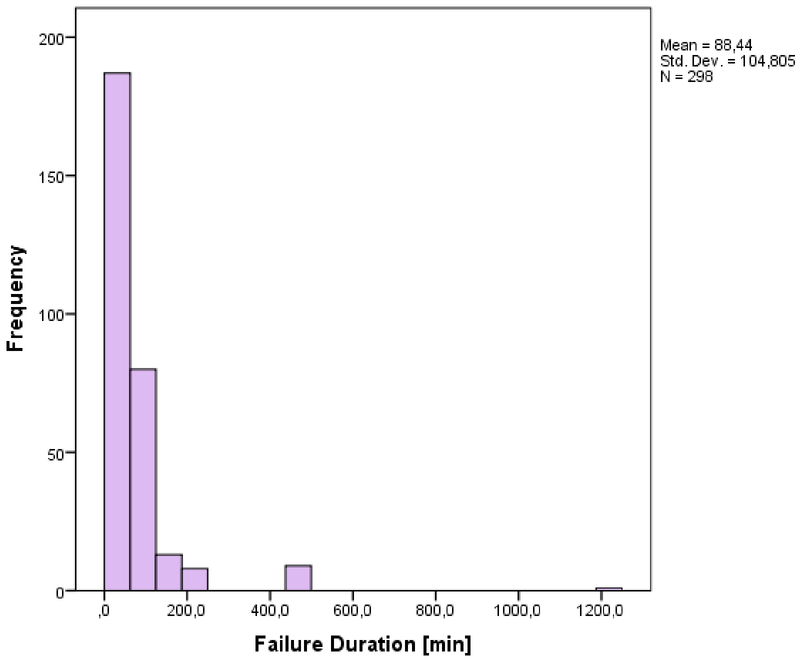


Fig. 1. Histogram of machine failure duration

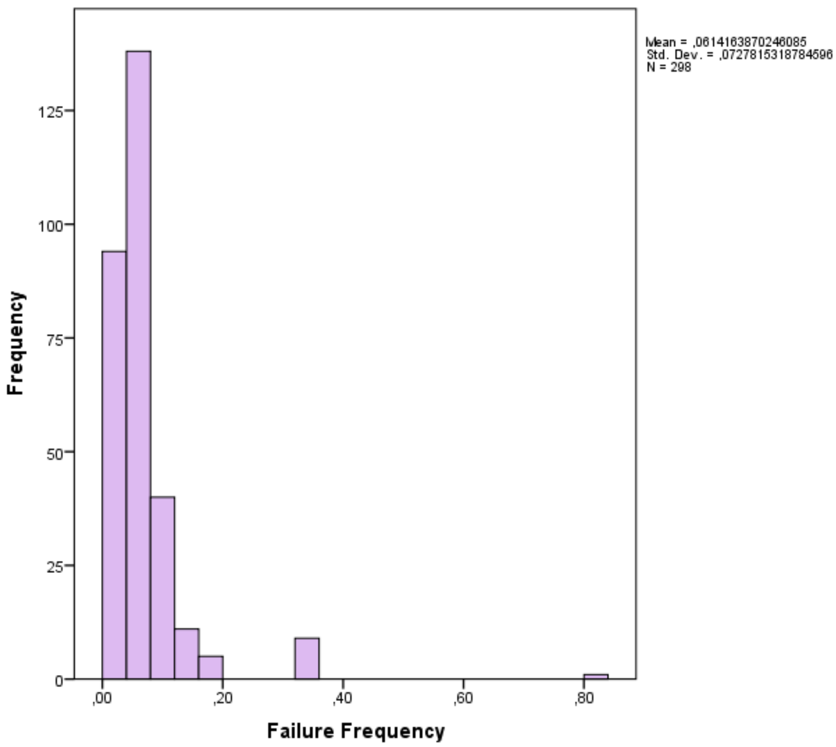
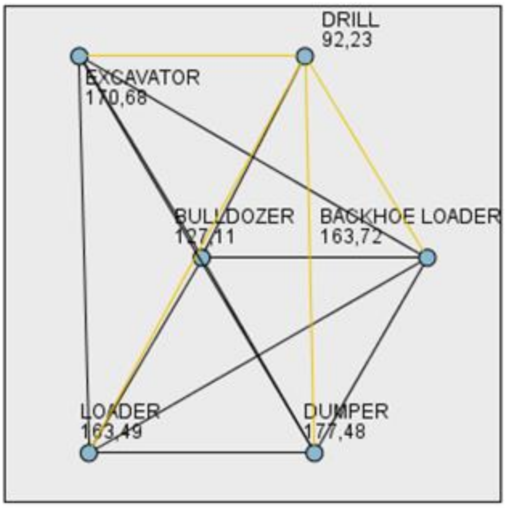


Fig. 2. Histogram of failure frequency

Kruskal - Wallis H Test (one-way ANOVA on ranks)

After the Komologorov-Smirnov test, the Kruskal-Wallis H test was selected as adequate. The results of the comparison of failure duration are given in Table 2, while the relationships between them are given in Figure 3, and the results of the comparison of failure frequency are given in Table 3, and their relationships are in Figure 4. In the software, the significance level is set to 5%, while the confidence interval is 95%.



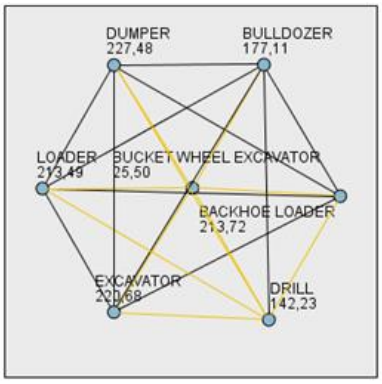
Each node shows the sample average rank of TypeofMachine.

Fig. 3. Relationships between the failure duration of the observed machines

Table 2. Results of the comparison of the duration of failure of mining machines

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
DRILL - BULLDOZER	34.881	17.079	2.042	0.041	0.864
DRILL - LOADER	-71.261	17.079	-4.172	0.000	0.001
DRILL - BACKHOE LOADER	71.491	17.079	4.186	0.000	0.001
DRILL - EXCAVATOR	-78.451	17.079	-4.593	0.000	0.000
DRILL - DUMPER	-85.251	17.079	-4.992	0.000	0.000
BULLDOZER - LOADER	-36.380	16.904	-2.152	0.031	0.659
BULLDOZER - BACKHOE LOADER	-36.610	16.904	-2.166	0.030	0.637
BULLDOZER - EXCAVATOR	-43.570	16.904	-2.578	0.010	0.209
BULLDOZER - DUMPER	-50.370	16.904	-2.980	0.003	0.061
LOADER - BACKHOE LOADER	0.230	16.904	0.014	0.989	1.000
LOADER - EXCAVATOR	7.190	16.904	0.425	0.671	1.000
LOADER - DUMPER	13.990	16.904	0.828	0.408	1.000
BACKHOE LOADER - EXCAVATOR	-6.960	16.904	-0.412	0.681	1.000
BACKHOE LOADER - DUMPER	-13.760	16.904	-0.814	0.416	1.000
EXCAVATOR - DUMPER	6.800	16.904	0.402	0.687	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-side tests) are displayed. The significance level is 0.05.



Each node shows the sample average rank of TypeofMachine.

Fig. 4. Relationships between failure frequency of observed machines

Table 3. Results of the comparison of the frequency of failure of mining machines

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
BUCKET WHEEL EXCAVATOR - DRILL	116,729	20.055	5.820	0.000	0.000
BUCKET WHEEL EXCAVATOR - BULLDOZER	151.610	19.849	7.638	0.000	0.000
BUCKET WHEEL EXCAVATOR - LOADER	187.990	19.849	9.471	0.000	0.000
BUCKET WHEEL EXCAVATOR - BACKHOE LOADER	188.220	19.849	9.482	0.000	0.000
BUCKET WHEEL EXCAVATOR - EXCAVATOR	195.180	19.849	9.833	0.000	0.000
BUCKET WHEEL EXCAVATOR - DUMPER	201.980	19.849	10.176	0.000	0.000
DRILL - BULLDOZER	34.881	20.055	1.739	0.082	1.000
DRILL - LOADER	-71.261	20.055	-3.553	0.000	0.008
DRILL - BACKHOE LOADER	71.491	20.055	3.565	0.000	0.008
DRILL - EXCAVATOR	-78.451	20.055	-3.912	0.000	0.002
DRILL - DUMPER	-85.251	20.055	-4.251	0.000	0.000
BULLDOZER - LOADER	-36.380	19.849	-1.833	0.067	1.000
BULLDOZER - BACKHOE LOADER	-36.610	19.849	-1.844	0.065	1.000
BULLDOZER - EXCAVATOR	-43.570	19.849	-2.195	0.028	0.591
BULLDOZER - DUMPER	-50.370	19.849	-2.538	0.011	0.234
LOADER - BACKHOE LOADER	0.230	19.849	0.012	0.991	1.000
LOADER - EXCAVATOR	7.190	19.849	0.362	0.717	1.000
LOADER - DUMPER	13.990	19.849	0.705	0.481	1.000
BACKHOE LOADER - EXCAVATOR	-6.960	19.849	-0.351	0.726	1.000
BACKHOE LOADER - DUMPER	-13.760	19.849	-0.693	0.488	1.000
EXCAVATOR - DUMPER	6.800	19.849	0.343	0.732	1.000

CONCLUSION

After preliminary research, and based on the research conducted, it can be concluded that there is a significant difference in the data regarding the duration of failure between the drill and the loader, then between the drill and the backhoe loader, the drill and the excavator and the drill and the dumper. There is no statistically significant difference in the data between the other machines. From the point of view of the frequency of failures, there are differences between bucket wheel excavator and backhoe loader, bucket wheel excavator and bulldozer, bucket wheel excavator and drill, bucket wheel excavator and loader, bucket wheel excavator and dumper, bucket wheel excavator and excavator, drill and dumper, drill and excavator, drill and combine and drill and loader. In other cases, there is no significant difference between the data on the frequency of dismissal.

Research and analysis like this could be further developed in a way that is much more detailed, and for that a larger sample of data would be needed, so that the results would be more accurate.

By increasing the sample size with more precise results, we could achieve concrete guidelines for the further management of such a system, as well as the introduction of new measures to reduce risk, and therefore better results of the mining system such as this one.

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APPLICATION OF DIFFERENTIAL EQUATIONS IN VIBRATION ANALYSIS

Ljiljana Pecić[1], **Violeta Đorđević**[2], **Marko Milivojčević**[1]
[1]Academy of Technical and Art Applied Studies Belgrade, department School of Electrical and Computing Engineering, Belgrade, Serbia,
[2] Academy Šumadija, department Trstenik, Kragujevac, Serbia
e-mail: ljiljanap@viser.edu.rs

Abstract: In engineering considerations, especially in modeling, describing various parametric dependencies, the complex mathematical analyzes of problems are required, where more complicated mathematical modeling, is necessary where knowledge and application of complex mathematical calculation procedure is needed. Differential equations occur in all areas of engineering and science, since they describe many real physical processes. In general, most physical processes involve more than one independent variable, so the corresponding differential equations are partial differential equations. In this paper, the analysis of free vibrations is processed, using a simple system of masses - springs.
Key words: vibration, differential equations

INTRODUCTION

In a significant segment of engineering practice calculations are based on solving various mathematical expressions that describe certain, concrete and real problems that engineers encounter in practice. Since the language of mathematics describes real problems, apropos modeling real problems, mathematical description often, for various reasons, does not completely match (accuracy) with the real problem, apropos does not represent his realistic picture.
Mathematical models of various processes from engineering practice are mainly represented by a system of algebraic or differential equations. By solving such mathematical models by finding their derivatives, zero functions, integrals, etc., it is possible to report exact solutions to mathematical problems, and in the most cases they must be approximated by approximate solutions.
Partial differential equations occur in all fields of science and engineering, and most real physical processes can be described using them. In many cases, simplified approximations are used, so partial differential equations can be reduced to ordinary differential equations, and sometimes to algebraic equations.
Partial differential equations are equations that give a relation between a function or several variables and partial derivatives of some function in relation to its independent variables. In most engineering problems, independent variables are either spatial (x, y, z) or spatial and temporal (x, y, z, t), and the dependent variable depends on the process being modeled.
Vibrations are a form of oscillatory motion of mechanical systems, in which the displacements of the points of the system are small compared to the dimensions of the system, and the period of oscillation is much smaller than the time in which the motion is observed. Free vibrations occur when the system is taken out of equilibrium under the action of internal forces and allowed to heal. The system oscillates with a constant amplitude at one frequency - its own frequency.
Engineering projects often deal with some kind of vibrations. In this paper, step by step, one method of solving a practical engineering problem, a spring system, is shown, using partial differential equations.

PHYSICAL MODEL FOR MATHEMATICAL FORMULATION

The mass-spring system is the simplest model for the analysis of mechanical vibrations. As its name suggests, it consists of a mass and a spring. The spring in the system serves to support the mass. A spring does not have to be a spiral spring, any elastic body can be viewed as a spring.

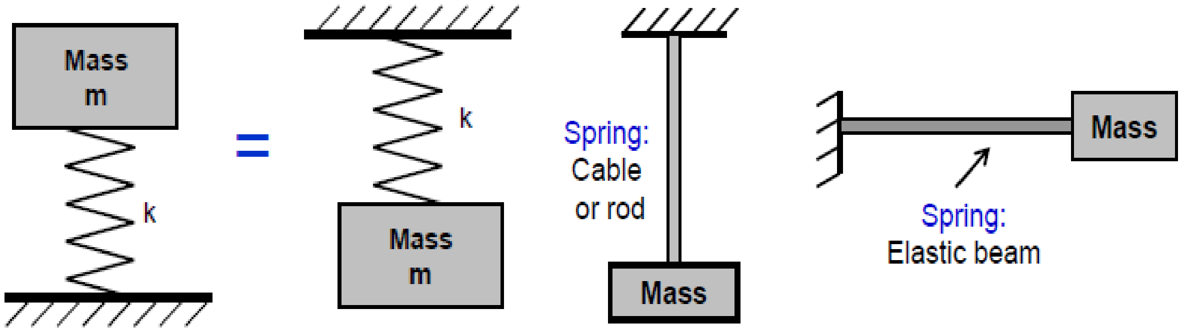

Fig. 1. Mass system - spring

As shown in the following figure, the starting point is the freely suspended spring (s). Then a load of mass m is attached to the spring, its elongation occurs (x is the magnitude of the elongation of the spring under the action of mass m) and this position is considered as the initial equilibrium position (b).
Finally, a small pull down and a quick release causes the mass to move down - passing its initial equilibrium position (vibration of the mass at time t, h + y (t) - stretching the spring at time t) (c).

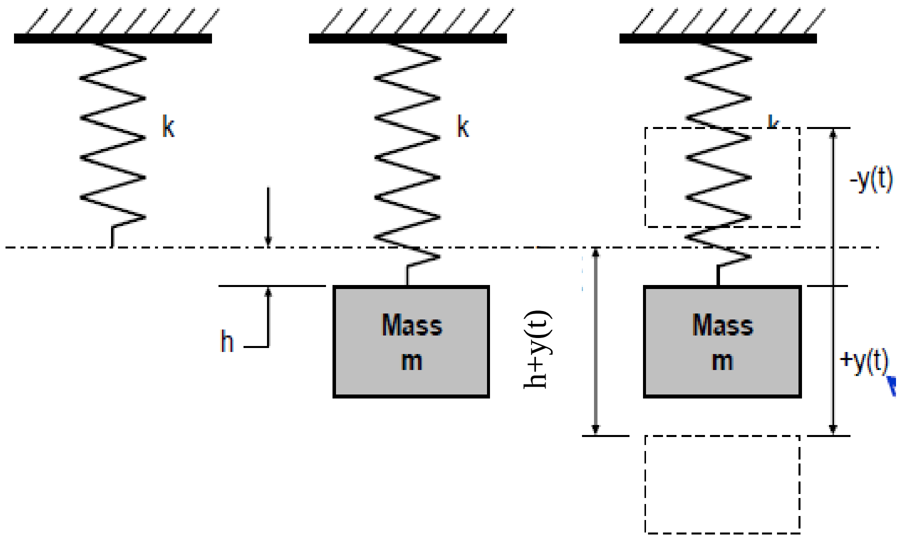

Fig. 2. Physical model of vibration

MATHEMATICAL FORMULATION OF THE MASS - SPRING SYSTEM

In Europe, biodiesel is most used in transportation, agriculture, forestry and construction and due to their bio-degradability characteristic and less emission of harmful gases in a comparison to the classic fuel.
Germany is world champion in the production of eco-fuels. The factory "Horen industries, in the German city Freiburg will soon begin production of biodiesel generation. As raw materials, in addition to traditional biomass, will be used agricultural wastes-stem, straw and pulverous straw. Until now, for the production of biodiesel only crop of family agricultural was suitable.
Obstacle to the wider introduction of alternative energy sources makes his undurability, because bio-fuel quickly loses its quality and becomes a cause premature of engine fatigue. To the rapid deterioration of the biological product oxygen contributes, which is his ingredient.
When determining the mathematical formulation of the mass-spring system, air resistance during mass movement is not taken into account. Looking at the previous figure, the figure under b) shows static,

and the figure under c) dynamic equilibrium. The forces acting in the case of static equilibrium are: elastic spring force (F_s) and gravity force (F). The forces acting in the case of dynamic equilibrium are: elastic force of the spring (F_s), force of gravity (F) and inertial force ($F(t)$).

When the system is taken out of balance, the elastic force tends to return the body to its original position. When this happens, under the action of the force of inertia, the body continues to move until the moment when the spring is maximally stretched and when the elastic force begins to act again, but in the opposite direction. This process is repeated, which leads to oscillatory movement of the body at the natural frequency of the system, which depends on the properties of the system - body mass and spring stiffness.

The period of oscillation represents the time required for the system to perform one full oscillation T_n (s). Oscillation frequency represents the number of oscillations performed in a unit of time $f_n = 1/T_n$ (Hz = 1/s). Elongation (displacement) represents the distance of a material point or body from the equilibrium position. Amplitude represents the maximum displacement in simple periodic motion.

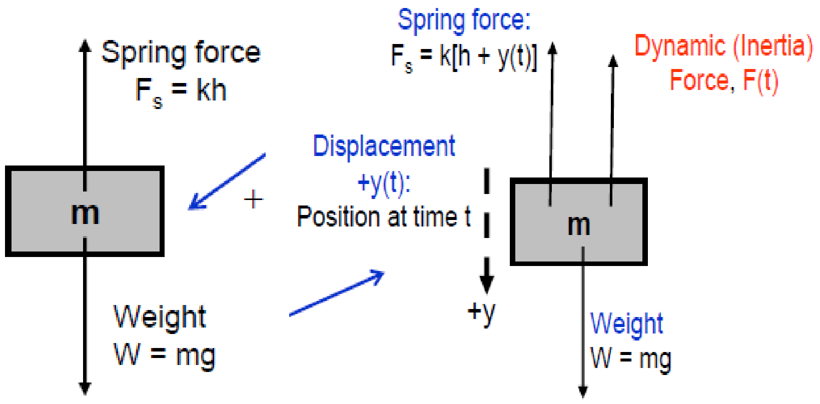

Fig. 3. Static and dynamic equilibrium

Equilibrium of forces at static equilibrium can be noted as:

$$\sum F_y = F - F_s = 0 \tag{1}$$

$$F = F_s \tag{2}$$

$$mg = kh \tag{3}$$

Equilibrium of forces at dynamic equilibrium, at the observed time t, satisfies Newton's first law:

$$\sum\left(-F(t) - F_s + F\right) = 0 \tag{4}$$

Since there is a dynamic force here, there will be:

$$F(t) = ma \tag{5}$$

Since acceleration is the first derivative of speed, and the second derivative of position in time, that is:

$$a = \frac{d^2 y(t)}{dt^2} \tag{6}$$

when we replace this expression with the previous equation, the next equation is obtained:

$$F(t) = m\frac{d^2 y(t)}{dt^2} \tag{7}$$

and the force of the spring will be:

$$F_s = k[h + y(t)] \tag{8}$$

so that it was obtained:

$$-m\frac{d^2y(t)}{dt^2} - k[h + y(t)] + mg = 0 \tag{9}$$

When the condition from static equilibrium mg = kh is replaced by the previous equation, a second-order differential equation is obtained for the current position y (t) when the mass vibrates m.

$$m\frac{d^2y(t)}{dt^2} + ky(t) = 0 \tag{10}$$

where y (t) is the current position of the mass.
When we divide the equation by m, we get:

$$\frac{d^2y(t)}{dt^2} + \frac{k}{m}y(t) = 0 \tag{11}$$

The solution of the equation can be obtained by comparing the previous equation with a typical second-order differential equation in the equation:

$$\frac{d^2u(x)}{dx^2} + a\frac{du(x)}{dx} + bu(x) = 0 \tag{12}$$

In this case, after comparison, we conclude that a = 0 and b = k / m. This is the case when it comes to free undamped vibrations. The solution of the equation depends on the discriminator a2 - 4b.
There are three possible solutions:

1) $a^2 – 4b > 0$ - in this case both roots of the equation are real numbers and the solution of the equation is of the form::

$$u(x) = e^{-\frac{ax}{2}}\left(c_1 e^{\sqrt{a^2-4b}x/2} + c_2 e^{-\sqrt{a^2-4b}x/2}\right) \tag{13}$$

2) $a^2 – 4b < 0$ - in this case both roots of the equation are complex numbers and the solution of the equation is shape:

$$u(x) = e^{-\frac{ax}{2}}\left(c_1 e^{\frac{ix}{2}\sqrt{4b-a^2}} + c_2 e^{-\frac{ix}{2}\sqrt{4b-a^2}}\right) \tag{14}$$

The complex form of this equation is not always suitable for engineering analysis, so the equation is used much more often:

$$u(x) = e^{-\frac{ax}{2}}\left[A\sin\left(\frac{1}{2}\sqrt{4b-a^2}\right)x + B\cos\left(\frac{1}{2}\sqrt{4b-a^2}\right)x\right] \tag{15}$$

where A and B are arbitrary constants.

3) $a^2 - 4b = 0$ - in this case the solution of the equation is of the form:

$$u(x) = e^{-\frac{ax}{2}}\left(c_1 + c_2 x\right) \quad (16)$$

Therefore, we have the following $a^2 - 4b = 0 - 4$ (k/m) < 0, which is the second case of the solution and is given in the form:

$$y(t) = e^{-\frac{0 \cdot x}{2}}\left[A\cos\left(\frac{1}{2}\sqrt{4\frac{k}{m} - 0^2}\right)t + B\sin\left(\frac{1}{2}\sqrt{4\frac{k}{m} - 0^2}\right)t\right] \quad (17)$$

apropos,

$$y(t) = A\cos\sqrt{\frac{k}{m}t} + B\sin\sqrt{\frac{k}{m}t} \quad (18)$$

where A and B are arbitrary constants determined by given conditions.
Common expression of solutions for an equation:

$$m\frac{d^2u(x)}{dx^2} + ku(x) = 0 \quad \text{je} \quad (19)$$

$$y(t) = c_1 \cos \omega_0 t + c_2 \sin \omega_0 t \quad (20)$$

where c_1 and c_2 are arbitrary constants determined by given conditions, and ω0 is the circular or angular vibration frequency of the mass-spring system:

$$\omega_0 = \sqrt{\frac{k}{m}} \quad (21)$$

Analogous to the angular frequency, the actual vibration frequency is:

$$f = \frac{\omega_0}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \quad (22)$$

The mathematical solution of $y(t) = c_1 \cos \omega_0 t + c_2 \sin \omega_0 t$ consists of cosine and sine functions of the variable t, so it is an oscillatory function, which oscillates around the "zero time" axis with the amplitude of vibrations y (t).
According to this mathematical solution and the graph shown in the following figure, it follows that the system will oscillate forever, which, of course, is not possible in a real situation, mass cannot oscillate forever, after a while, the vibrations will stop.

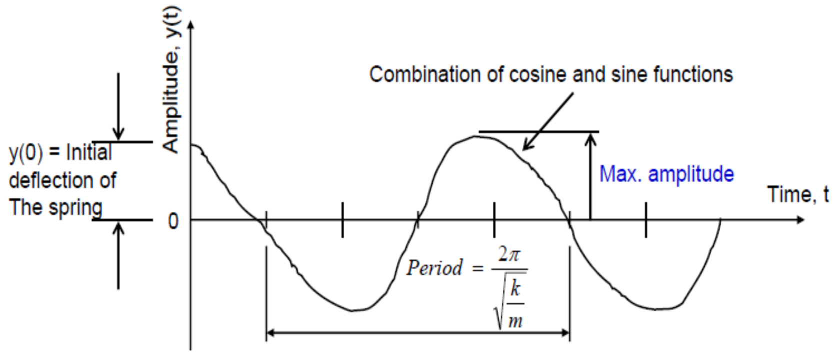

Fig. 4. Graphic representation of mass-spring system vibration

APPLICATION OF DIFFERENTIAL EQUATIONS

The above calculation can be applied to a specific example of unloading the machine. The truck unloads a heavy machine, weighing 3555 N, using a crane. If the rope is suddenly stuck at time t, with an initial speed v0 = 0.1 m / s, it can be expected that the machine will be exposed to "up - down - up" vibrations. The constant of the elastic steel rope (spring stiffness) is k = 1050 N / mm, the rope is a steel cable with a diameter of 13 mm. The maximum allowable stress of the material (strength) is σ = 275 N / mm2.

The following patterns can be used to determine: the vibration frequency of the machine, the maximum rope voltage caused by the machine vibration and the maximum rope stress. It can also be determined whether the rope would break.

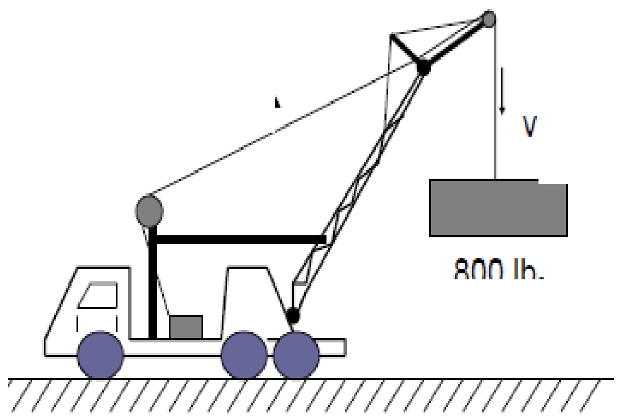

Fig. 5. Example of unloading a machine

Since the machine is attached to an elastic rope (steel cable) that has the characteristics of a spring, this situation can be viewed as a simple mass system - a spring. The frequency and amplitude of the vibrating machine can be determined using expressions derived from a simple mass-spring system.The vibration frequency of the machine is given by the following equations.

Circular or angular frequency is:

$$\omega_0 = \sqrt{\frac{k}{m}} \tag{23}$$

The weight of the machine is determined based on its weight from the sample:

$$F = mg \Rightarrow m = \frac{F}{g} = \frac{3555}{9{,}81} = 362{,}38 kg \tag{24}$$

so from here we got:

$$\omega_0 = \sqrt{\frac{1050000}{362{,}38}} = 53{,}83 rad/s \tag{25}$$

and when we replace this in the frequency pattern, we get:

$$f = \frac{\omega_0}{2\pi} = \frac{53{,}83}{2\pi} = 8{,}57\, Hz(1/s) \tag{26}$$

The maximum stress in the rope is determined by the total elongation of the steel rope, ie. the maximum amplitude of vibration of the machine. To obtain the amplitude of a vibrating machine, it is necessary to solve the differential equation of the following form, under appropriate conditions. The shape of differential equation is:

$$m\frac{d^2 y(t)}{dt^2} + ky(t) = 0 \tag{27}$$

with conditions:

$$y(0) = 0 \ \text{ i} \tag{28}$$

$$\left.\frac{dy(t)}{dt}\right|_{t=0} = 0{,}1 m/s \tag{29}$$

The first derivative of displacement is speed, at the moment t = 0, so initial speed is v_0 = 0,1m/s.
The solution of the previous equation is:

$$y(t) = c_1 \cos \omega_0 t + c_2 \sin \omega_0 t \tag{30}$$

$$y(t) = c_1 \cos 53{,}83 t + c_2 \sin 53{,}83 t \tag{31}$$

Arbitrary constants c_1 and c_2 in the previous equation can be determined using given conditions, from which we get that $c_1 = 0$; $c_2 = 1.8898$. Thus, the vibration amplitude of the machine is obtained in the following form:

$$y(t) = 1{,}8898 \sin 53{,}83 t \tag{32}$$

From this expression the maximum amplitude is obtained:

$$y_{\max} = 1{,}8898\, mm \tag{33}$$

The appropriate maximum voltage is in the rope:

$$T_m = k y_{\max} + F = 1050 \cdot 1{,}8898 + 3555 = 5540\, N \tag{34}$$

The maximum stress in the rope (normal stress) is obtained from the following expression:

$$\sigma_{\max} = \frac{T_m}{A} \tag{35}$$

A is the cross-sectional area of the steel rope and amounts:

$$A = \frac{d^2\pi}{4} = \frac{13^2\pi}{4} = 132{,}73\,mm^2 \tag{36}$$

When this result is replaced in the previous equation, we get:

$$\sigma_{\max} = \frac{5540}{132{,}73} = 41{,}74\,N/mm^2 \tag{37}$$

From this it can be concluded that the rope will not break because the maximum induced stress in the steel rope is much less than the given allowable stress (material strength), ie.

$$\sigma_{\max} = 41{,}74\,N/mm^2 < \sigma = 275\,N/mm^2 \tag{38}$$

CONCLUSION

Algorithms for analytical solution of partial differential equations do not exist in the general case. Only special types are considered in the case of partial differential equations of the second order.
For a function with two or more variables, it is relatively easy to find many partial differential equations whose solution is with appropriate boundary conditions. Conversely, finding a solution for a given partial differential equation with given boundary conditions is much more difficult and usually impossible analytically.
However, there are three things that can help engineers in this case:

- many problems in engineering include a relatively small number of types of partial differential equations that are up to the second derivative
- there are a large number of standard analytical methods that provide solutions to important partial differential equations that appear in models of real processes
- computer software such as Mathematica, Maple and MATLAB can perform analytical manipulations that would be extremely difficult to perform manually, so the set of analytical methods for engineers has been significantly expanded.

Solving practical models, using known partial differential equations, is usually very difficult analytically and computers are used to obtain approximate numerical values. A large number of numerical methods have been developed for solving partial differential equations, which in practice significantly overcomes the lack of analytical methods.

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MAIN WAYS ON WHICH STAINLESS STEELS COULD CORRODE

Zoran Karastojković[1], Jasmina Pekez[2], Milan Miladinov[3]
[1]Society for Ethics and Evaluation in the Arts and Sciences, 11000 Belgrade
[2]University Novi Sad, Technical faculty „Mihajlo Pupin“ 23000 Zrenjanin
[3]“Sanacija i ispitivanje metala”, d.o,o, 11060 Belgrade
e-mail: pekezjasmina@gmail.com

Abstract: The monitoring of corrosion in common structural steels is present in every day practice and/or activites, while the same processes are less present at stainless steels. It does not mean that corrosion of stainless steels not exists anyway, but could be found, however, not at the same intensity or rate as in structural steels. Stainless contain chromium, in some kinds of them the presence of nickel is avoided mainly from economical reasons. Stainless steels are exposed to various working conditions and/or environmental media, so the different corrosion atacks will took place. Here will be analysed some of the most frequently corrosion processes and types which may be appeared at stainless steels.
Key words: stainless steels, corrosion ways, surface changes, structural changes,

1. INTRODUCTION

Stainless steels often are classified as *noble* metals, but it is evident that many of themmay corrode. The corrosion processes, however, depend from the environmental surroundings, but also from the chemical composition of used stainless steel. The fabricating methods durigng stainless steel production (as shaping, welding or heat treatment) also may have the influence on the final corrosion appearance/result.
Stainless steels with nickel contest (above 8%) posses pretty well corrosion resistance, but from economical reasons frequently are used nickel-free steels, niether the chosen steel is corroded and degraded. Corrosion atacks at stainless steels roughly may be registered (sometimes by naked eye) at or near the surface, or inside the product (when the changes of steel micro-structure might be registered microscopicaly). For both approaches, the corrosion revealing at surface or inside, the solid knowledge both from chemistry and metallurgy is needed. The appearance of mixed types of corrosion may not be excluded, indeed.
Almost stainless steels are passivated, but some of them may corrode. The corrosion rate at stainless steels commonly is, however, lesser than at usual structural steels. For all metals, the tendency corrosion is determined by (electro)chemical reactions when anode and cathode exist. The corrosion will took place every time when two metals with different electrochemical potentials are in contact, which is known as „contact“ corrosion. But, other types of corrosion are pretty complex and need further considerations, sometimes by using electrochemical and thermodynamical approaches. The evaluation of kinetics (for determination of corrosion rate) always is an imortant task for choosing and applying a kind of steel. Many (standard) laboratory tests are available, but service conditions&results are irreplaceable.

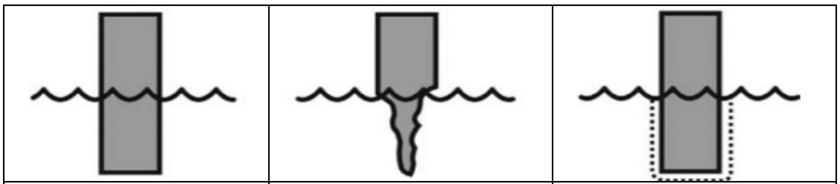
2. MAIN GRUOPS OF STAINLESS STEELS

Stainless steels frequently are classified according to their chemical composition and/or stracture(s). The main alloying elements at those steels are chromium and nickel, Fig. 1, while the stainless steels with nickel as a dominant alloying element are pretty less known, the main reason for that is only a high price of nickel.

STAINLESS STEELS				
Fe – Cr		**Fe – Cr – Ni**		**Fe – Ni - Cr**
corrosion resitant, contain carbon resistant to wear, impact and abrasion		more corrosion resistant, multialloyed, soft and tough		corrosion stable at acids and elevated temperatures

Fig. 1. Main large groups of stainless steels

All of those steels may be immune, corrosion active or might be passivizated, Fig. 2.



immunity	corrosion	passivization

Fig. 2. Typical reactions of immersed metal into liquid media

These regions are well visible at Pourbaix diagrams, for some metals shown in Fig. 3.

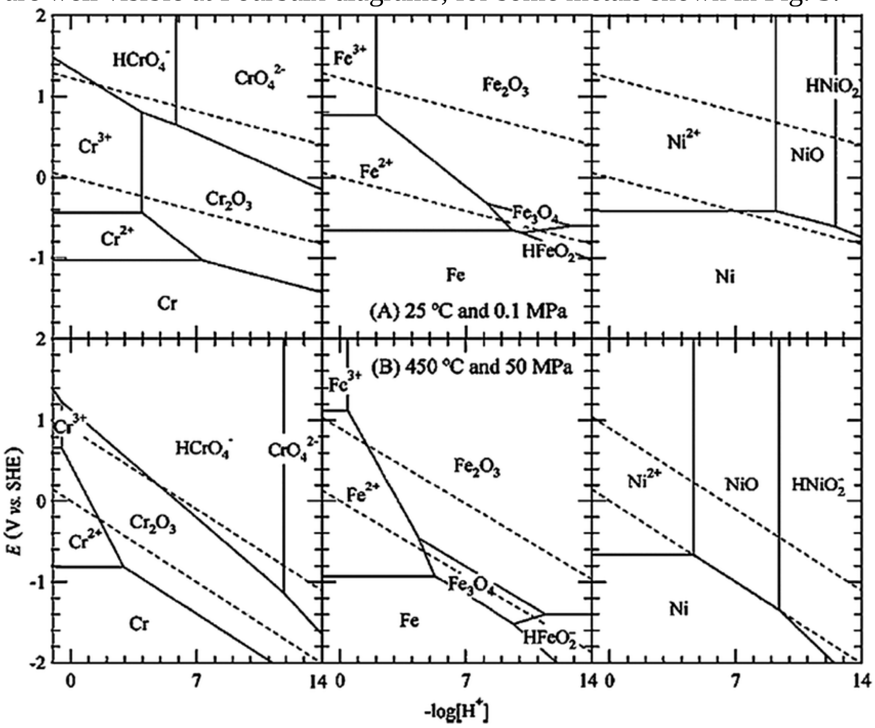


Fig. 3. Porbaix diagrams for main alloying elements from stainless steel in water

The principal dissadvatage of such diagrams is in its validation only for given material and for given conditions, it means just for one media. If any detail is changed that the new diagram must be examined and plotted.

3. FREQUENT TYPES OF CORROSION IN STAINLESS STEELS

Widely known types of stainless steels belong to: ferritic, austenitic, martensitic or a kind of their mixed structure, as like duplex steels or a precipitation hardening (PH) steels. The new generations of stainless steels, beside chromium or chromium&nickel, frequently contain a kind of (micro)alloying element(s). The presence of microalloying elements usually lead for improving the corrosion resistance and weldability. Frequently types of corrosion appeared in stainless steels are: general,

pitting, intergranular, contact, galvanic or corrosion under stress. Another types of corrosion degradation at stainless steels (as like crevice, sulfide or chloride) are less present at our regia, so those ways of corrosion will not be discussed here. For all types of corrosion is characteristic influence of temperature: the higher temperature the corrosion rate is increasing, which is easily explainable by increasing the chemical activity.
Further, during welding at some kinds of stainless steel the corrosion may have appeared on a specific way – known as a sensitization, and this type here will be closely analized. Here is considered that mechanisms of general corrosion is pretty known, while other types as the empirical estimation of pitting corrosion needs detailed explanation.

Pitting Resistance Equivalent number (PRE)

The effect of pitting corrosion frequently is visible by naked eye. It is established that resistance against to pitting corrosion may be explained by an equivalent number (PRE), which includes the sum of present main alloying elements into stainless steel; the greater PREN number means greater resistance to pitting corrosion, so this equivalent number needs short explanation The PREN numbers for stainless steels which contain high content of chromium or molybdenum and nitrogen are more resistant to pitting corrosion, and will be calculated as follows:

for ferritic steels: $$PREN = \%Cr + 3{,}3\,(\%Mo + 0{,}5\%W) \quad ... \quad (1)$$

for austenitic and duplex steels: $$PREN = \%Cr + 3{,}3\,(\%Mo) + x(\%N) \quad . \, (2)$$

where: x = 16 for duplex (austenitic-ferritic) stainless steels and
x = 30 for austenitic staniless steels.

On the base of these values obtained results for common steels are given in Table 1.

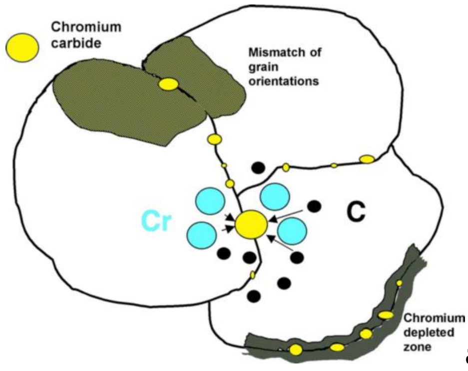
Table 1. Minimum PREN values for some stainless steels

steel	304L	316L	CAF 2304	317L	2205	904L	CAF 2507	254 CMO	654 CMO
$PREN_{16xN}$	19	26	26	30	35	36	43	43	56
$PREN_{30xN}$	20	26	-	30	-	37	-	46	63

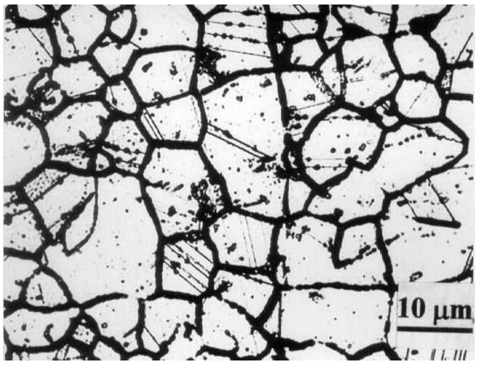
The influence of copper was not invloved in equations 1. or 2, either it improves the corrosion resistance of such steel.

Sensitization as a intergranular corrosion

Sensitization is a kind of intergranular corrosion associated with carbide or nitride preci-pitation along crystal grains, when chromium and carbon in the steel forming the chromium carbide particles, Fig. 4a), making the dark net throughout the steel. Fig. 4b).



a)



b)

Fig. 4. Scetch of precipitation of chromium carbides along grain borders a) and metallographic view of sensitization at stainless steel 304 b)

At austenitic stainless steels the critical temperatures are arround 700-750^{0}C, see Fig. 5.

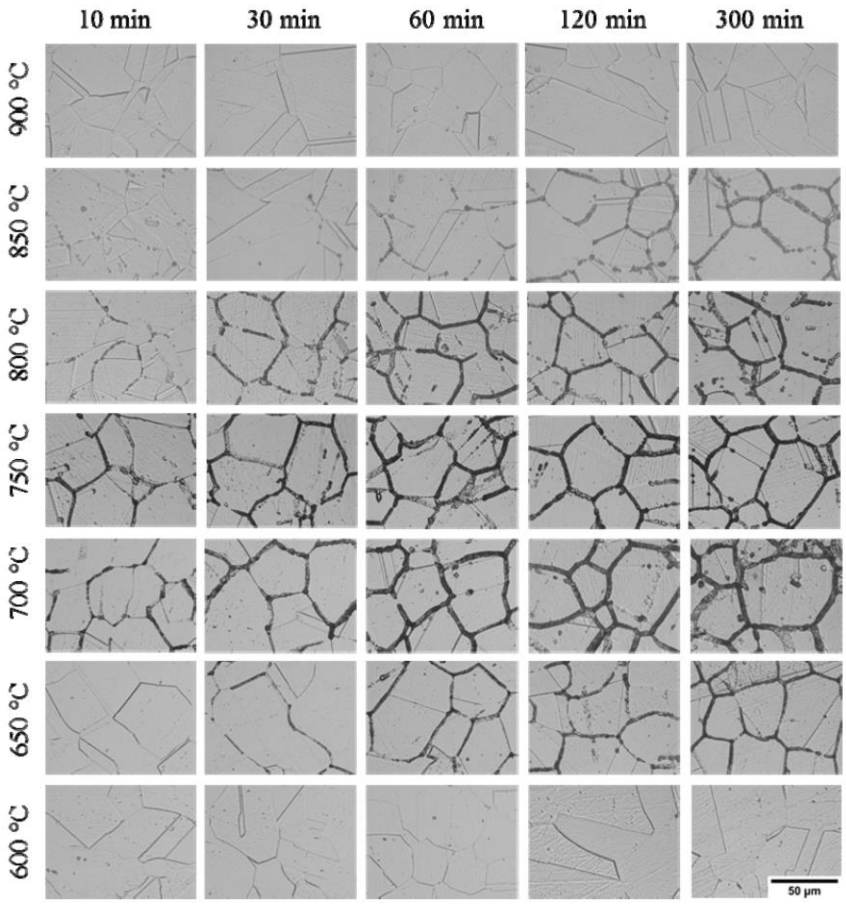
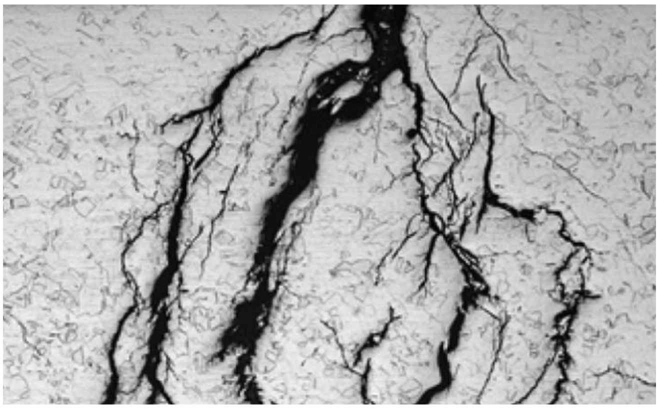


Fig. 5. Annealing temperatures responsible for sensitization of an austenitic stainless steel [8]

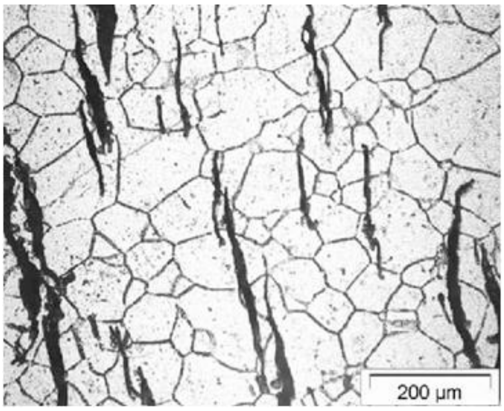
Such distributed carbides, along to grain boundaries, reduces the corrosion resistance. Sensitization will be appeared in austenitic steels if they exposed at temperatures 425-850^{0}C and than cooled at a relatively slow rate, commonly after welding or air cooling after annealing. Also, the carbide precipitation depends from carbon content. The most critical temperature range is around 700^{0}C, at which 0.06% carbon steels will precipitate carbides in about 2 minutes, whereas 0.02% carbon steels rather are immune for precipitation. The precipitated carbides may be dissoluted if the steel is heated over 950^{0}C, in duration 10-40min, followed by water quenching, but this kind of heat treatment will not be applicable on large (welded) components/structures. Stabilized grades of stainless steels, with titanium, niobium even tantalum, are less exposed to this kind of corrosion.

Stress Corrosion Cracking (SCC)

Such corrosion is appeared during the combined action of stress and certain corrosive environment. This kind of corrosion might be intergranular, Fig. 6a) or transgranular, Fig. 6b), but always at normal direction to tensile stress, as could be see from Fig. 6c).



а)



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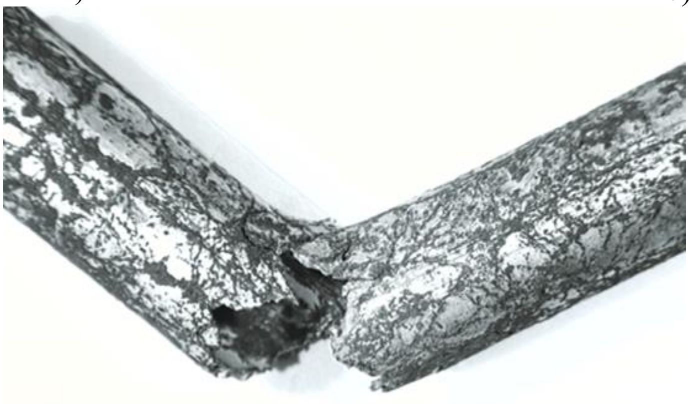

в)

Fig. 6. Microscopis view of stress corrosioin at stainless steels: a) cracks as irregular net, b) cracks at direction normal to tensile stress and c) macroscopic view of one damaged bar under stress corrosion

In some cases the resistivity of stress corrosion may be reduced by shot pinning at the surface of the object, when compressive stress is introduced. Another approach for avoiding the stress corrosion effects is applying a final annealing, but both methods are not a waranty for succssesful elimination of stress corrosion.

Chloride Corrosion Cracking

In chemical plants in contact with chloride solutions this type is emphasis. The cold worked stainless steels are more active for corroding at chloride containing atmosphere. The presence of nickel in steel reduces this form of corrosion.

Sulfide Stress Corrosion Cracking (SSC)

This type of corrosion is important for users in the oil/gas industry when hydrogen sulfide (H_2S) is present. The tensile stresses always favorize this kind of corrosion.

Galvanic Corrosion

Corrosion is, however, an electrochemical process with flow of electrons especially in the contact of dissimilar metals. The two metals must be widely separated according to their position on the galvanic series, as could be found in wide literature [4,10]. Practically, it is neccessary to avoid the mixing of metals, even during fabrication of a given metal structure.

Contact corrosion

Contact corrosion should be avoided even at stainless steels, when two metals posses large differences in electronegativity of coupled materials, even when an usual structural steel is in contact with stainless steel, see Fig. 7.

Fig. 7. Two examples of contact corrosion at atmospheric conditions between stainless steel and galvanized plain steel

For avoiding this kind of corrosion, at warehouse the stainless steels and plain carbon steels must be separated. The clean surface and atmosphere is well protection, however.

CONCLUSION

Either stainless steels were developed for preventing corrosion at plain steels, in some circumstances (explained by electrochemical potential and pH of surrounding media) those steel may corrode. On a simplified manner, the corrosion processes may be regarded as outer (in contact with different media or material) or inner type (when internal structural changes took place) at used stainless steel. For most outer corrosion types, the changes at the surface frequently are visible just by naked eye, while for monitoring the inner types are neccessary to provide the metallographic analysis. Some important types of corrosion here were shown.

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Session 2

Energetics and Process Technique

COMPARISON BETWEEN FOUR AND FIVE PARAMETERS SORPTION ISOTHERM MODELS

Vangelce Mitrevski[1], Cvetanka Mitrevska[2], Ljupco Trajcevski[1]
[1]University St.Kliment Ohridski, Faculty of Technical Sciences, Bitola, North Macedonia
[2]International Slavic University Gavrilo Romanovic Derzavin,
Faculty for Safety Engineering, Sveti Nikole, North Macedonia
e-mail: vangelce.mitrevski@uklo.edu.mk

Abstract: In this paper, the results of comparative statistical analysis between four and five non temperature dependent sorption isotherm models are presented. In order to find which model gives the best results, some numerical experiments were made. The experimental data set for equilibrium moisture content and the water activity for quince at four different temperatures were used. For each model and data set, the coefficient of determination was calculated and models were ranked afterwards. After choosing the best four and five parameters model with the high value of coefficient of determination, the residual plot was checked graphically.
Key words: four and five parameters models, statistical evaluation, moisture content data.

INTRODUCTION

The food sorption isotherm describes the thermodynamic relationship between the water activity, a_w and the equilibrium of moisture content, X_{eq} at constant temperature and pressure. Measurement and modeling of sorption isotherms of food materials has attracted numerous researches because their values are used in the industrial practice. Many models are used for the mathematical modeling of equilibrium of moisture content data of food materials [1-3, 5, 22]. Popovski and Mitrevski [12-16, 18] and Mitrevski [9] proposed eight methods for generating new sorption isotherm models. Genealy sorption models are selected on the basis of several statistical parameters, but all criterions of model selection by the goodness of fit, including the correlation coefficient or coefficient of determination, root mean squared error and the mean relative deviation. The selection of a sorption isotherm model with graphical evaluation of the residual randomness is also popular [20]. In this paper, the results of the comparative statistical analysis between thirty-two four and fifteen five-parameter sorption isotherm models for approximation experimental equilibrium data of quince are presented.

MATERIAL AND METHODS

The equilibrium moisture content of quince was determined at temperatures of 15, 30, 45 and 60°C using static gravimetric method [10]. Ten saturated salt solutions L_iCl, CH_3COOK, $MgCl$, K_2CO_3, $Mg(NO_3)_2$, $NaBr$, $SrCl_2$, $NaCl$, KCl and $BaCl_2$ were used to give defined constant equilibrium relative humidity in the glass jars from 0.110 to 0.920. Two dry samples of quince were placed on holder into each of the ten glass jars and exposed to atmospheres of various relative humidity. The glass sorption jars were placed and kept in the temperature controlled cabinet type maintained at temperatures 15, 30, 45 and 60°C with an accuracy of ±0.1°C. Three replications were made at each temperature and equilibrium relative humidity in the glass jars, using two samples per replication and the average values of equilibrium moisture content were calculated [10]. The change of samples mass was determined by electrical balance type KERN PLJ360-3M, with precision of 0.001 g every 7 days. The equilibrium between samples and their environment was reached after 21 days when is achieved by the constant weight after two successive weighing of samples. The equilibrium moisture content of the quince samples was determined gravimetrically by drying in an oven at temperature of 105°C and atmospheric pressure for 24 h.

RESULTS AND DISCUSSIONS

The experimental values for the equilibrium moisture content, X_{eq} on the quince slices at each water activity, a_w for the four different temperatures were fitted with thirty-two four (Table 1) and fifteen, five parameters sorption isotherm models (Table 2).

Table 1. Four parameters sorption models for approximation sorption data of quince

Number of model	Model	References
M01	$X_{eq} = a_w(\frac{A}{1-Ba_w} + \frac{C}{1-Da_w})$	[6]
M02	$X_{eq} = Aa_w^B + \exp[(a_w - C)^2 D]$	[7]
M03	$X_{eq} = \frac{a_w}{1-a_w}(\frac{A}{1-Ba_w} + \frac{C}{1-Da_w})$	[8]
M04	$X_{eq} = Aa_w^B + Ca_w^D$	[11]
M05	$X_{eq} = A + Ba_w + Ca_w^2 + Da_w^3$	[4]
M06	$X_{eq} = \exp(Aa_w)B + \exp(Ca_w)D$	[12]
M07	$X_{eq} = A(\frac{a_w}{1-a_w})^B + C(\frac{a_w}{1-a_w})^D$	[12]
M08	$X_{eq} = \exp[A\ln(a_w)^2]B + \exp[C\ln(a_w)^2]D$	[12]
M09	$X_{eq} = \frac{A}{(1-Ba_w)} + \frac{C}{(1-Da_w)}$	[12]
M10	$X_{eq} = A(-\ln a_w)^B + C(-\ln a_w)^D$	[12]
M11	$X_{eq} = a_w(1+a_w) + (\frac{1}{1-Ba_w} + \frac{C}{1-Da_w})$	[12]
M12	$X_{eq} = A[-\ln(1-a_w)]^B + C[-\ln(1-a_w)]^D$	[12]
M13	$X_{eq} = \frac{A}{B-\ln a_w} + \frac{C}{D-\ln a_w}$	[12]
M14	$X_{eq} = \frac{A}{(1-a_w)^B} + \frac{C}{(1-a_w)^D}$	[13]
M15	$X_{eq} = a_w[\frac{A}{(1-Ba_w)^2} + \frac{C}{(1-Da_w)^2}]$	[13]
M16	$X_{eq} = [\frac{Aa_w}{(1-Ba_w)(1-Ca_w)}]^D$	[13]
M17	$X_{eq} = [\frac{A}{1-Ba_w} + C]^D$	[13]
M18	$X_{eq} = [\frac{A}{1-Ba_w} + Ca_w]^D$	[13]
M19	$X_{eq} = \frac{Aa_w(1-a_w^B)}{(1-a_w)(1-Ca_w)} + D$	[14]
M20	$X_{eq} = \frac{Aa_w}{(1-Ba_w)(1-Ca_w)} + D$	[14]
M21	$X_{eq} = (\frac{A}{B-\ln a_w})^C + D$	[14]
M22	$X_{eq} = \frac{A}{1-Ba_w} + Ca_w + D$	[14]
M23	$X_{eq} = \frac{Aa_w^3}{(1-Ba_w)(1-Ca_w)(1-Da_w)}$	[15]
M24	$X_{eq} = (\frac{A}{1-Ba_w} + C)\frac{a_w}{1-Da_w}$	[15]
M25	$X_{eq} = a_w[\frac{A}{(1-a_w)(1-Ba_w)} + \frac{C}{1-Da_w}]$	[16]
M26	$X_{eq} = \frac{Aa_w}{(1-a_w)(1-Ba_w)} + Ca_w^D$	[16]
M27	$X_{eq} = \frac{Aa_w}{(1-Ba_w)} + Ca_w^D$	[16]
M28	$X_{eq} = \frac{Aa_w}{(1-Ba_w)} + \frac{C}{(1-Da_w)}$	[16]
M29	$X_{eq} = a_w[\frac{A(1+a_w)}{(1-Ba_w)} + \frac{C}{(1-Da_w)}]$	[16]
M30	$X_{eq} = a_w[\frac{A}{(1-Ba_w)(1-Ca_w)} + \frac{D}{(1-a_w)}]$	[16]
M31	$X_{eq} = \exp(Aa_w^B + Ca_w^D)$	[18]
M32	$X_{eq} = \frac{a_w}{(Aa_w + B)} + \frac{Ca_w^D}{(1-a_w)}$	[22]

Table 2. Five parameters sorption models for approximation sorption data of quince

Number of model	Name of model	References
M01	$X_{eq} = \frac{ABa_w}{1+Aa_w} + Ea_w + \frac{CDa_w}{1-Ca_w}$	[21]
M02	$X_{eq} = (\frac{A}{1-Ba_w} + \frac{Ca_w}{1-Da_w})a_w + E$	[17]
M03	$X_{eq} = (\frac{A}{1-Ba_w} + \frac{Ca_w}{1-Da_w})\frac{a_w}{1-a_w} + E$	[17]
M04	$X_{eq} = Aa_w^B + Ca_w^D + E$	[17]
M05	$X_{eq} = Ae^{Ba_w} + Ce^{Da_w} + E$	[17]
M06	$X_{eq} = A(\frac{a_w}{1-a_w})^B + C(\frac{a_w}{1-a_w})^D + E$	[17]
M07	$X_{eq} = Ae^{B\ln^2 a_w} + Ce^{D\ln^2 a_w} + E$	[17]
M08	$X_{eq} = \frac{A}{1-Ba_w} + \frac{C}{1-Da_w} + E$	[17]
M09	$X_{eq} = A(-\ln a_w)^B + C(-\ln a_w)^D + E$	[17]
M10	$X_{eq} = (\frac{A}{1-Ba_w} + \frac{C}{1-Da_w})(1+a_w)a_w + E$	[17]
M11	$X_{eq} = A[(-\ln(1-a_w))]^B + C[-\ln(1-a_w))]^D + E$	[17]
M12	$X_{eq} = \frac{A}{B-\ln a_w} + \frac{C}{D-\ln a_w} + E$	[17]
M13	$X_{eq} = A(1-a_w)^B + C(1-a_w)^D + E$	[17]
M14	$X_{eq} = [\frac{A}{(1-Ba_w)^2} + \frac{C}{(1-Da_w)^2}]a_w + E$	[17]
M15	$X_{eq} = \frac{Aa_w}{1-Ba_w} + \frac{Ca_w^D}{1-a_w} + E$	[17]

In scientific literature, for the goodness of fit of experimental sorption data and selection of the best isotherm model, following statistical criterions are used: coefficient of determination, R^2, root mean squared error, RMSE, and the mean relative deviation, MRD. The selection of a sorption isotherm model with graphical evaluation of the residual randomness is also popular [20]. Plotting of the residuals against independent variable is a measure of distribution errors. If the sorption model is correct, then the residual should be only random independent errors with a zero mean, constant variance and arranged in a normal distribution. If the residual plots indicate a clear pattern, the model should not be accepted [20]. In this study the value on coefficient of determination, R^2 and graphical evaluation of the residual randomness were the main statistical indicators for selection of the best sorption isotherm model. The method of indirect non-linear regression analysis and estimation methods of Quasi-Newton, Simplex, Simplex and quasi-Newton, Hooke-Jeeves pattern moves, Hooke-Jeeves pattern moves and quasi-Newton, Rosenbrock pattern search, Rosenbrock pattern search and quasi-Newton, Gauss-Newton and Levenberg-Marquardt from computer software Statistica (Statsoft Inc., Tulsa, OK, http://www.statsoft.com) [23], were used to approximate the experimental equilibrium moisture content data of quince. On the basis of experimental data, and each mathematical model from Table 1 and Table 2, the values of coefficient of determination, R^2, was calculated. After that, the models were ranked on the basis of values of the coefficient of determination (Table 3) and (Table 4).

Table 3. Ranking the four parameters models

Model	R^2	Rank	Model	R^2	Rank	Model	R^2	Rank
M01	0.9912	17	M12	0.9910	27	M23	0.9911	26
M02	0.9915	6	M13	0.9911	20	M24	0.9912	16
M03	**0.9916**	**3**	M14	0.9907	28	**M25**	**0.9916**	**2**
M04	0.9915	8	M15	0.9913	11	M26	0.9907	29
M05	0.9848	31	M16	0.9912	15	M27	0.9912	14
M06	0.9911	24	M17	0.9912	18	M28	0.9915	5
M07	**0.9916**	**4**	M18	0.9894	30	M29	0.9913	12
M08	0.9915	7	M19	0.9911	19	**M30**	**0.9916**	**1**
M09	0.9911	23	M20	0.9911	22	M31	0.9914	9

M10	0.9912	13	M21	0.9782	32	M32	0.9913	10
M11	0.9911	21	M22	0.9911	25	-	-	-

Table 4. Ranking the five parameters models

Model	R^2	Rank	Model	R^2	Rank
M01	0.9913	3	M09	0.9901	7
M02	0.9913	3	M10	0.9913	3
M03	**0.9916**	**1**	M11	0.9911	4
M04	0.9915	2	M12	0.9913	3
M05	0.9915	2	M13	0.9910	5
M06	0.9907	6	M14	0.9913	3
M07	0.9910	5	M15	0.9913	3
M08	0.9911	4	-	-	-

From Table 3 it is evident that the four parameters models on McLaren-Rowen and Popovski&Mitrevski with referent number M03, M07, M25 and M30, has the highest value of coefficient of determination, R^2 = 0.9916 (from rank 1 to rank 4). While from Table 4 that the five parameters model of Popovski&Mitrevski with referent number M03, has the highest value of coefficient of determination, R^2 = 0.9916 (rank 1). So, those models correlate the experimental values of sorption data of quince better than other sorption models.
The values of model parameters, A, B, C, D, E for the models, were estimated by fitting the models to experimental equilibrium moisture content data of quince using estimation methods which minimized the sum squares errors. The estimated values of parameters for each model are given in Table 5.

Table 5. Estimated values of parameters for model M03, M07, M25 and M30 and M03

Model	A	B	C	D	E
XEQ=AW/(1-AW)*((A/(1-B*AW)) + (C/(1-D*AW)))	0.0209	1.0623	1.4456	0.0937	-
XEQ=AW*((A/(1-AW)*(1-B*AW))+(C/(1-D*AW)))	0.1231	0.2102	-0.0098	1.0583	-
XEQ=AW*((A/(1-B*AW)*(1-C*AW))+(D/(1-AW)))	0.0209	1.0623	1.4456	0.0937	-
XEQ = ((A/(1-B*AW))+(C/(1-D*AW))) *(AW/(1-AW))+E	0.1372	-0.5734	-0.0005	1.0601	-0.0052

XEQ - equilibrium moisture content, AW- water activity, A, B, C, D, E - parameters

The experimental and predicted values for equilibrium moisture content for quince at four temperatures are shown on Fig. 1a to Fig. 1b.

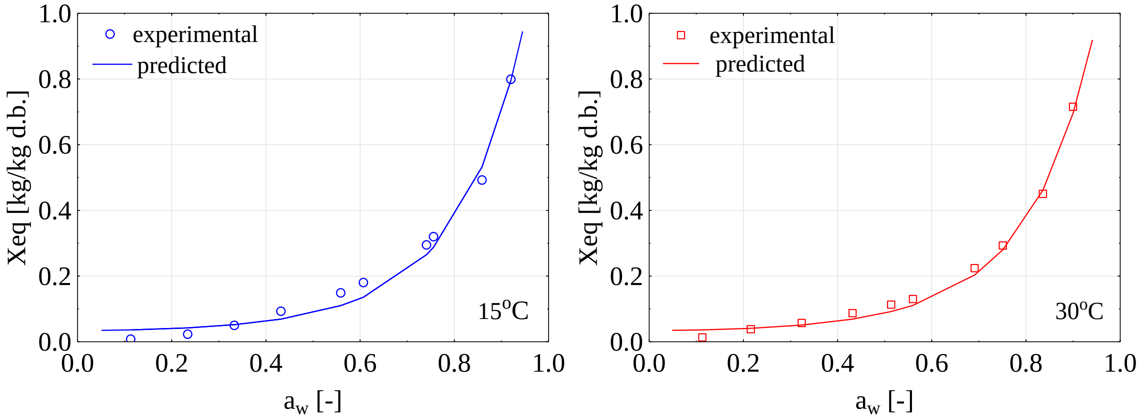

Fig.1a Experimental and predicted sorption isotherms for quince at 15 and 30°C
Model M30 (four parameters)

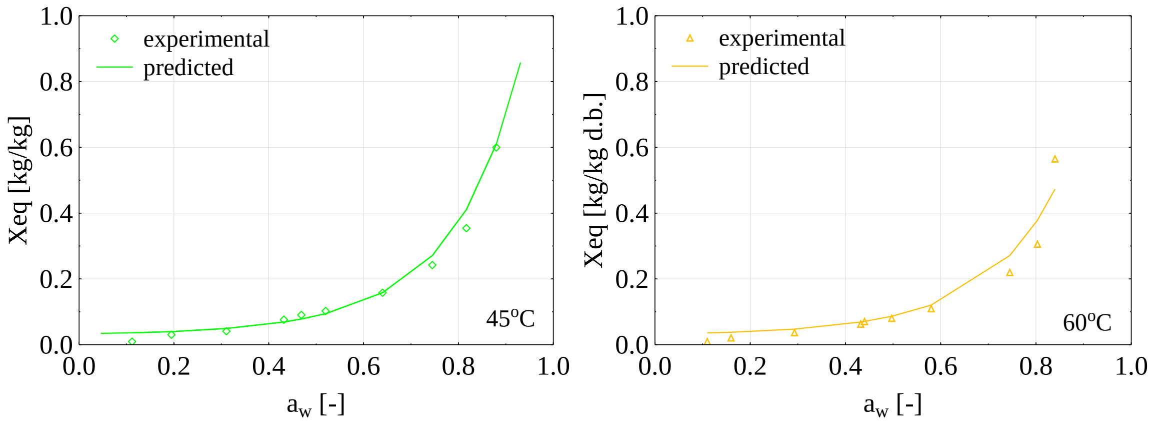

Fig.1b Experimental and predicted sorption isotherms for quince at 45 and 60°C
Model M30 (four parameters)

From Fig.1a to Fig.1b is evident that has a good agreement between the experimental and predicted values of equilibrium moisture data of quince.
Analyzing the residues on regression analysis for each of the models M03, M07, M25 and M30 for four parameters models and M03 for five parameters model, the plots of the residues against the predicted values did not indicate abnormal distribution. In Fig.2a to Fig.2b the plots of the residues against the experimental values, with M30 (four parameters) and M03 (five parameters) are presented.

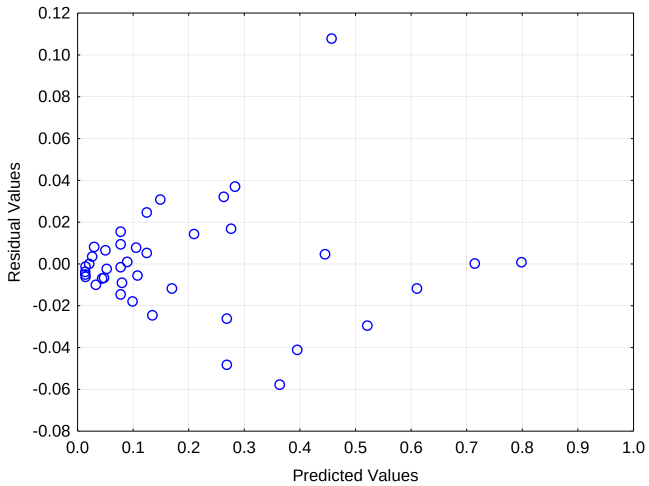

Fig. 2a Residuals plot of sorption data for quince-Model M30

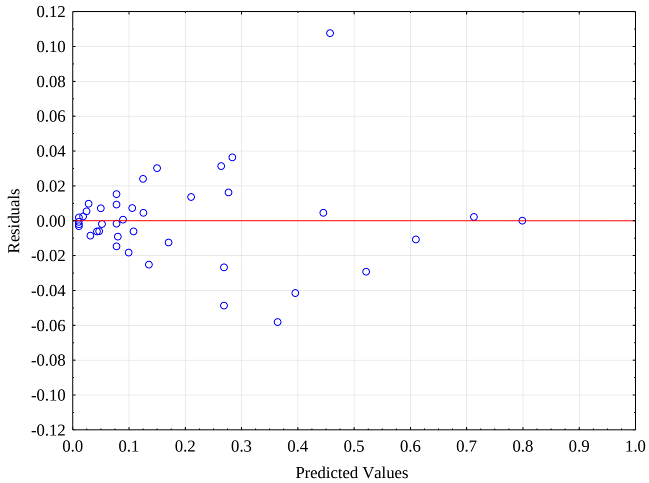

Fig. 2b Residuals plot of sorption data versus predicted values for quince-Model M03

CONCLUSION

In this study statistical performance between thirty-two four and fifteen five-parameter sorption isotherm models for approximation experimental equilibrium data of quince were studied. The value on coefficient of determination and graphical evaluation of the residual randomness were the main assessment criterions for statistical evaluation of the sorption isotherm models. In accordance with those statistical criterions it was concluded that the more four parameters models of has the better statistical fit than five parameters models. According to small number of parameters we suggested four parameters model for approximation on experimental equilibrium moisture data of quince.

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THE INCREASE IN ENERGY EFFICIENCY OF (NANO)MATERIALS BY IMPROVING THEIR SUPERCONDUCTING PROPERTIES

Dušan I. Ilić[1], Jovan P. Šetrajčić[2], Siniša M. Vučenović[3]
[1]University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
[2]Academy of Sciences and Arts of the Republic of Srpska, Banja Luka, B&H
[3] University of Banja Luka, Faculty of Natural Sciences and Mathematics, Banja Luka, B&H
e-mail: [1]dusilic69@uns.ac.rs, [2]jovan.setrajcic@gmail.com, [3]vucenovic.s@gmail.com

Abstract: Despite some disadvantages (high cost and limited commercial application due to complicated processing), nanostructured materials generally possess outstanding properties compared to conventional materials, resulting in a much broader potential for their application. One of the most promising is related to the fact that by phonon energy gap engineering (so-called "phononica"), one can influence the thermodynamic properties of the material (its thermal capacitance, specifically), which, in turn, has a considerable effect on the betterment of its superconducting properties and consequently on energy savings and energy efficiency improvement. This paper will examine how the change of external influences, manifested through the changes in boundary parameters, affects the thermodynamic properties of ultrathin films.
Keywords: energy efficiency, superconductivity, specific heat, phononica

INTRODUCTION

With the news of creating a superconducting material at room temperature for the first time [1-2], the century-old dreams of obtaining clean, cheap and readily available energy and its efficient transport and storage began to be realized. However, the results mentioned above were achieved under extremely high pressures necessary to convert the material, obtained by combining hydrogen with sulfur and carbon, into a superconducting state, roughly corresponding to the pressures at the Earth's centre. Although this value has since been reduced to a third, these are still extremely high pressures, which must be lowered for superconductivity to become an economically acceptable method for producing and using energy. In recent years, a branch of solid-state physics called phononics (or "phononica") has gained much popularity and portends that it could contribute significantly to solving this problem.
Phonons [3-4] are quasiparticles behaving as quanta of mechanical vibrations in solids and are in charge of transmitting energy (heat and sound) through them (alone or coupled with other existing particles and quasiparticles). Phononics [5-6] is a discipline that involves understanding and managing materials' phononic properties. It provides opportunities for controlling many physical properties (thermal, optical, mechanical, acoustic, etc.) of materials at the nanoscale, which is also reflected on more massive structures and provides a step towards the next technological revolution in solid state physics. Phononics is based on applying energy gap engineering of the phononic subsystem in spatially limited structures to create the desired physical (primarily thermodynamic, but also other) properties adapted to particular applications. This can be achieved in one of the following ways: by reducing (adjusting) the dimensions of the nanostructure, choosing a suitable material for the nanostructure itself and the environment surrounding it, and heterostructuring. Whatever method is selected, it can be concluded that the change we want to achieve in the physical properties of the given nanostructure was accomplished by changing the boundary parameters. It will be shown below that by influencing the thermodynamic properties of ultrathin films caused by phonons by changing the boundary parameters is possible to achieve better superconducting properties of the material and get closer to the goal of conducting room-temperature superconductivity.

PROPERTIES OF PHONONS IN NANOSTRUCTURES

The influence of boundary parameters on the thermodynamic properties of nanostructures will be shown in the example of an ultrathin crystalline film [7], depicted in Fig. 1. It is the simplest case of a solid-state nanostructure whose translational symmetry is broken along only one direction, taken here as the Z-axis. In contrast, the structure is unlimited in the other two crystallographic orientations. For the quantum mechanical effect of size to be fully manifested, the number of atomic layers of an ultrathin film must not exceed ten. Otherwise, the properties of this structure will be analogous to those of massive crystal structures (bulk). The crystalline structure is the simplest one, a simple cubic with one atom per elementary cell ($|\vec{a}_x| = |\vec{a}_y| = |\vec{a}_z| \equiv |\vec{a}|$). Still, this fact does not endanger the generality of the theoretical approach, for it is possible to set up a statistical and dynamical equivalence between rectangular structures and structures with lower symmetry, as shown in [8]. Thus, the possibility of applying the described method is much broader.

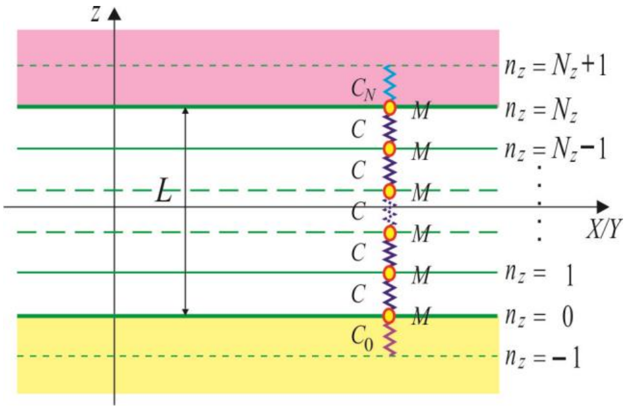

Fig. 1. Ultrathin crystalline film model structure

Atoms within the film are interconnected by Hooke's forces, which are described by the corresponding elastic constants (C). In doing so, it was taken into account that the torsion constants can be neglected compared to the tension constants. However, the atoms from the boundary surfaces of the film are connected in the Z-direction with the atoms of other environments, which implies that the corresponding forces are different from those between the atoms inside the film. This fact is expressed by modifying the related elastic constants (C_0 and C_N) with parameters ε and γ ($\varepsilon, \gamma > -1$): $C_{0,N} = (1 + \varepsilon,\gamma)\, C$.
Calculating phonon dispersion law and determining phonon spectra and possible phonon states in ultrathin films will be conducted from the standard Hamiltonian of the phonon subsystem, adapted to bounded crystalline structures and divided into the kinetic part, surface interaction potential, and volume interaction potential [9-10]:

$$H = T + V^S_{eff} + V^V_{eff} \tag{1}$$

where

$$T = \sum_{\alpha;\vec{n}} \frac{p^2_{\alpha;\vec{n}}}{2M}$$

is total kinetic energy, while

$$\begin{aligned} V^S_{eff} = \sum_{\alpha;n_x,n_y} \frac{C_\alpha}{4} \Big[& 2(1+\varepsilon)\left(u_{\alpha;n_x,n_y,0}\right)^2 + 2(1+\gamma)\left(u_{\alpha;n_x,n_y,N_z}\right)^2 + 2\left(u_{\alpha;n_x,n_y,1} - u_{\alpha;n_x,n_y,0}\right)^2 \\ & + 2\left(u_{\alpha;n_x,n_y,N_z} - u_{\alpha;n_x,n_y,N_z-1}\right)^2 + 2\left(u_{\alpha;n_{x+1},n_y,0} - u_{\alpha;n_x,n_y,0}\right)^2 \\ & + 2\left(u_{\alpha;n_{x-1},n_y,0} - u_{\alpha;n_x,n_y,0}\right)^2 + 2\left(u_{\alpha;n_x,n_{y+1},0} - u_{\alpha;n_x,n_y,0}\right)^2 \\ & + 2\left(u_{\alpha;n_x,n_{y-1},0} - u_{\alpha;n_x,n_y,0}\right)^2 + 2\left(u_{\alpha;n_{x+1},n_y,N_z} - u_{\alpha;n_x,n_y,N_z}\right)^2 \\ & + 2\left(u_{\alpha;n_{x-1},n_y,N_z} - u_{\alpha;n_x,n_y,N_z}\right)^2 \\ & + 2\left(u_{\alpha;n_x,n_{y+1},N_z} - u_{\alpha;n_x,n_y,N_z}\right)^2 + 2\left(u_{\alpha;n_x,n_{y-1},N_z} - u_{\alpha;n_x,n_y,N_z}\right)^2 \Big] \end{aligned}$$

is the surface interaction potential, and

$$V_{eff}^{Z} = \sum_{\alpha;n_x,n_y} \frac{C_\alpha}{4} \left\{ \sum_{n_z=1}^{N_z-1} \left[\left(u_{\alpha;n_x+1,n_y,n_z} - u_{\alpha;n_x,n_y,n_z} \right)^2 + \left(u_{\alpha;n_x-1,n_y,n_z} - u_{\alpha;n_x,n_y,n_z} \right)^2 + \right.\right.$$
$$\left. + \left(u_{\alpha;n_x,n_{y+1},n_z} - u_{\alpha;n_x,n_y,n_z} \right)^2 + \left(u_{\alpha;n_x,n_{y-1},n_z} - u_{\alpha;n_x,n_y,n_z} \right)^2 \right] +$$
$$\left. + \sum_{n_z=1}^{N_z-2} \left(u_{\alpha;n_x,n_y,n_{z+1}} - u_{\alpha;n_x,n_y,n_z} \right)^2 + \sum_{n_z=2}^{N_z-1} \left(u_{\alpha;n_x,n_y,n_{z-1}} - u_{\alpha;n_x,n_y,n_z} \right)^2 \right\}$$

is the volume interaction potential. Here, M is the mass of atoms, $u_{\alpha;n_x,n_y,n_z}$ is the displacement of atom in position $\vec{n} \equiv n_x, n_y, n_z$ from its equilibrium in direction $\alpha \equiv x, z, y$ and $p_{\alpha;\vec{n}}$ corresponding momentum. $C_{\alpha;\vec{n},\vec{n}+\vec{\lambda}} \equiv C_{\alpha;n_z,n_z\pm1}$ are the Hook's elastic constants between the first neighbors. $n_{x,y} \in \left(-N_{x,y}/2, +N_{x,y}/2\right)$ is the atom counter in directions X and Y $\left(N_{x,y} \sim 10^8/\mathrm{cm}^3 \to \infty\right)$, while $n_z \in (0, N_z)$ is the atom counter in Z – direction $(N_z \leq 10)$. Concerning that ultrathin film is confined along the Z – direction, there are boundary conditions in the form

$C_{N_z,N_{z+1}} = C_{N_{z+1},N_z} = (1+\gamma)C\ ;\ C_{-1,0} = C_{0,-1} = (1+\varepsilon)C.$

The phonon dispersion law will be determined using phonon twotime commutator Green's function [11]

$$G_{\vec{n},\vec{m}}^{\alpha}(t-t') \equiv \langle\langle u_{\alpha;\vec{n}}(t) | u_{\alpha;\vec{m}}(t') \rangle\rangle = \Theta(t-t')\ \langle [u_{\alpha;\vec{n}}(t), u_{\alpha;\vec{m}}(t')] \rangle_0 \quad (2)$$

with the corresponding equation of motion in the form

$$-M\omega^2 G_{\vec{n},\vec{m}}^{\alpha}(\omega) = -\frac{i\hbar}{2\pi}\ \delta_{\vec{n},\vec{m}} + \frac{1}{i\hbar}\ \langle\langle [p_{\alpha;\vec{n}},\ H] |\ u_{\alpha;\vec{m}} \rangle\rangle_\omega\ . \quad (3)$$

Carrying out the procedure detailed in [9] and restricting to the so-called "free surfaces model", in which surface perturbations are negligible $(\varepsilon = \gamma = 0)$, which means that an elastic interaction of the atoms from the boundary surfaces of the film with atoms/molecules of surrounding environments is of the same nature and strength, we are obtaining the phonon dispersion law in ultrathin crystalline films, in the following form:

$$\mathcal{E}_{\vec{k}} = \frac{E_{\vec{k}}}{E_0} = 2\sqrt{\sin^2\frac{ak_x}{2} + \sin^2\frac{ak_y}{2} + \sin^2\frac{ak_z(\nu)}{2}} \equiv 2\sqrt{X^2 + Y^2 + \sin^2\frac{ak_z(\nu)}{2}} \quad (4)$$

where $E_0 = \hbar\Omega_\alpha$, $X \equiv \sin(ak_x/2)$, $Y \equiv \sin\left(ak_y/2\right)$ and $k_z(\nu) = \frac{\pi}{a}\frac{\nu}{N_z+2}$, $\nu = 1,\ 2,\ 3, \ldots,\ N_z + 1.$

Equation (4) is of the same form as the one for massive crystalline structures. The main difference, however, is that the quasimomentum of phonons in spatially limited structures, such as ultrathin films, can have only discrete values in the Z – direction and is continual in X – and Y – directions. This is the leading cause of the fact that phonons in confined crystalline structures possess upper as well as lower energy gaps [9], which is why the area of allowed phonon energies in nanostructures is narrower than that in bulk samples for the value of the sum of these gaps. This makes the basis for the concept of phonon engineering (nanophononics).

PHONON THERMODYNAMICS IN ULTRATHIN FILMS

The starting point for computation of the ultrathin film internal energy is the standard form [3]

$$U_f = 3\sum_{k_x,k_y,k_z} E_{\vec{k}} \left(e^{E_{\vec{k}}/\theta} - 1 \right)^{-1} \quad , \quad (5)$$

where $E_{\vec{k}} = aE_0\sqrt{k^2+q^2}$, and $\theta = k_B T = \hbar\omega_D$ (k_B is the Boltzmann constant, T the temperature, and ω_D the Debye frequency; superscript "f" applies to a film). Taking into consideration the selected ultrathin film model structure (unbounded in the X – and Y – directions and up to ten atomic layers in the Z – direction), the wave vector values must be modified from that for the bulk structure $\left(k_{bulk}^D = \sqrt[3]{6\pi}/a\right)$ to the one appropriate for the ultrathin film – a disc with the base $ak_{x/y}^D = a\sqrt{k_x^2 + k_y^2}$ and height $a\Delta k_z^m = a\left(k_z^{max} - k_z^{min}\right)$, where $k_{x/y}^D$ is the Debye wave vector of the ultrathin film

$$k_{x/y}^{D}=\frac{2\pi}{a}\sqrt{\frac{2}{a\Delta k_z^m}}\ .$$

Also, a transformation from the sum to the integral in the cylindrical coordinate system in the equation (5) must be conducted:

$$\sum_{k_x,k_y,k_z} E_{\vec{k}}\left(\mathrm{e}^{E_{\vec{k}}/\theta}-1\right)^{-1}\mapsto \frac{N_xN_y(N_z+1)a^3}{4\pi^2}\left(k_z^{max}-k_z^{min}\right)\cdot I(\theta)\ ,$$

with

$$I(\theta)=\int_0^{k_{x/y}^D}dk\ \frac{k\ E_{\vec{k}}}{\mathrm{e}^{E_{\vec{k}}/\theta}-1}\ .$$

Performing the procedure described in detail in [10], for the internal energy of the ultrathin film the following expression is obtained:

$$U_f=\frac{3N_fa^3}{4\pi^2}\Delta k_z^m\frac{\theta^3q^2}{\Delta^2}\left\{\left(\frac{\Delta}{\theta}\right)^2\left[Z_1\left(\frac{\Delta}{\theta}\right)-b^2Z_1\left(b\cdot\frac{\Delta}{\theta}\right)\right]+2\left(\frac{\Delta}{\theta}\right)\left[Z_2\left(\frac{\Delta}{\theta}\right)-b\cdot Z_2\left(b\cdot\frac{\Delta}{\theta}\right)\right]+\left[Z_3\left(\frac{\Delta}{\theta}\right)-Z_3\left(b\cdot\frac{\Delta}{\theta}\right)\right]\right\}\ , \tag{6}$$

where $Z_r(X)=\sum_{j=1}^{\infty}j^{-r}\cdot\mathrm{e}^{-j\cdot X}$ are Dyson's functions, $N_f=N_xN_y(N_z+1)$ is the total number of atoms inside the film, $\Delta=aE_0q$ and $b=\sqrt{1+\left(\frac{k_{x/y}^D}{q}\right)^2}$. Thanks to right on these parameters, the ultrathin film's internal energy and heat capacity depending on the boundary parameters ε and γ, as well as on the number of layers N_z.

Calculation of the thermal capacitance per unit volume of the ultrathin film will be conducted utilizing the well-known expression

$$C_f=\frac{1}{N_fa^3}\frac{\partial U_f}{\partial T}=\frac{k_B}{N_fa^3}\frac{\partial U_f}{\partial\theta}\ ,$$

which, with the application of equation (6) and bearing in mind the rules of differentiation for Dyson functions, reduces to

$$C_f=\frac{3k_B}{4\pi^2}\Delta k_z^mq^2\left\{\frac{\Delta}{\theta}\left[\left(\mathrm{e}^{\Delta/\theta}-1\right)^{-1}-b^3\cdot\left(e^{b\cdot\Delta/\theta}\right)^{-1}\right]+3\left[Z_1\left(\frac{\Delta}{\theta}\right)-b^2Z_1\left(b\cdot\frac{\Delta}{\theta}\right)\right]+\right.$$
$$\left.+6\frac{\theta}{\Delta}\left[Z_2\left(\frac{\Delta}{\theta}\right)-b\cdot Z_2\left(b\cdot\frac{\Delta}{\theta}\right)\right]+6\left(\frac{\theta}{\Delta}\right)^2\left[Z_3\left(\frac{\Delta}{\theta}\right)-Z_3\left(b\cdot\frac{\Delta}{\theta}\right)\right]\right\}$$

and finally

$$\mathcal{C}_f=\frac{C_f}{C_0}=\frac{5\Delta\mathcal{E}_m\mathcal{E}_{min}^2}{16\pi^6}\left\{\frac{\Delta}{\theta}\left[\left(\mathrm{e}^{\Delta/\theta}-1\right)^{-1}-b^3\cdot\left(e^{b\cdot\Delta/\theta}\right)^{-1}\right]+3\left[Z_1\left(\frac{\Delta}{\theta}\right)-b^2Z_1\left(b\cdot\frac{\Delta}{\theta}\right)\right]+\right.$$
$$\left.+6\frac{\theta}{\Delta}\left[Z_2\left(\frac{\Delta}{\theta}\right)-b\cdot Z_2\left(b\cdot\frac{\Delta}{\theta}\right)\right]+6\left(\frac{\theta}{\Delta}\right)^2\left[Z_3\left(\frac{\Delta}{\theta}\right)-Z_3\left(b\cdot\frac{\Delta}{\theta}\right)\right]\right\}\ , \tag{7}$$

whereby the following notations are introduced: $C_0=\frac{12}{5}\pi^4\frac{k_B}{a^3}$ is the constant related to the thermal capacitance of the bulk structures, and $a\Delta k_z^m=\Delta(a\Delta k_z^m)=ak_z^{max}-ak_z^{min}=\mathcal{E}_{max}-\mathcal{E}_{min}=\Delta\mathcal{E}_m$. According to equations (6) and (7), the internal energy and thermal capacitance per unit volume of the ultrathin film depends on the boundary parameters ε and γ, and on the number of layers N_z through the quantities Δ, b and $q=\frac{1}{a}\sqrt{\rho_{k_z}^{min}+2}$.

ANALYSIS AND DISCUSSION

In this section, we will discuss the influence of boundary parameters on the thermodynamic properties of the investigated structure (ultrathin film) to identify those areas within the low-temperature region where the ultrathin film is expected to exhibit better superconducting properties compared to bulk samples. As already mentioned, these are areas where the thermal capacitance of the film has a lower values than that of the bulk. Changing the boundary parameters of the film can be understood as placing different material environments above and below the film's upper and lower boundary surfaces. It must be noted that the results demonstrated here are only preliminary because the far more extensive and complex research, with a much larger number of parameters and investigated combinations, is in progress. In that respect, for the sake of clarity and overview, we will consider the change of only one parameter (ε) while the other is fixed at the value $\gamma = -0.75$ (which means that the bond between the boundary atoms of the film and the environment is weaker than the bond between the particles inside the film).
Relative phonon energies for different values of boundary parameters for a five-layered ultrathin film (with two boundary layers and three planes within the film) in the low-temperature region (from absolute zero to the area close to Debye temperature) are shown in Table 1, while the relative temperature dependence of the thermal capacitance for the ultrathin film, with various combinations of the boundary parameters, is illustrated in Fig. 2. A particular interest has been put into finding areas with lower values of the thermal capacitance of the film than those in the bulk structures because it indicates possibilities for better superconducting properties.

Table 1. Relative phonon energies for different values of boundary parameters

$\gamma = -0.75$						
ε	-0.75	-0.40	$+0.50$	$+2.50$	$+3.40$	$+5.00$
$\mathcal{E}_{max}$	1.90760	1.91258	1.93978	2.21350	2.38623	2.68328
$\mathcal{E}_{min}$	0.30059	0.36270	0.41542	0.44229	0.44672	0.45140
$\Delta\mathcal{E}$	1.60701	1.54988	1.52436	1.77121	1.93951	2.23188

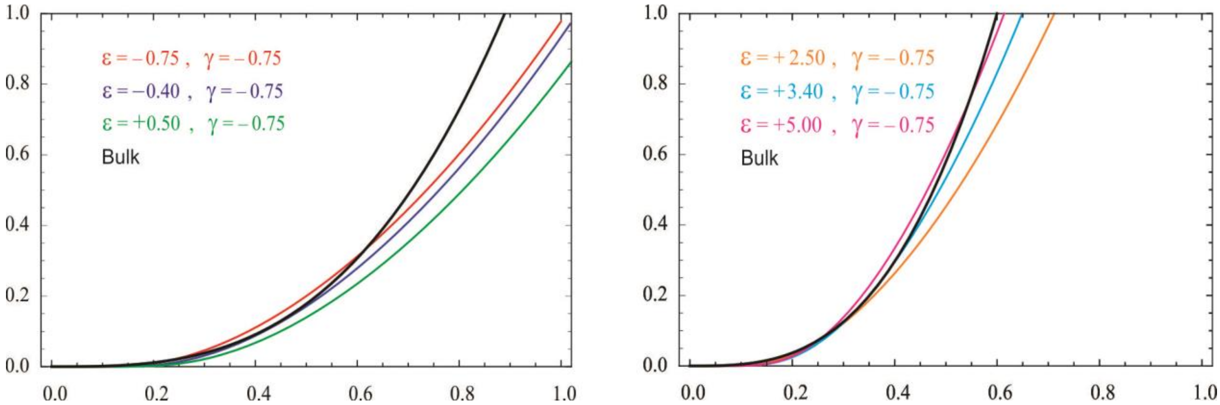

Fig. 2. Dependence of the specific heat of bulk (black line) and film structures in the low-temperature region for selected values of boundary parameters

With parameter $\varepsilon \in [-0.75, -0.40]$, or $\varepsilon > +3.40$ (i.e., for extreme values) the two intersection points are present, where $\mathcal{C}_f = \mathcal{C}_{bulk}$. Between them $\mathcal{C}_f > \mathcal{C}_{bulk}$, but in front of the first and behind the second intersection point it is always $\mathcal{C}_f < \mathcal{C}_{bulk}$. Also, in the range $\varepsilon \in [-0.40, +3.40]$ there is $\mathcal{C}_f < \mathcal{C}_{bulk}$ in the whole observed temperature range, and better superconducting properties of the film can be expected in that interval.

CONCLUSION

Although in the years after the discovery of the phenomenon of superconductivity, it seemed like science fiction, these days, we have come one step away from the "holy grail" of science and technology, the achievement of high-temperature superconductivity. Only one more, but by no means naive, difficulty remained to be resolved - superconductivity at room temperature was achieved at extremely high pressures to which the material was subjected. To make this technology economically and practically available and justified, it is necessary to lower the pressures to the order of atmospheric pressure. This paper hinted that this could be achieved by applying a relatively new but extremely promising discipline within solid state physics at the nanoscopic level - phononics. The basic idea is that by changing the boundary parameters, a more significant pressure of the external environment on the observed structure (ultrathin film) is achieved. This is accomplished by choosing a surrounding material whose atoms exert stronger interatomic forces on the boundary atoms of the system than the forces between the particles inside the structure. In addition, the influence on the boundary surfaces of the nanostructure through the change of the boundary parameters drastically affects its thermodynamic properties and reduces the thermal capacity, which in turn significantly improves the superconducting properties of the material.

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INFLUENCE OF SUNSPACE PARTITION WALL THERMAL MASS ON THE ENERGY EFFICIENCY OF INDIVIDUAL RESIDENTIAL BUILDINGS

Ana Vukadinović[1], Jasmina Radosavljević[1], Amelija Đorđević[1], Milan Protić[1]
[1]University of Niš, Faculty of Occupational Safety in Niš, Serbia
e-mail: ana.vukadinovic@znrfak.ni.ac.rs

Abstract: In passive solar buildings, solar radiation is converted into thermal energy that is accumulated in the thermal mass of the building and used for heating. This research investigates thermal mass of a passive solar building with a sunspace by considering the vertical thermal mass within the wall that separates the sunspace and the adjacent room (thermos-accumulative partition wall). Twelve variants of the MODEL of a residential building with sunspace, with different types of thermo-accumulative partition walls (P1 - P12) were considered. Model variants included partition walls with different thermal characteristics, different types of materials, and construction thicknesses. In this research, EnergyPlus software, based on the principles of heat balance, was used for dynamic simulation to determine the heat load of the building and the required energy for heating and cooling. Concerning the twelve considered variants of the thermal mass in the composition of the thermo-accumulative partition wall between the sunspace and the room, it was determined that the variants containing 0.4 m thick concrete or 0.38 m thick brick in the wall structure have better energy properties compared to structures with the same coefficient of heat transfer coefficient, but with a smaller thickness of concrete (d=0.20 m) or brick (d=0.25 m). Savings in the total annual required energy for heating and cooling were up to 7.20%.
Keywords: thermo-accumulative partition wall, sunspace, energy performance

INTRODUCTION

Compared to the period 40 years ago, world energy consumption in the building sector, increased by 1.8% on an annual basis. Past research shows that this trend of increasing energy consumption will continue. With the energy consumption of 2790 Mtoe (million tons of oil equivalent) in 2010, the consumption is expected to exceed 4400 Mtoe by 2050 [1] Three-quarters of the total energy consumption in buildings comes from the sector of residential buildings. Greater representation of passive solar buildings would contribute to the reduction of this percentage, while savings in energy used for heating, cooling, and air conditioning would be achieved at the same time.
In passive solar buildings, solar radiation is converted into thermal energy that is accumulated in the thermal mass of the building and used for heating of building interior space (living room, bedrooms and work rooms, etc.) [2] In areas with a warm climate, the use of thermal mass is recommended because thermal mass can prevent overheating of buildings and mitigate large day-night fluctuations of temperature. In areas with a moderate climate, the correct selection of materials depends on their mechanical, physical, and structural characteristics. Non-transparent elements of the envelope can represent the thermal mass of the object if the walls are composed of materials whose absorption capabilities are high in relation to the volume of the material (stone, concrete, brick).
The basic principle of passive solar sunspace is based on the "greenhouse effect". Solar radiation reaches the interior space through the glazed surfaces, where it is absorbed by the dark surfaces of the thermal mass. Between the sunspace and the room, a massive wall is most often formed, through which the heat is transferred to the interior of the building and the room adjacent to the sunspace. The thermal mass is usually the southern partition wall of the building (the wall between the sunspace and the interior rooms of the building) with a thickness of 20-40 cm made of concrete or brick [2]. The accumulated heat in the wall is further transferred by conduction into the building interior (living room, bedroom, study, etc.). The thermo-accumulative wall can be with or without an opening on it.
Suarez et al. investigated the thermal behavior of an experimental object with a sunspace using the ANSYS 12.1 software. The experimental building was located in the north of Spain. The thermal mass of the building consisted of the sunspace floor structure, with a 0.20 m thick sand filling. The obtained results showed that the heat energy transmitted from floor thermal mass to the environment was highest in spring and autumn [3]

The effect of thermal mass on heat gains in a residential building with a sunspace, in cold climate conditions, was investigated by Rempel et al. [4]. The thermo-accumulative mass was the sunspace floor. Two types of thermal mass materials were considered, concrete and water (in tanks). In the considered variants of the thermal mass, a greater increase in air temperature (40-70%) was recorded in the morning hours and significantly less in the evening hours (20-40%). Remple et al. also investigated the influence of the thickness of concrete floor thermal mass and found that a thickness of 5.1 cm is the most suitable for interior space heating in the evening hours. If the interior room heating in the early morning hours is required, then the thickness of the concrete, within the thermal mass of the floor structure, is 15 cm [4]

Bastien and Athienitis investigated the influence of the position of the thermo-accumulative mass (floor, wall, or both) and the percentage of glazing of the sunspace on the air temperatures inside the room. They used numerical methods: finite difference thermal network - FD and frequency response - FR. The research included the analysis of the obtained internal temperatures depending on the thickness and position of the thermo-accumulative mass [5]

In Iran, research was conducted on a passive building with a sunspace and a thermo-accumulative partition wall with water. The sunspace of this building was positioned towards the south and had triple glazing on the front and single glazing on the roof surface sloped by a 35°. Two variants of the thermal mass were experimentally analyzed: with and without a water tank. For different climatic conditions of the location of the building, simulations were performed using the EnergyPlus software. The obtained results showed that the application of the sunspace has a positive effect on interior room heating. For the investigated variant of the building model with thermal mass consisting of water tanks, better thermal comfort conditions were achieved. It was found that the greatest increase in temperature is achieved in January, during the coldest days [6]

Sanchez-Ostiz et al. investigated the energy performance of a building with a sunspace, namely: a building with a sunspace and a horizontal thermal mass (P1), a building with a sunspace without a thermal mass (P2), a building without a sunspace (P3) and a building with a sunspace and a vertical thermal mass (P4), to determine the optimal model of a building with a sunspace for the climatic conditions of Spain [7]

This research investigates the influence of the thermal mass of the thermal storage wall in the building with a sunspace on the total required energy for heating and cooling during one year. A model of the building with a sunspace was created and model variants containing different types of materials in the structure of the partition wall. Different thermal mass and different layer thicknesses of the structure were also considered. The formed object model is located in Niš.

MATERIAL AND METHODS

Building model

EnergyPlus software was used to determine the building's energy properties. The dynamic simulations in EnergyPlus software are based on the basic laws of physics and the principles of heat balance. Heat balancing is the basis of all calculations that determine the heat load of the building and the required energy for heating and cooling.

Research on the thermal mass of a passive solar building with a sunspace was conducted by considering the vertical thermal mass within the wall that separates the sunspace and the adjacent room (thermo-accumulative partition wall). A MODEL of the building with a sunspace was created, with G+1 floors with a floor aspect ratio of 2.25:1. Sunspace was placed on the entire length of the south-facing facade. The width of the sunspace in this model is 1.2 m. The length of the building is 14.4 m and the width is 6.4 m. The total area of the base of the building is Po=184.32 m^2 and the area of the sunspace is Ps= 34.56 m^2. The sunspace is fully glazed and the window-to-wall ratio of the building is WWR=20%. The model of a building is located in Niš.

Meteonorm software package was used to create a meteorological file for the city of Nis based on the measured meteorological parameters for the period from 1991 to 2010. The setpoint temperature for the heating system is 20°C, and for the cooling system is 25°C. The natural ventilation system is defined in such a way as to ensure a certain number of air exchanges per person during 24 hours.

Table 1 shows the values of the heat transfer coefficient "U" for facade walls, floor and roof construction, and windows of the model of individual passive residential buildings with a sunspace.

Table 1. Values of heat transfer coefficient for defined elements of the thermal envelope of the building

Type of structure	U [W/m^{2}K]
Facade wall	0.29
The floor on the ground	0.28
The flat roof	0.15
Windows, Sunspace glazing	1.50

Twelve sub-variants of the MODEL were considered with different types of heat-accumulating partition walls (P1 - P12) whose basic characteristics are shown in table 2. Formed variants of the model included walls with different thermal characteristics, different types of materials, and construction thicknesses. Within the formed variants different thermo-accumulative partition walls were considered: concrete constructions with a thickness of 0.2 m and 0.4 m, brick constructions with a thickness of 0.25 m and 0.38 m, and different thicknesses of thermal insulation material from 0.05 m to 0.15 m.

Table 2. Considered partition wall types and their characteristics (structure, material composition, and thermal characteristics)

Marking of the partition wall	**Name** (thermo-accumulative partition wall)	**Characteristics of the material in the composition of the wall**						**Wall heat transfer resistance – R [m^{2}K/W]**	**Wall heat transfer coefficient – U [W/m^{2}K]**
		Type of material in the composition of the partition wall	**Material thickness [m]**	**Thermal conductivity [W/mK]**	**Specific heat capacity [J/kgK]**	**Density [kg/m^3]**	**Relative coefficient of diffusion of water vapor**		
P1	Thermo-accumulative partition wall made of brick (0.25 m) and thermal insulation (0.15 m)	Exterior plaster	0.02	0.72	840	1860	20	5.02	0.199
		EPS (Expanded Polystyrene)	0.158	0.035	1400	25	150		
		Brick	0.25	0.85	840	1650	150		
		Internal plaster	0.01	0.72	840	1860	20		
P2	Thermo-accumulative partition wall made of concrete (0.2 m) and thermal insulation (0.15 m)	Exterior plaster	0.02	0.72	840	1860	20	5.021	0.199
		EPS (Expanded Polystyrene)	0.154	0.035	1400	25	150		
		Concrete	0.2	0.51	1000	1400	150		
		Internal plaster	0.01	0.72	840	1860	20		
P3	Thermo-accumulative partition wall made of brick (0.25 m) and thermal insulation (0.099 m)	Exterior plaster	0.02	0.72	840	1860	20	3.354	0.298
		EPS (Expanded Polystyrene)	0.099	0.035	1400	25	150		
		Brick	0.25	0.85	840	1650	150		
		Internal plaster	0.01	0.72	840	1860	20		
P4	Thermo-accumulative partition wall made of concrete (0.2 m) and thermal insulation (0.096 m)	Exterior plaster	0.02	0.72	840	1860	20	3.352	0.298
		EPS (Expanded Polystyrene)	0.0962	0.035	1400	25	150		
		Concrete	0.2	0.51	1000	1400	150		
		Internal plaster	0.01	0.72	840	1860	20		

P5	Thermo-accumulative partition wall made of brick (0.25 m) and thermal insulation (0.07 m)	Exterior plaster	0.02	0.72	840	1860	20	2.52	0.397
		EPS (Expanded Polystyrene)	0.07	0.035	1400	25	150		
		Brick	0.25	0.85	840	1650	150		
		Internal plaster	0.01	0.72	840	1860	20		
P6	Thermo-accumulative partition wall made of concrete (0.2 m) and thermal insulation (0.067 m)	Exterior plaster	0.02	0.72	840	1860	20	2.521	0.397
		EPS (Expanded Polystyrene)	0.0671	0.035	1400	25	150		
		Concrete	0.2	0.51	1000	1400	150		
		Internal plaster	0.01	0.72	840	1860	20		
P7	Thermo-accumulative partition wall made of brick (0.38 m) and thermal insulation (0.15 m)	Exterior plaster	0.02	0.72	840	1860	20	5.019	0.199
		EPS (Expanded Polystyrene)	0.153	0.035	1400	25	150		
		Brick	0.38	0.85	840	1650	150		
		Internal plaster	0.01	0.72	840	1860	20		
P8	Thermo-accumulative partition wall made of concrete (0.4 m) and thermal insulation (0.14 m)	Exterior plaster	0.02	0.72	840	1860	20	5.019	0.199
		EPS (Expanded Polystyrene)	0.14	0.035	1400	25	150		
		Concrete	0.4	0.51	1000	1400	150		
		Internal plaster	0.01	0.72	840	1860	20		
P9	Thermo-accumulative partition wall made of brick (0.38 m) and thermal insulation (0.094 m)	Exterior plaster	0.02	0.72	840	1860	20	3.353	0.298
		EPS (Expanded Polystyrene)	0.094	0.035	1400	25	150		
		Brick	0.38	0.85	840	1650	150		
		Internal plaster	0.01	0.72	840	1860	20		
P10	Thermo-accumulative partition wall made of concrete (0.4 m) and thermal insulation (0.0825 m)	Exterior plaster	0.02	0.72	840	1860	20	3.353	0.298
		EPS (Expanded Polystyrene)	0.0825	0.035	1400	25	150		
		Concrete	0.4	0.51	1000	1400	150		
		Internal plaster	0.01	0.72	840	1860	20		
P11	Thermo-accumulative partition wall made of brick (0.38 m) and thermal insulation (0.065 m)	Exterior plaster	0.02	0.72	840	1860	20	2.519	0.397
		EPS (Expanded Polystyrene)	0.0651	0.035	1400	25	150		
		Brick	0.38	0.85	840	1650	150		
		Internal plaster	0.01	0.72	840	1860	20		
P12	Thermo-accumulative partition wall made of concrete (0.4 m) and thermal insulation (0.053 m)	Exterior plaster	0.02	0.72	840	1860	20	2.519	0.397
		EPS (Expanded Polystyrene)	0.0533	0.035	1400	25	150		
		Concrete	0.4	0.51	1000	1400	150		
		Internal plaster	0.01	0.72	840	1860	20		

RESULTS AND DISCUSSION

Dynamic simulations were carried out in the EnergyPlus software package for the formed variants of the MODEL, and the dynamic behavior of the object throughout the year was determined and the required energy for heating required energy for cooling, and the total required energy for heating and cooling for the entire year was calculated.
The results of dynamic simulations for the considered variants of the partition wall MODEL P1 to P12 at the percentage of glazing WWR=20% are shown in table 2. Based on the results given in the table, the reference model, variant P8, was determined. The P8 variant requires the least energy for heating as well as the total annual required energy. Variant P8 includes a partition wall made of concrete 0.4 m thick with thermal insulation made of EPS (expanded polystyrene) 0.14 m thick. Table 3 shows the percentage increase, or decrease, of the total required energy for heating and cooling the building compared to the reference model P8.

Table 3. Results obtained by simulation for MODEL (variants P1 - P12), WWR=20%, for different types of the partition wall

Partition wall type designation	**MODEL**					
	Total required energy for heating [kWh]	Total required energy for cooling [kWh]	Total required energy for heating and cooling [kWh]	Percentage increase (+) or decrease (-) of the total required energy for heating	Percentage increase (+) or decrease (-) of the total required energy for cooling	Percentage increase (+) or decrease (-) of the total required energy for heating and cooling
P1	8878.34	5600.51	14478.85	+0.40	+0.10	+0.28
P2	8884.45	5604.68	14489.13	+0.47	+0.17	+0.36
P3	8905.98	6068.61	14974.59	+0.71	+8.46	+3.72
P4	8915.79	6074.31	14990.10	+0.83	+8.57	+3.83
P5	8927.08	6532.14	15459.22	+0.95	+16.75	+7.07
P6	8936.57	6540.97	15477.54	+1.06	+16.91	+7.20
P7	8843.63	5617.68	14461.31	+0.01	+0.41	+0.16
P8	8842.78	5595.01	14437.79	Ref.	Ref.	Ref.
P9	8878.58	6057.83	14936.41	+0.40	+8.27	+3.45
P10	8865.24	6053.39	14918.63	+0.25	+8.19	+3.33
P11	8901.01	6496.82	15397.83	+0.66	+16.12	+6.65
P12	8889.13	6490.22	15379.35	+0.52	+16.00	+6.52

Figure 1 shows the total annual required energy for heating, the total annual required energy for cooling and total annual required energy for heating and cooling, variants of the MODEL that include different types of the partition wall between the sunspace and the room (P1 - P12) at the percentage of glazing WWR=20%.

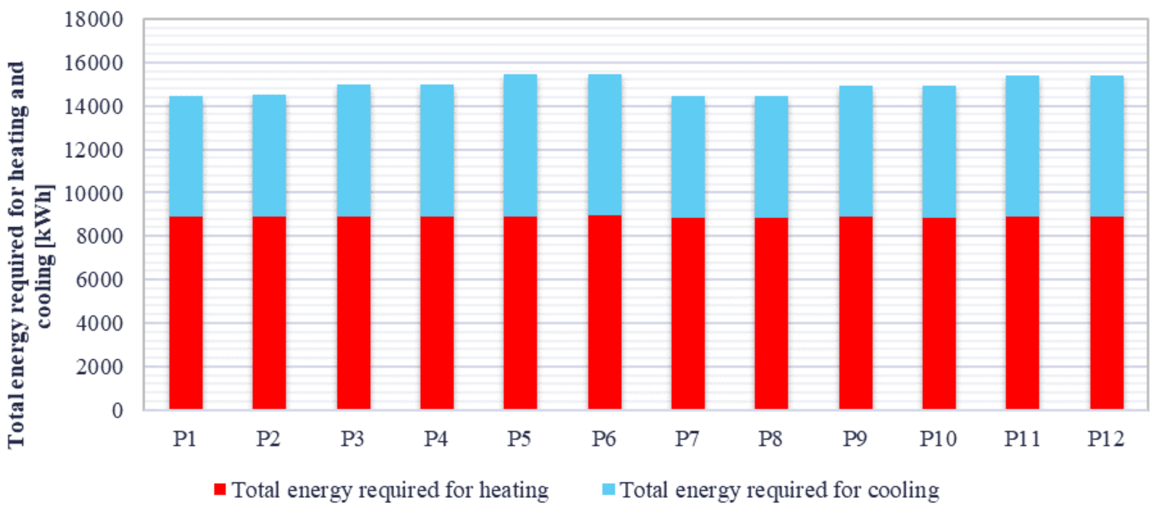

Figure 1. Total annual required energy for heating and cooling for MODEL of different types of the partition wall (subvariants P1 - P12) with WWR=20%

The obtained results showed that the energy required for heating the building MODEL and all its variants (P1 - P12) is the lowest for variant P8 (MODEL variant P8), where the partition wall is made of concrete with a thickness of 0.40 m and thermal insulation made of EPS 0.14. That model was taken as a reference model.

The highest required energy for heating is for variant P6 (0.2 m thick concrete and 0.067 m thermal insulation) and amounts of 8936.57 kWh, i.e. 1.06% more compared to the reference model. In other considered subvariants of the model, the required energy for heating the building is slightly higher compared to the reference model (up to 1%), but the required energy for cooling of some models is significantly higher. In the case of variants P5, P6, P11, and P12, the required energy for cooling the building is higher by 16.75%, 16.91%, 16.12%, and 16.00% compared to the reference model, respectively. These subvariants have a heat transfer coefficient of U=0.397 W/m^{2}K.

The total annual required energy for heating and cooling is the highest in subvariant P6 (partition wall made of concrete 0.2 m and thermal insulation 0.067 m) and amounts to 15477.54 kWh, which is 7.20% more compared to the reference model.

CONCLUSION

Based on the analysis of the research subject, it can be concluded:

• When materials with a high thermal capacity are installed in certain parts of the building structure, such a building can store a larger amount of heat during the day, which will be released slowly into the interior space during the night.

• Concerning the twelve considered variants of the thermal mass in the composition of the thermo-accumulative partition wall between the sunspace and the room, it was determined that the variants that contained 0.4 m thick concrete or 0.38 m thick brick in the wall structure have better energy properties compared to constructions with the same heat transfer coefficient, but with a smaller thickness of the material of concrete (d=0.20 m) or brick (d=0.25 m). Savings in the total annual required energy for heating and cooling were up to 7.20%.

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ENERGY RECOVERY POSSIBILITIES DURING WORKING CYCLE OF WHEEL LOADERS

Jovan Pavlović[1], Vesna Jovanović[1], Nikola Petrović[1]
[1]University of Niš, Faculty of Mechanical Engineering
e-mail: jovan.pavlovic@masfak.ni.ac.rs, vesna.jovanovic@masfak.ni.ac.rs, petrovic.nikola@masfak.ni.ac.rs

Abstract: This work represents a mathematical model of wheel loader for numerical analysis of working cycle. The results of the analysis show that during certain operations of manipulation tasks in loader's working cycle there are possibilities for energy recuperation that can be accumulate using hydrostatic system and return to the drive system of the machine for use in other operations of the manipulation task As an example, the results of numerical analysis using software MSC Adams are given for the wheel loader which have in mass 15.000 kg.

INTRODUCTION

Because of reduction of pollutant emissions, with rising fuel prices and increasingly stringent regulation, the major challenges for the mobile machinery manufacturers is the improvement of energy efficiency. In mobile machinery drive systems of transmission and manipulators are mainly hydraulic and the development of energy saving solutions and efficient hydraulic system have become a priority for researchers. One of the most effective approach is the machine hybridization but other solutions can be adopted.
A wheel loaders are part of mobile machinery mainly used to load and unload bulk materials and for light excavation work. The general configuration of wheel loader kinematic chain consists of: the rear and front moving member and the manipulator with arm and bucket. The rear and front moving mechanism are connected by vertical joint thus forming articulated vehicle.
For the numerical analysis of the loader's working cycle, general mathematical models of loader kinematic chain and mathematical models of loader manipulation tasks were defined. The purpose of the analysis is to determine the required power of the loader in individual operations of manipulation task [1].

MATHEMATICAL MODEL OF WHEEL LOADER

Mathematic model of a loader with a general four-member configuration of the kinematic chain comprising: the rear L_1 and the front L_2 support and movement member (Figs. 1) and the loader mechanisms with the boom L_3 and the bucket L_4. The rear and the front support and movement members are connected using a vertical rotary fifth-class joint O_2, thus forming the movement mechanism of the machine. The kinematic chain of the loader mechanisms is of planar configuration. The axes of the rotary joints O_i are parallel, and the centres of the joints lie in the same plane - the plane of the loader mechanisms. The intersection of the bucket cutting edge through the plane of the loader mechanisms represents the centre of the bucket cutting edge O_w.
The assumptions of the mathematical model of the loader kinematic chain are: (1) the support surface and the kinematic chain members of the loader are modelled using rigid bodies; (2) the first joint between the support and movement member and the loader support surface has a variable position (O_{11}, O_{12}), lies in the centre of the surface where tires meet the ground, and has the form of rotary joints whose axes represent potential (longitudinal z–z) loader rollover lines; (3) during a manipulation task, theloader is subjected to external (technological) forces-digging resistance W and gravitational forces (weights) of: members of the kinematic chain, members of the drive system, and material scooped up by the loader bucket; (4) the kinematic chain of the wheel loader is observed during the digging operation as an open-configuration chain whose final member—the bucket, is subjected to the digging resistance W in the centre of the bucket cutting edge and in the plane of the whel loader mechanisms [2].

The area of the loader model is determined by an absolute coordinate system *OXYZ* with unit vectors *i*; *j*; *k* along the coordinate axes *OX*, *OY*, and *OZ*. The loader support surface lies in the horizontal *OXZ* plane of the absolute coordinate system, while the vertical *OY* axis of the same system falls on the axis of the kinematic pair of the front and rear member of the support and movement mechanism.

In the final member of the chain–the bucket, the O_4x_4 axis of the local coordinate system passes through the centre of joint O_4 and the centre of the bucket cutting edge O_w. The member of the kinematic chain L_i is determined, in its local coordinate system $O_i\, x_i\, y_i\, z_i$, by a set of values (Fig. 1):

$$L_i = \left\{ \hat{\boldsymbol{e}}_i, \hat{\boldsymbol{s}}_i, \hat{\boldsymbol{t}}_i, m_i, \hat{\boldsymbol{J}}_i \right\} \tag{1}$$

where: $\hat{\boldsymbol{e}}_i$ – the unit vector of joint O_i axis which connects link L_i to the previous link L_{i-1} (Fig. 1), $\hat{\boldsymbol{s}}_i$ – the vector of the position of joint O_{i+1} centre which is used to connect the chain link L_i to the next member L_{i+1}, $\hat{\boldsymbol{t}}_i$ – the vector of the position of the member L_i mass centre, m_i – the link mass, $\hat{\boldsymbol{J}}_i$ – the tensor of the moment of inertia of the link. Vector quantities marked with a 'cap' relate to the local coordinate system, while those without a 'cap' relate to the absolute coordinate system.
By fictitiously breaking the kinematic chain of the manipulator in the joint O_i ($i=3,4$) from the equilibrium condition of the rejected part of the chain, the loads in the center of the joint are determined:

- resultant force:

$$\boldsymbol{F}_{ri} = \boldsymbol{F}_{gi} + \boldsymbol{F}_i + \boldsymbol{W} \quad \forall\, i = 3,4 \tag{2}$$

- resultant moment:

$$\boldsymbol{M}_{ri} = \boldsymbol{M}_{gi} + \boldsymbol{M}_i + \boldsymbol{M}_{wm} + \boldsymbol{M}_{ww} \quad \forall\, i = 3,4 \tag{3}$$

where: F_{gi} - resultant of gravitational forces of the members of the rejected part of the chain, F_i - resultant of inertial forces caused by the movement of the members of the rejected part of the chain, W - force of resistance when loading the material, M_{gi} - resulting moment of gravitational forces, M_i - resulting moment of inertia caused by movements of the chain members, M_w - moment of resistance when loading the material, M_{ww} - moment of resistance force when gripping the material.
Loading moments of loader manipulator drive mechanisms:

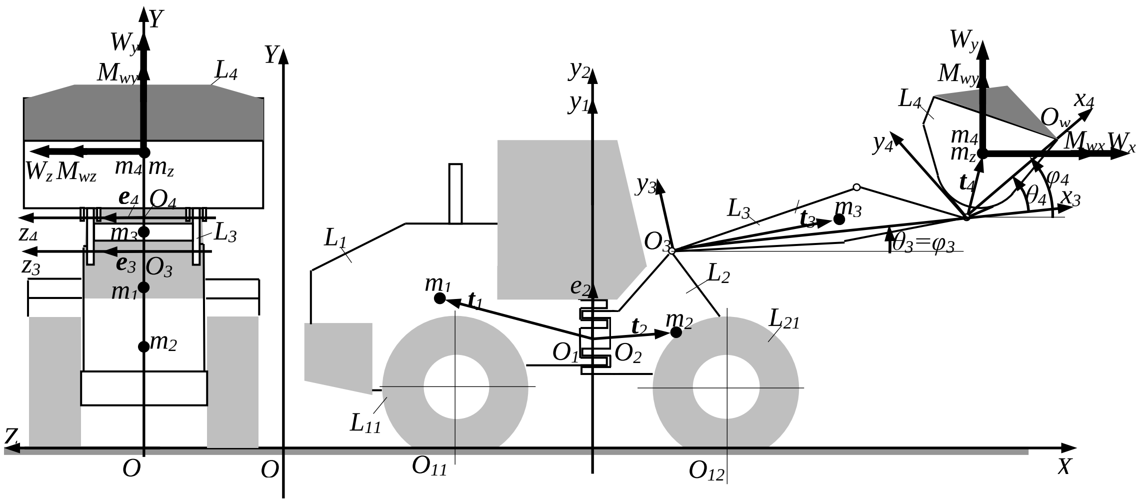


Fig.1. Mathematical model of wheel loader

$$\boldsymbol{M}_{oi} = \boldsymbol{M}_{ri} \cdot \boldsymbol{e}_i \qquad \forall \qquad i = 3,4 \tag{4}$$

where: e_i - unit vector of the joint axis of the executive member of the drive mechanism.
Based on the defined mathematical model of the kinematic chain, using the Automatic Dynamic Analysis of Mechanical Systems (MSC Adams) software, the operation of the loader was simulated according to the specified simulation conditions determined by different models of the manipulation tasks of the loader. MSC Adams software is used for dynamic analysis of mechanical systems. It is particularly suitable for dynamic simulation of mobile systems with mechanisms of different configurations. It is based on the second kind of Lagrangian equations [2].

Models of manipulation tasks

It has already been said that loaders of all sizes have found application in numerous economic branches performing different functions with different tools and manipulation tasks.
For the numerical simulation of the loader, work technology models were developed for the primary function of the loader - intermittent (cyclic) material transport with a bucket-shaped tool.
Work technology models are determined by the operation parameters of the manipulation task of the cyclic work of the loader. The basics of operation of the cyclic manipulation task of the loader-welder are: loading, transfer and unloading of materials.

Research [3][4] related to the efficiency of loader work shows that the basic operations of the manipulation task are performed in different ways. According to the results of the conducted research, the method of carrying out the loading operation depends, among other things, on the type of material, working conditions (whether the material is in an unlimited or limited space) and the operator of the machine. The material transfer operation depends significantly on the relative position of the loading and unloading sites. However, for the planning of works with more voluminous material in an unlimited area of the loading point and a certain position of the material unloading point, the paths of the material transfer operation have the shape of the latin letter *V* or *Y*. Typical *V* and *Y* paths of the material transfer form connected sections of the movement path of the loader back with full with the bucket from the point of loading and part of the forward movement path of the loader with a full bucket towards the place of material unloading. The unloading operation is usually carried out in a special transport place or a place with limited or unlimited space.
Examples of numerical loader simulation are given for three manipulation tasks with different loading methods, moving on a flat surface.

- In the first (I) method of materials loading (Fig. 2a) the buscket is lowered - on the surface, by movement of the loader, bucket horizontally penetrates the materials. At the end of movement of the machine, bucket is loading by rotation around the joint O4 on the top of the arm, until the it exit from the material massif.
- Second method (II) (Fig. 2b) of bucket penetration, is realized with two shorter operations of the first method, but on two different height in the material.
- Third method (III) with the arched trajectory (Fig. 2c) of bucket pentration is achieved with a simultaneously movement of loaders, arm lifting and bucket rotatation.

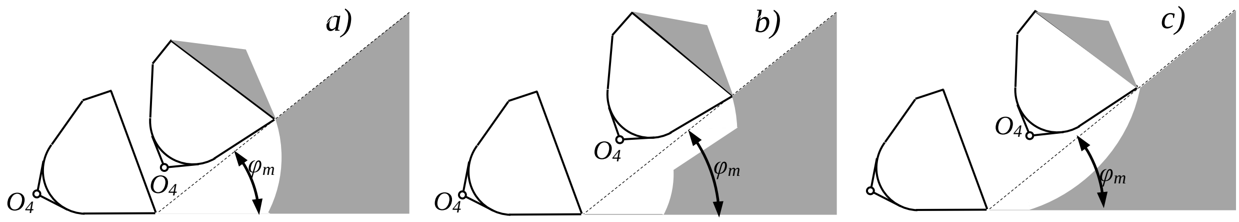


Fig.2. Material loading methods

RESULTS OF SIMULATION

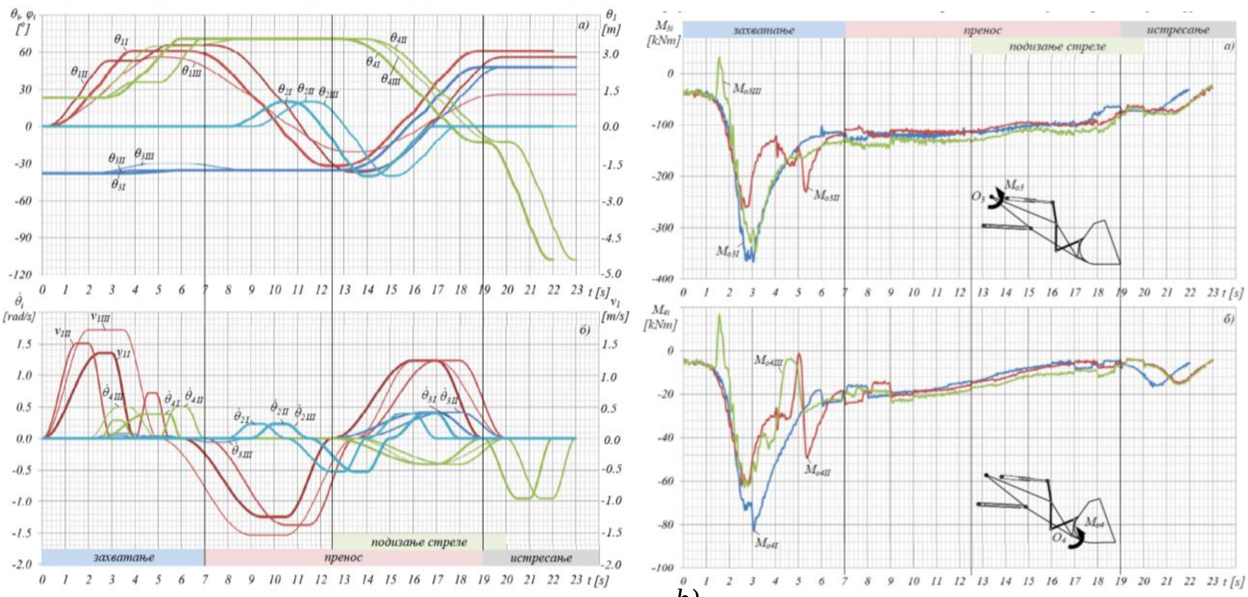
According to the defined general mathematical model of the kinematic chain and manipulation tasks, using MSC Adams and EDEM software [2], the operation of the loader with mass *m=15100 kg* and bucket volume $V=2.7\ m^3$ was simulated. The required geometric and dynamic parameters of the members of the kinematic chain of the simulated loader variant were determined according to the developed *3D* model of the loader that corresponds to the physical model of the *WA320* loader manufactured by Komatsu.

With the developed procedure of dynamic simulation of the loader, research was carried out with the aim of determining the importance and size of kinematic, dynamic and energy parameters of individual operations of the manipulation task of the loader required for the synthesis of the drive mechanisms of the manipulator

In the case of manipulation tasks with the first (I), second (II) and third (III) methods of material loading, during transfer and unloading operations, changes in the position and movement of the members of the kinematic chain of the loader are similar, only they are shifted in time due to the different duration of individual loading operations.

The transfer operation begins (*t=6 s*) with the straight-line movement of the support-movement mechanism L_1-L_2 back, which continues (*t=8 s*) with maneuvering - the curvilinear movement back by turning the support-movement members L_1-L_2, with angular velocity, first in one then in the opposite direction until the backward movement stops (*t=12,5 s*). During curvilinear movement forward, the rotation of the members of the supporting-moving mechanism continues until their straightening ($\theta_2=0$) (*t=17.5 s*), when the straight forward movement begins, lifting the arm L_3 and moving the bucket L_4 without spilling material up to the height of unloading everything until the stop of forward movement (*t=19 s*), when the unloading operation begins by turning only bucket L_4.

Based on the parameters of the kinematic chain of the mathematical model of the loader and the developed models of manipulation task of movement kinematics using the *MSC Adams* software, load moments M_{o3} and M_{o4} (Fig. 3a, b) of the arm and bucket drive mechanisms of the loader manipulator were determined according to equation 3. The load moment M_{o3} of the drive mechanism of the arm L_3 acts around the O_3z_3 axis of the pivot joint O_3, which connects the arm to the first member of the L_2 support-moving mechanism. The load moment M_{o4} of the driving mechanism of the bucket L_4 acts around the axis O_4z_4 of the pivot joint O_4 by which the bucket is attached to the tip of the boom L_3.



a) *b)*

Fig.3. Simulation results: a) angular velocities of the members of the kinematic chain of the loader b) load moments of the drive mechanisms: arm M_{o3}, b) buckets M_{o4} during the first (I), second (II) and third (III) methods of the material loading

During manipulation tasks, the load moments of the mechanism are the highest during loading operations (*t=0-8 s*). The nature of their change depends on the way the material is loaded ie. on the forces and moments of loading resistance that occur.

The greatest load moments are at the first (*I*) method of loading because, in the linear path of bucket penetration, the possible higher amount of material than in the second stepwise and third (III) arc method of loading.
At material transfer operations (*t=7-20 s*), the load moments of mechanisms are slightly different because gravitational forces that afect mechanisms are not the same due to the volume of materials in the bucket at different ways of loading. It is characterable that when the material are transfer (*t=7-20 s*) load moment Mo4 has small values because the bucket is in transfer position when the loaded material, as a primary load of the mechanism, has a direction close to the axis of the joint O_4 At that time, the bucket with the loaded material is almost balanced compared to the joint O_4 and the bucket mechanism is minimally loaded. In the initial phase of the unloading operation (*t=19-22 s*), the bucket is opening and the direction of the resulting bucket force and materials are moving away from the axis of the joint O_4 with the increase of the torque of the bucket mechanism.

Determination of energy parameters

By numerical simulation of the loader also it is determined the required power (Fig. 4) of the drive mechanisms by equation:

$$N_e = \dot{\theta}_i \cdot M_{oi} \qquad \forall \quad i = 3,4 \tag{5}$$

where: $\dot{\theta}_i$ - angular velocity of kinematic chain members, M_{oi} – load moments of arm and bucket mechanisms.

Required power can have a positive or negative value during manipulation tasks, for three differente loding methods. Positive power values represent the required power to drive the mechanisms, and negative values represent the available potential power that can be recovered by hybrid drive systems [2]. The results of the analysis show that the arm mechanism needs the most power during the transfer operation when the arm with a full bucket is lifted from the transport to the unloading position (*t=12.5-19 s*). The maximum power of the bucket mechanism is required during the operation of loading the material. The power for recuperation occurs (*t=6-9 s*) when lowering the arrow with a full bucket from the position after the loding operation to the transport position of the bucket and when the bucket is emptying (*t=19-22 s*).

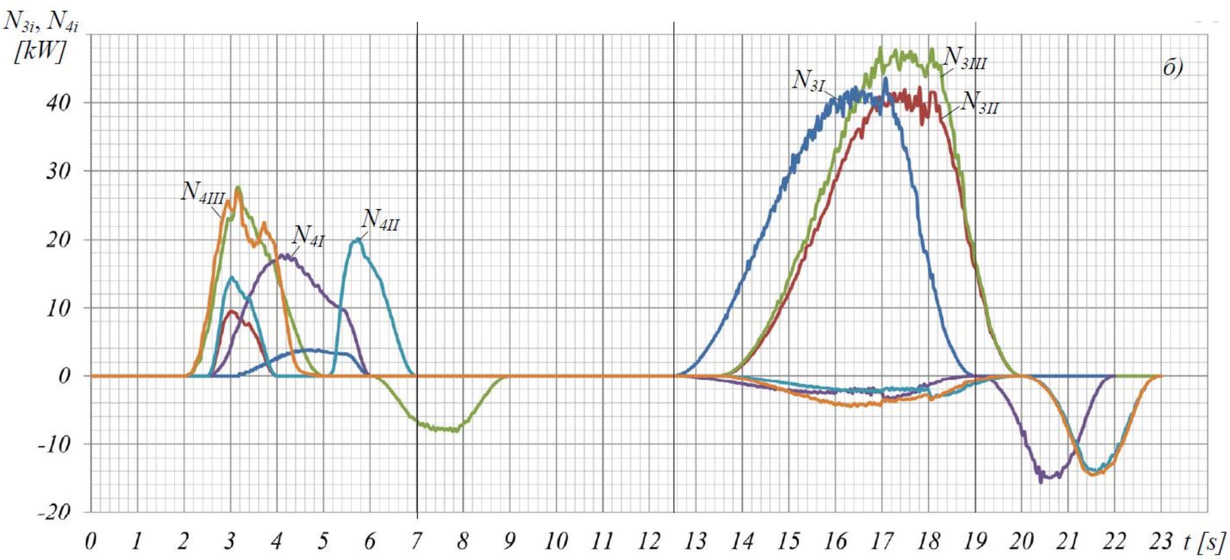


Fig.4. Required power of mechanisms at first (I), second (II) and third (III) mode of material loading

CONCLUSION

The paper presents the results of the numerical analysis of loader's working cycle which shows that in the material unloading phases of manipulation tasks of loaders considerable inertial and gravitational energies occur that can be recovered and returned to the drive system of machines and increase their energy efficiency. For the numerical analysis of the loader's working cycle, general mathematical models of loader kinematic chain and mathematical models of loader manipulation tasks were defined that can be used for mechanisms optimazation that can combine with energy recovery have effects in energy efficiency

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CONCEPTS FOR MUNICIPAL ENERGY COMMUNITIES IN AUSTRIA

Momir Tabakovic[1], Mihajlo Keseric[1]
[1]University of Applied Sciences Technikum Wien, Höchstädtplatz 6, 1200 Wien
e-mail: momir.tabakovic@technikum-wien.at

Abstract: This paper deals with the economic efficiency of energy communities. Due to the new legislation in Austria, it is now possible to sell the generated energy not only to the energy supplier, but also to persons who are on the same grid level as oneself. As this legislation is quite new and only a few pilot projects have been implemented. The aim of this paper is to carry out an economic analysis of an energy community in a city in upper Austria with and without a biogas plant, respectively with different stages of expansion. Since the City is supplied by two different transformers, the municipality cannot be merged into one energy community and has been divided into energy community A and B.
Key words: energy communities, renewable energy, scenarios

INTRODUCTION

Energy communities represent an innovative concept for the Austrian energy economy. The inhabitants of a community or city are enabled to produce, store, and share energy. There is a close interaction between the consumption, production, storage, and sale of energy across property boundaries [1]. Energy communities enable economic, ecological, and social community benefits for the end users [2]. In order to accelerate an energy transition and to be able to increase the self-consumption, two energy communities are founded in the Upper Austrian City, with 7,959 inhabitants. In order to initiate the project in this city, a company has so far installed seven PV systems. These comprise a total of 655.65 kWp, a total storage capacity of 137 kWh with an output power of 10 kW, which each battery has. Furthermore, the upper Austrian City will now also be supported by this company to establish two energy communities in order to achieve economic and ecological advantages. For the implementation of the project, a detailed actual situation analysis and simulation is required, which is presented in this paper. The goal is to promote the expansion of renewable energies through the two newly founded energy communities in order to reduce the import of fossil energy sources and to enable a higher added value locally through less expenditure in this sector. In this way, a major contribution can also be made ecologically through short transmission distances between producers and end consumers, which will be reflected in an improvement of the carbon footprint in the long term [3]. This type of innovative use of renewable energies can thus achieve both economic and ecological successes, which are to be determined and analysed in detail within the framework of this paper in order to initiate the implementation of the energy community.

MATERIAL AND METHODS

The procedure for this project is divided into several sub-steps. The first step is to research the literature on energy communities in general. The main aim here is to retrieve the current state of the art, to read up on projects that have already been successfully implemented in order to obtain a better reference for one's own work, and to meet the requirements for energy communities. As a basis for the creation of a model, load and generation profiles have already been made available for analysis and further use by the company. These are used to build the model and then to simulate it with the help of the Python programme. The data is then evaluated after the simulation. This should provide information about the economic viability of the individual scenarios examined, so that at the end of the project work a recommendation can be made for or against the implementation of an energy community in the city.

Steps towards the establishment of a renewable energy community in Austria

Above all, the legal principles set out in Part 6 of the Renewable Energy Sources Act and in ElWOG § 16c must be observed. Each member is obliged to comply with these legal principles at all times [4]. The Renewable Energy Directive (RED II) and the Electricity Market Directive (EMD) also play an important role in the area of energy communities.

Once the planning steps have been completed, the contracts with the individual members can be drawn up. It is also important to note that a legal entity and an association or cooperative must be established. With the establishment of the corporate form, the community becomes capable of acting and can make use of services. The legal entity is needed in order to be able to conclude contracts with the grid operator. Registration as a market participant is also necessary in order to receive the market partner ID and to be able to conclude the contract with the grid operator. For the installation of a generation system, the PV system must be installed and connected to the main line of the building. A smart meter or load profile meter must be installed at each consumer in order to be able to measure the electricity consumption of the members and the electricity production of the PV system. The grid operator and energy supplier must be informed about the completion of the installation in order to generate the connection of the PV system to the electricity grid. The exact steps for establishing an EEG can also be found in Fig. 1 [5].

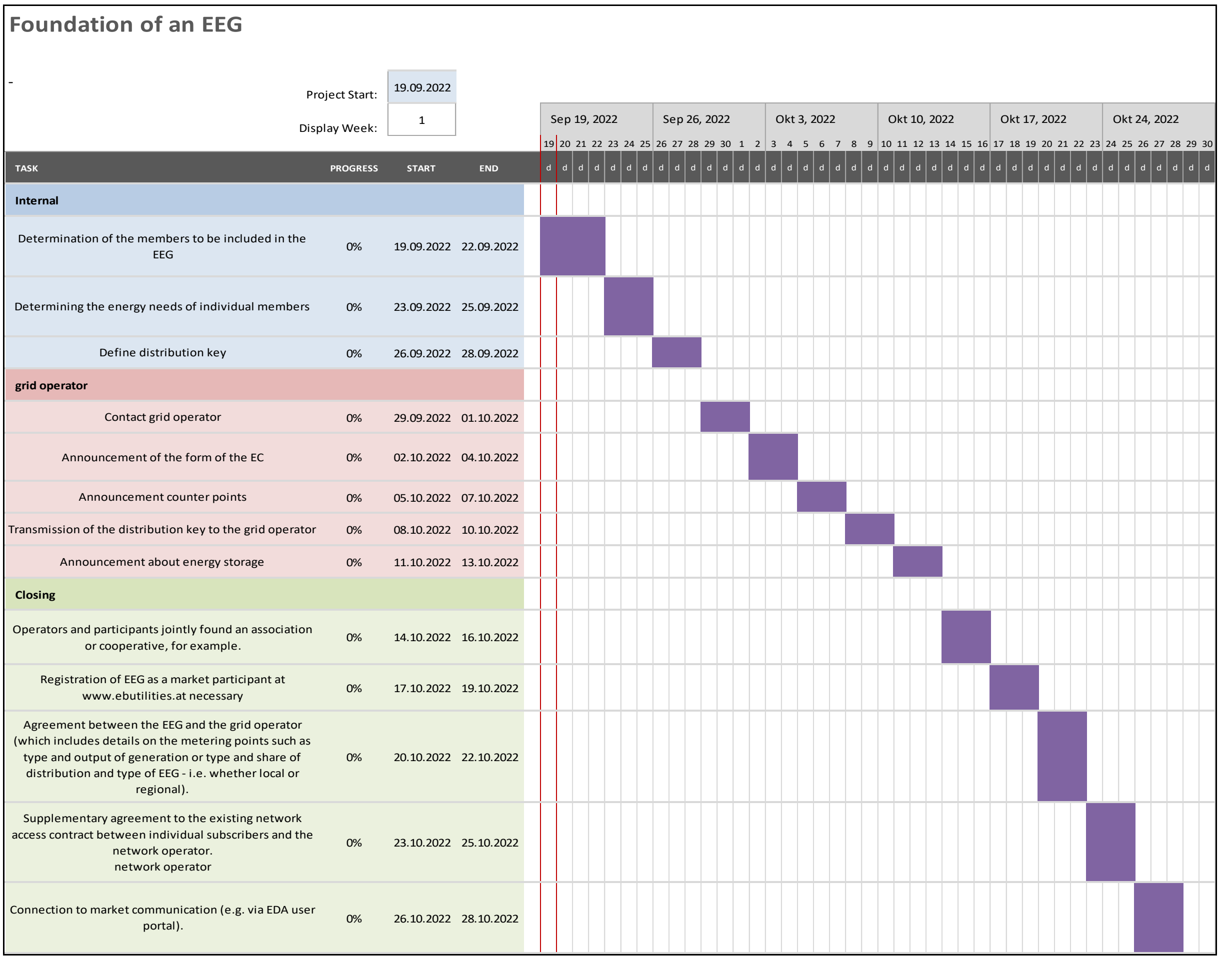

Fig. 1. Gant chart on the establishment of an EC [5]

Simulation

The simulation of the energy community is to be done in Python. Mainly measured data of energy consumption of the participants will be used in order to reflect the effects of the energy community as realistically as possible. These measurements were carried out in the City from April 2021 to April 2022. Due to some measurement errors and failures, the data is partly incomplete. However, since the annual energy consumption is known, the data was processed and supplemented so that it could be used for the simulation. If no measured data was available, standard load profiles were used for the simulation [6]. Since measurements were not taken at every building in the city, some load profiles were not available at all. To counteract this, the same load profile was used for buildings that have a similar load profile. This was then scaled to the actual annual energy consumption of the consumer.

In a first step, the consumers' data is loaded into the program. This makes it possible to work with these load profiles. Since some of the participants are not only consumers but also prosumers, a photovoltaic generation profile is also needed. This would be measured for a 1 kWp system. In order to be able to use it for the simulation, it is also scaled to the respective system size of the participants.

Once the generation and consumption profiles are known, they can be offset. Through this offsetting, the energy demand and the energy return of all buildings are known. Since some of the buildings have energy storage, these must also be taken into account in this simulation. Prioritization plays an important role for these buildings because an order must be defined where the energy is to flow to and whether the storage unit is allowed to release energy to the community or not. In the case of this simulation, it is handled as follows: The energy generated by the photovoltaics is to be used mainly in the building and only when the energy storage is full and the energy demand is so low that the photovoltaics can cover it completely, the energy is to be made available to the participants of the energy community. Furthermore, sharing the energy storage is not planned. Since it is now known how much energy each participant needs and how much the prosumers supply, this data is used to dynamically share the prosumers' surplus energy. This means that the participants who currently need energy can buy it from the energy community. The sharing of energy in the event of a shortage of surplus energy as follows: The larger the amount of energy required by the individual consumers, the more entitlement they have to the surplus energy. This means that a consumer who has a demand of 10 kWh receives more energy than one with a demand of 5 kWh. In the opposite case, i.e., if there is a surplus of energy, each participant may also contribute a certain part of his/her energy. The participant who produces more energy may also contribute more. The energy flows that have now been determined must also be priced. For this purpose, the calculated data is exported by Python into CSV files. These files are then processed in excel and the respective profit of the entire energy community is calculated with the help of these files. Furthermore, the savings potential for the individual participants is also determined with the help of the data. This is calculated for the following cases: with and without photovoltaics (for the prosumers), and with and without the energy community (for all participants). Finally, the data is used to create diagrams in order to present the results clearly.

RESULTS AND DISCUSSION

In this chapter, the results of the simulations are presented. The economic efficiency calculation here only refers to the ongoing operation, which means that no investment costs are taken into account. In addition, the following energy prices were assumed.

- Feeding into the public grid/sale to the energy supplier = 5 c/kWh
- Sale of energy to the energy community = 15 c/kWh
- Purchase of energy from the energy community = 17 c/kWh
- Purchase of energy from the grid = 30 c/kWh

Three scenarios were simulated. The first scenario shows the partial expansion of Energy Community A. The second shows how the economics would change if all the planned energy concepts were implemented. The third and last one looks at these two scenarios and adds a biogas plant to them. Thus, four tables of results will be presented.

Table 1. Participants of the Energy Community A

Energy Community A		
Nr.	**Name/Type**	**Annual electricity consumption (kWh)**
1	Drucksteigerungsanlage	2 794.00
2	NEB.1 / Tischlerei	801.00
3	Heizungs Basisanlage	10 335.00
4	Resort	54 401.00
5	Park & Ride Anlage	752.00
6	Wasserversorgung	14 232.00
7	Altstoffsammelzentrum	8 391.00
8	öffentliches WC	16 346.00
9	Pumpe Wasserentsäuerung	160.00
10	Pumpe Pumpenhaus/ Wasserwe	290 400.00
11	DSA 1 / Drucksteigerungsanlage	9 497.00
12	Drucksteigerungsanlage	9 949.00
13	Kanal-Pumpwerk NORD	984.00
14	Beleuchtungs Kreisverkehr	2 963.00

Table 1 shows the participants of Energy Community A. It should be mentioned that the "Resort" consists of more than one building but was combined into one load profile. Furthermore, the pressure boosting (Drucksteigerungsanlage), heating(Heizungs Basisanlage) and pumping systems (Pumpe and Pumpwerk) were also combined into one load profile. The same applies to the entire street lighting (Beleuchtung) within Energy Community A.

Table 2. PV systems in the first and second scenario

Transformer station	Name	PV [kWp]	Storage capacity [kWh]	discarge power [kW]
EGR00060	Neue Mittelschule	118.4	19.2	10
EGR00060	Resort	258.63	38	10
EGR00060	Altstoffsammelzentrum	29.6	29	10
EGR00060	Badeanlage	50.3	0	-
EGR00060	Forsthaus	7.8	0	-
EGR00060	Öffentliches WC	37.7	29	10
	Summe	502.43	115.2	

Table 2 shows the participants who are equipped with a PV system in the first scenario. These are not marked in colour. These two prosumers both have a capacity of more than 100 kW, which should benefit the energy community, as energy can thus also be fed into it and used by the participants and not used by the prosumers to cover their own consumption. It should also be mentioned that the batteries are not made available to the energy community.

The prosumers that are added to the existing prosumers are shown in green. Although they do not have as much power as the first two prosumers, they also do not consume as much energy, which is why they represent an enrichment for the energy community.

Table 3. Overview of the energy flows of the first scenario for the consumers in the Energy Community A

Location	EEG_Purchase [kWh]	Grid_Purchase [kWh]	EEG_buy [kWh]	Feed-in_EEG [kWh]	Without EEG and PV [kWh]	Without EEG with PV [kWh]	With EEG and PV [kWh]	Savings [€]
Resort	-	23 242.22	139 350.41	111 048.95	15 905.54	- 5 547.30	- 19 482.34	35 387.88
Forsthaus	1 011.12	2 161.14		-	951.68	-	820.23	131.45
Badeanlage	78 296.18	207 645.14		-	85 782.40	-	75 603.89	10 178.50
öffentliches WC	3 879.92	12 050.66		-	4 779.17	-	4 274.78	504.39
Neue Mittelschule	996.69	39 903.71	40 793.81	16 383.20	25 399.57	8 060.53	5 202.32	20 197.25
Altstoffsammelzentrum	2 064.31	6 061.97			2 437.88	-	2 169.52	268.36
Straßenbeleuchtung	9 027.47	108 277.95	-	-	35 191.63	-	34 018.06	1 173.57
Wasserwerk	72 475.24	218 160.38	-	-	87 190.68	-	77 768.90	9 421.78
Pumpen DSA	5 585.84	16 814.16	-	-	6 720.00	-	5 993.84	726.16
Tischlerei	255.36	545.64	-	-	240.30	-	207.10	33.20
Wasserversorgung	3 549.01	10 682.99	-	-	4 269.60	-	3 808.23	461.37
Pumpenwerk	139.26	419.19	-	-	167.54	-	149.43	18.10
Kindergarten	2 863.83	8 051.96	-	-	3 274.74	-	2 902.44	372.30

Table 3 shows the results of the first scenario. The titles that can be found in this table describe the following energy flows:

- EEG_Purchase = Amount of energy that I bought from the energy community.

- Grid_Purchase = Amount of energy I have purchased from the public grid / from the energy supplier

- EEG_buy = amount of energy that the energy community has bought from the prosumers

- Feed-in_EEG = Amount of energy that was fed into the public grid / sold to the energy provider

- Without EEG and PV = energy costs, without PV systems and without energy community

- Without EEG with PV = energy costs of the prosumers who own a PV system in this scenario.

- With EEG and PV = energy costs of all participants if they participate in the energy community

- Savings = difference between "Without EEG and PV" and "With EEG and PV" = the savings I can achieve by participating in the Energy Community.

These titles were used for all scenarios and mean the same in each.

In Table 3, we will see that an amount of energy of 180 144.22 kWh was traded in the Energy Community. For the operator of this energy community this means a profit of 3 602.88 €. The participants who benefited most from the participation were, the Resort with a saving of 35 387,88 €, the “Neue Mittelschule” with a saving of 20 197,25 € and the “Badeanlage” with a saving of 10 178,50 €. The participant with the lowest saving was the pumping station with a saving of 18.10 €.

Table 4. Overview of the energy flows of the second scenario for the consumers in the Energy Community A

Location	EEG_Purchase [kWh]	Grid_Purchase [kWh]	EEG_buy [kWh]	Feed-in_EEG [kWh]	Without EEG with PV [kWh]	With EEG and PV [kWh]	Savings [€]
Resort	0.02	17 316.73	92 789.98	151 533.46	15 905.54	- 16 300.15	32 205.68
Forsthaus	13.90	1 581.30	2 638.40	4 253.54	951.68	- 131.68	1 083.36
Badeanlage	42 752.09	197 716.92	1 676.02	7 465.81	85 782.40	65 958.24	19 824.16
öffentliches WC	0.05	3 073.45	8 292.28	19 116.42	4 779.17	- 1 277.62	6 056.79
Neue Mittelschule	898.60	40 055.20	26 530.52	57 720.23	25 399.57	5 303.73	20 095.84
Altstoffsammelzentrum	0.02	1 259.80	8 535.25	16 383.20	2 437.88	- 1 721.50	4 159.39
Straßenbeleuchtung	8 826.46	108 478.97	-	-	35 191.63	34 044.19	1 147.44
Wasserwerk	75 134.91	215 500.70	-	-	87 190.68	77 423.15	9 767.54
Pumpen DSA	5 790.83	16 609.17	-	-	6 720.00	5 967.19	752.81
Tischlerei	264.24	536.76	-	-	240.30	205.95	34.35
Wasserversorgung	3 679.25	10 552.75	-	-	4 269.60	3 791.30	478.30
Pumpenwerk	144.37	414.08	-	-	167.54	148.77	18.77
Kindergarten	2 957.70	7 958.10	-	-	3 274.74	2 890.24	384.50

Table 4 shows the results of the second scenario. Looking at Table 4, one will see that an amount of energy of 140 462.45 kWh was traded in the energy community. For the operator of this energy community this means a profit of 2 809,25 €. The participants who benefited the most from the participation were, the Resort with a saving of 32 205,68 €, the Neue Mittelschule with a saving of 20 095,84 € and the Badeanlage with a saving of 19 824,16 €. The participant with the lowest saving was the pumping station. This one was able to save € 18.77 by participating. Compared to the first scenario, the savings as well as the traded quantity inside the energy community have decreased. This is due to the expansion of PV capacities. The consumers, who previously had to buy their energy for either 15 or 30 c/kWh, can generate their own energy through the PV systems and do not have to pay for it.

Table 5. Overview of the energy flows of the third scenario for the consumers in Energy Community A based on the first scenario

Location	EEG_Purchase [kWh]	Grid_Purchase [kWh]	EEG_buy [kWh]	Feed-in_EEG [kWh]	Without EEG and PV [kWh]	Without EEG with PV [kWh]	With EEG and PV [kWh]	Savings [€]
Resort	17 617.76	5 624.45	57 310.71	193 088.65	15 905.54	- 5 547.30	- 13 568.68	29 474.22
Forsthaus	2 584.76	587.50			951.68	-	615.66	336.02
Badeanlage	231 116.21	54 825.12			85 782.40	-	55 737.29	30 045.11
öffentliches WC	12 760.10	3 170.48			4 779.17	-	3 120.36	1 658.81
Neue Mittelschule	30 992.62	9 907.77	17 194.58	66 997.23	25 399.57	8 060.53	2 312.03	23 087.54
Altstoffsammelzentrum	6 588.32	1 537.96			2 437.88	-	1 581.40	856.48
Straßenbeleuchtung	87 058.57	30 246.85			35 191.63	-	23 874.01	11 317.61
Wasserwerk	230 661.70	59 973.92			87 190.68	-	57 204.66	29 986.02
Pumpen DSA	17 777.66	4 622.34			6 720.00	-	4 408.90	2 311.10
Tischlerei	652.63	148.37			240.30	-	155.46	84.84
Wasserversorgung	11 295.17	2 936.83			4 269.60	-	2 801.23	1 468.37
Pumpenwerk	443.21	115.24			167.54	-	109.92	57.62
Kindergarten	9 038.38	1 877.41			3 274.74	-	2 099.75	1 174.99
Biogas power plant			584 081.81				87 612.27	87 612.27

Table 5 shows the energy flows of the third scenario. As already mentioned, this builds on the first scenario and adds a biogas power plant to it, which has an electrical output of 250 kW. Since no generation profile of a gas-fired power plant could be found, this was created by assumption. It was decided that this power plant should be used to cover the base load. This means that it will run constantly with its full listing. It should also be mentioned that the power plant is shut down once a month for maintenance and does not feed any energy into the energy community at this time. In the summer months, the power plant is shut down for major maintenance. If we now look at the results in Table 5, we see that an amount of energy of 658 587.09 kWh was traded in the energy community. For the operator of this energy community this means a profit of 13 171.74 €. This is more than twice as high as that of the two previous scenarios. The same applies to the amount of energy traded, which more than tripled compared to the two previous scenarios. There were also changes in the savings due to the gas power plant. The savings of the Resort, for example, are smaller than in the two previous scenarios, they now amount to 29 474.22 €. It is lower, but still one of the biggest in this scenario. If we compare this with the bathing facility, we see that the savings of this participant have increased by 10 000 and 20 000 € respectively. It now amounts to 30,045.11 €. Thus, the bathing facility has the largest saving in this scenario. Behind it is the waterworks with a saving of € 29 983.02. If we look at the last row in Table 5, we see the results for the gas power plant. This sold more energy to the energy community than both prosumers together. Furthermore, the gas power plant does not purchase any energy from the energy community, but only sells its own energy to it. For this reason, the gas-fired power plant has no "savings", but a profit, which it makes through the energy community. This amounts to € 87,612.27 in this scenario.

Table 6. Overview of the energy flows of the third scenario for the consumers in Energy Community A based on the second scenario

Location	EEG_Purchase [kWh]	Grid_Purchase [kWh]	EEG_buy [kWh]	Feed-in_EEG [kWh]	Without EEG and PV [kWh]	Without EEG with PV [kWh]	With EEG and PV [kWh]	Savings [€]
Resort	13 457.56	3 859.19	38 161.22	206 162.21	15 905.54	- 7 021.15	- 12 586.75	28 492.29
Forsthaus	1 183.52	411.68	1 075.13	5 816.81	951.68	133.96	- 127.41	1 079.08
Badeanlage	188 825.39	51 643.62	748.73	8 393.10	85 782.40	71 683.61	47 061.44	38 720.96
öffentliches WC	2 613.10	460.40	3 596.68	23 812.02	4 779.17	- 448.38	- 1 147.76	5 926.93
Neue Mittelschule	31 006.60	9 947.19	11 207.52	73 043.24	25 399.57	8 073.60	2 921.99	22 477.58
Altstoffsammelzentrum	1 066.37	193.45	3 684.38	21 234.06	2 437.88	- 867.97	- 1 375.04	3 812.93
Straßenbeleuchtung	86 970.06	30 335.36			35 191.63	-	23 885.52	11 306.11
Wasserwerk	231 615.80	59 019.82			87 190.68	-	57 080.63	30 110.05
Pumpen DSA	17 851.20	4 548.80			6 720.00	-	4 399.34	2 320.66
Tischlerei	655.69	145.31			240.30	-	155.06	85.24
Wasserversorgung	11 341.89	2 890.11			4 269.60	-	2 795.15	1 474.45
Pumpenwerk	445.05	113.41			167.54	-	109.68	57.86
Kindergarten	9 068.33	1 847.47			3 274.74	-	2 095.86	1 178.88
Biogas power plant			537 626.90		-	-	80 644.03	80 644.03

Table 6 shows the energy flows of the third scenario. This is now based on the second scenario. As in the previous scenario, which can be found in Table 5, the same generation profile was used for the biogas plant in order to be able to compare the results. In this scenario, an amount of energy of 596 100.55 kWh was traded within the energy community. This results in a profit for the operator of 11 922.01 €. Both values are smaller than those of the other gas scenario, this is due to the fact that the PV generation capacities were expanded and now less energy has to be purchased from the energy community.

Looking at the savings in Table 6, it can be seen that the bathing plant has the largest savings. In this case, it amounts to € 38 720.96. In this case, the bathing facility has the greatest savings compared to the other scenarios. Behind it is the waterworks with a saving of 30 110.05 €.

In this scenario, the biogas plant has sold more energy to the energy community than all prosumers together. However, the amount of energy has decreased compared to the previous case. Another effect of the expanded PV capacities. Due to the reduction or coverage of the energy demand by other generation plants within the energy community, the profit of the biogas plant also decreased to 80 644.03 €.

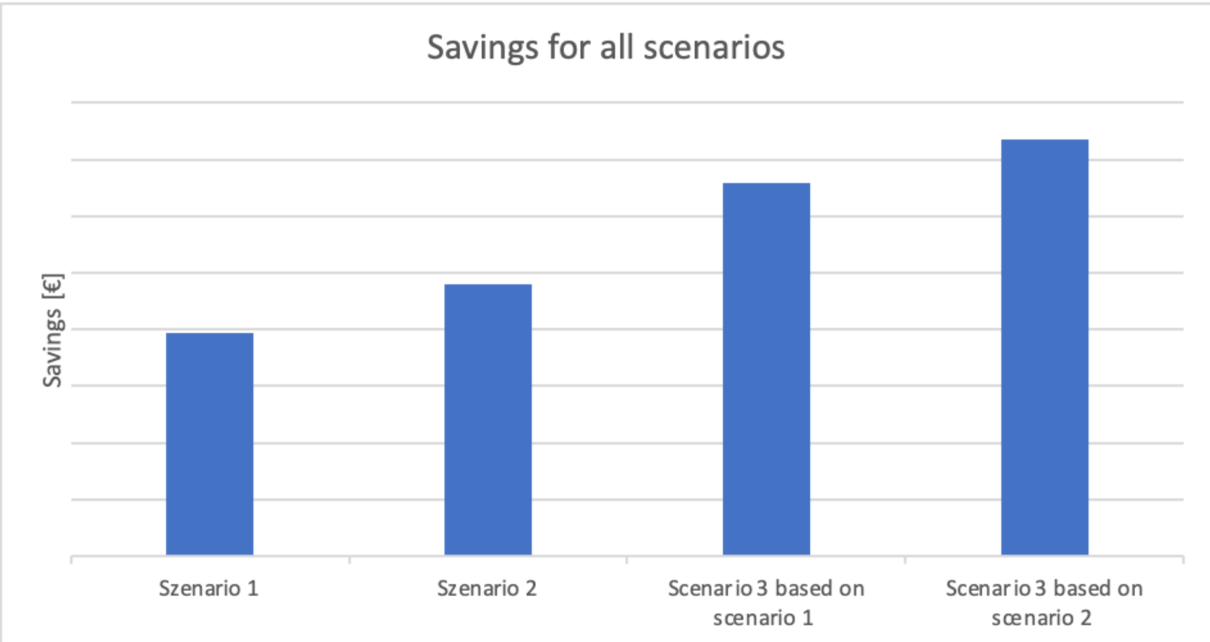

Fig. 2. Savings per scenario

Figure 1 shows the savings per scenario. It can be seen that the third scenario, which is based on the second, offers the greatest savings. This amounts to € 147 043.02. This saving only applies to the participants, the profit of the gas power plant was not taken into account here, as it is not a saving but a profit. The third scenario, which is based on the first, also has a greater saving than the first two scenarios. The savings of this scenario amount to 131 858.71 €. Due to the expansion of PV capacities, an increase in savings was also achieved. These increased from 78 874.31 € to 96 008.93 € from the first to the second scenario.
These results show that the biogas plant has a positive effect on the energy community. By integrating it, the savings of the individual participants could be increased.

CONCLUSION

Through the integration of the biogas plant, the economic efficiency of the individual participants was improved. The biogas plant provided most of the energy that the participants needed. This meant that no energy had to be bought from the energy supplier for 30 c/kWh but was purchased via the energy community for 17 c/kWh. For the operator of the biogas plant and the operator of the energy community, the third scenario with in the first expansion stage would be best, because there they would receive the most money. For the participants, the third scenario with in the second expansion stage would be best, because that is where they would save the most.
Not only did the biogas plant improve the economic efficiency, but this could also be improved by expanding the PV capacities. By expanding this, less energy had to be bought from the energy supplier, which means that more money can be saved.
In conclusion, it can be said that the biogas power plant and the expansion of the PV capacities have a positive effect on the profitability of Energy Community A in the City. However, the effect of the biogas plant is greater or leads to greater savings.

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ANALYSIS OF INSPECTION PLAN OF AIR COOLED HEAT EXCHANGER FOR NEEDS OF MAINTANCE AND SAFETY OF OIL&GAS PLANTS

Marko Jaric[1], Sanja Petronic[2], Nikola Budimir[1], Suzana Polic[3], Katarina Colic[1]
[1] Innovation Centre of the Faculty of Mechanical Engineering, University of Belgrade, Serbia
[2] The Academy of applied technical studies Belgrade, Serbia
[3] National Museum, Belgrade, Serbia
nbudimir81@gmail.com, nbudimir@mas.bg.ac.rs

Abstract: The paper shows preparation of inspection plan for air cooled heat exchanger in refinery. The importance of proper inspection, traceable prepared plan of inspection is discussed. The inspection of heat exchanger, according to the presented plan, includes visual testing - internal and external, ultrasound testing and liquid penetrate testing. The inspection plan is essential for maintenance the pressure equipment in refineries and is performed according to API 572 and API 510. The inspection of air cooled heat exchanger shows satisfactorily results.
Key words: heat exchanger, visual testing, inspection plan, API 572, API STD 510

1. INTRODUCTION

An air cooler is a unit of pressure equipment containing an open bundle of tubes housed in a steel frame. The air cooler uses air as a working, cooling medium, which is circulated by a fan placed above or below the tube bank [7]. The design of the air cooler uses standards such as API 661[6] and API 660 [5], EN 13445 and covers minimum requirements for design, materials, manufacturing, inspection, testing and preparation for initial delivery. In-service inspection of air-cooled heat exchangers is similar to other pressure vessel inspections and is performed according to API STD 510 [1] or according to standard EN 13445 and the Ped directive. During the inspection plan, it is preferable to use API RP 572 [3], API RP 577 and/or API RP 571. The inspection is applied primarily to determine the physical condition of the pressure vessel, as well as the type of damage, the speed at which the damage progresses in order to maintain the safety of the cooler itself, but and the entire plant. It is necessary to document all data obtained from the inspection, as well as data on replacement parts, reparation, rehabilitation, in order to track the history and assessment of the risk-based inspection (RBI). Safety and maintenance of the entire facility are the primary reasons for carrying out periodic inspections, which identify damages and take further steps to eliminate them, and thus prevent incidents of a larger or smaller scale.
The paper is organized in three parts: the first part describes the importance and the aspects of inspection planning, the second part shows inspection plan made for the air-cooled heat exchanger in the upstream plant and the third part shows results of its inspection.

2. INSPECTION PLANS

Several criteria should be considered when developing an effective inspection plan. The primary goal of the plan is to organize inspections (and supporting activities) that enable the owner to assess the condition of the pressure vessel.
Care should be taken to ensure that the inspections provide the information required to perform any applicable analyses, in a timely fashion, without imposing detrimental effects on the equipment
The frequency with which a pressure vessel should be inspected depends on several factors, including the rate of damage, the corresponding remaining useful life, and the risk of failure.
Maximum internal or external inspection intervals should be in accordance with API 510. Scheduling of shutdowns for maintenance or inspection is usually arranged through the collaboration of process, maintenance, and inspection groups.
The actual time for inspection will usually be determined through the collaboration of process, mechanical, and inspection groups, or by the mandate of a jurisdiction.

3. INSPECTION BOOK OF AIR COOLED HEAT EXCHANGER

This recommended procedure, standards, codes, and practices covers the inspection of pressure vessels. They include a description and the reason for inspection, cause of deterioration, frequency and methods of inspection, records and reports.

3.1. Main standards and procedures

Standards and procedures used for heat exchanger's inspection planning are se following:
Internal Procedure for Plant Inspection Philosophy
Internal Procedure for Visual Inspection - General Principles
Internal Procedure for Magnetic Particles Inspection
Internal Procedure for Liquid Penetrant Test
Internal Procedure for Visual Inspection of Pressure Vessels
Internal Procedure for Ultrasonic Thickness Examination Procedure
Internal Procedure for Safety
Internal Procedure for Measuring Thickness by Manual Ultrasonic Pulse Echo Contact Method
Guideline for repairing - inspection and maintenance work book
API STD 510 Pressure Vessel Inspection Code for In-service Inspection, Rating, Repair, and Alteration
API RP 572 Inspection of Pressure Vessel (Towers, Drums, Reactors, Heat Exchangers, and Condensers)

3.2 Inspection plan for air cooled heat exchanger

The plan of inspection of air cooled heat exchanger is presented in Table 1. This plan is applicable only to this particular exchanger and is made according to the inspection history, the internal procedures of the refinery where it is located and the project documentation.

Table 1. Inspection plan of air cooled heat exchanger

	Reference/ document	Acceptance/ Criteria	Verify/ document	Inspection level		
				Req*	CLI	CA
1.0						
Review Document						
Drawing, Design/Cataloge & Datasheet	ASME Sec. VIII	ASME Sec. VIII	General Drawing & Datasheet	Yes	R	R
NDT Equip. Calibr.	ASME Sec. V	ASME Sec. V	Calibr. Cert.	Yes	R	R
Previous Inspection Record	API 510	API 510	Inspection Workbook	Yes	R	R
Corrosion & Failure Threat	API 510	API 510	Corrosion Assessm.	Yes	R	R
Advance NDT Procedure			NDT Procedure	No	A	R
Repair of Pressure Vessel			Repair Procedure	No	A	R
Safety Precaution			Work permit & Risk Asses.	Yes	A	R
Review Document			General Drawing & Datasheet	Yes	R	R
Drawing, Design/Cataloge &			Calibr. Cert.	Yes	R	R

Datasheet						
2.0						
Visual Inspection						
External	Internal Procedure	API 510	Visual Inspection Report	Yes	P	M/R
Internal	Internal Procedure	API 510	Visual Inspection Report	Yes	P	W
3.0						
Extended Non-Destructive Test						
Scanning Wall (shell, head)	Internal Procedure	ASME Sec. V	NDT Report	No	P & T	M/R
Wall Thickness Check (Localized Scan)		API 510	NDT Report	Yes	P & T	M/R
Hardness		ASME Sec. II	Hardness Report	No	P & T	M/R
MT or PT on selected W. joints	Internal Procedure	ASME Sec. V	NDT Report	Yes	P & T	M/R
Other Advance NDT (TOFD; Acoustic Emission PEC; CHIME; etc)	API 510	ASME Sec. V	NDT Report	No	W	W
4.0						
Calculation Check						
Corrosion Rate Calculation	API 510	API 510	Calculation Report	Yes	P	R
Remaining Life Calculation	API 510	API 510	Calculation Report	Yes	P	R
MAWP Calculation (if derated)	API 510	API 510	Calculation Report	No	P	R
5.0						
Hydrotest	Internal Procedure	ASME Sec. VIII	Hydrotest Report	No	P & T	W
6.0						
Completed Pressure Vessel Inspection Work Book Report				Yes	P	R

3.3 Corrosion threats

Service fluid is Raw Gas operating at temperature 134°C, while design temperature is 170°C. Operating pressure is 25.6 bar, and design pressure is 39 bar. There is no protective internal lining. General corrosion and pitting or localized corrosion may be found on the internal surface of the air cooler.

3.4 External visual inspection instruction

1.Before starting the inspection of a vessel, especially one in severe service, the inspector should determine the pressure, temperature, and service conditions under which the vessel has been operated

since the last inspection. The inspector should also be aware of equipment construction details including materials of construction, the presence of internal attachments, and weld details.
2. A careful visual inspection should be made for corroded or broken parts, cracks, the tightness of bolts, the condition of paint or galvanizing material, the wear of ladder rungs and stair treads, the security of handrails, and the condition of booring on platforms and walkways.
3. Foundations of vessel are from structural steel fireproofed with concrete. They should be inspected for deterioration such as cracking, settling and spalling.
4. The nuts on anchor bolts should be inspected to determine whether they are properly tightened.
5. If any settling of the vessel has occurred, nozzles attached to the vessel should be inspected for distortion and cracking distortion. If there is any evidence of distortion or cracks in the area around the nozzles, all weld joints in this area should be examined for cracks.
6. Grounding connections should be visually examined to verify that good electrical contact is maintained. These connections provide a path for the harmless discharge of lightning or static electricity into the ground. The continuity of all ground wires should be checked.
7. Auxiliary equipment, such as gauge connections, may be visually inspected while the unit is in service. Undue vibration of these parts should be noted.
8. Certain types of corrosion may be found on external surfaces of a vessel. Among these are atmospheric corrosion, hydrogen blistering... In humid areas and in areas where corrosive chemical vapors are present in the air, corrosion of external surfaces may be a problem.

3.5 Results of external visual inspection

External inspection was conducted on the air cooled heat exchanger. External inspection covers the condition of the external metal surfaces and its external components.
Visual inspection is performed in accordance to internal procedure. Results are as following:
Ladders, Stairways, Platforms, and Walkways were found in good condition.
Foundations, Anchor Bolt, concrete/steel supports and nozzles were found in good condition.
Grounding Connection were found visually in good condition in time of inspection. Measured value of grounding connection electrical resistance was 0.32 Ohm. These values are under the standard values and additional checking and analyze is recommended in the future.
Auxiliary Equipment and protective coating were found in good condition.
External Metal Surfaces / External Evidence of Corrosion External metal surfaces were found in good condition. Corrosion was not observed on them in time of inspection.
Figure 1 and Figure 2 present air cooled heat exchanger from front side and from the back side respectively.

Figure 1. Air cooled heat exchanger (view from the front side)

Figure 2. Air cooled heat exchanger (view form the back side)

3.6 Internal visual inspection instruction

1. Inspectors should understand the function of the vessel internals and each nozzle to assess findings. The internal inspection of vessel shall be made in accordance API RP 572.
2. All areas of the vessel should be inspected after removing of plugs at inlet and outlet chamber. Especially attention shall be carried out at inspection of tubes at connection to tube sheet. The borescope should be used for this activity.
3. Welded joints in inlet and outlet chamber of air cooler should be closely checked. The borescope should be used for this activity.
4. General corrosion and pitting or localized corrosion may be found on the internal surface at inlet and outlet chambers.

3.7 Results of internal visual inspection instruction

Internal visual inspection has been performed by industrial borescope according to standards API 570[2] and API 574 [4].
Internal surfaces and tubes were inspected with the borescope and they were found in good condition in time of inspection.
Interior of header (Figure 3) and tubes was found in good condition. Corrosion in them was not observed in time of inspection.
All inspected tubes were found in good condition in time of inspection. Corrosion in the tubes was not observed in time of inspection.

Figure 3. Interior of the header was found in good condition in time of inspection

3.8 Results of UT and PT

Liquid penetrant testing shows no cracks in air cooled heat exchanger (Figure 4).

The results of UT thicknesses measurements correspond to the design values so corrosion rate cannot be determinate. Hence remaining life is also undetermined. Table 2 presents design thickness of air cooled heat exchanger parts, and Figure 5 presents results of UT thickness measurements. UT thickness measurements confirmed no corrosion appeared.

No	Item	Material	Design thickness (mm)
1	Tube plug sheet	SA-240-316	22.00 mm
2	Top/Bottom plate	SA-240-316	12.00 mm
3	End plate	SA-240-316	12.00 mm

Table 2. Design thickness of air cooled heat exchanger parts

Figure 4. Results of PT testing of the weld joints

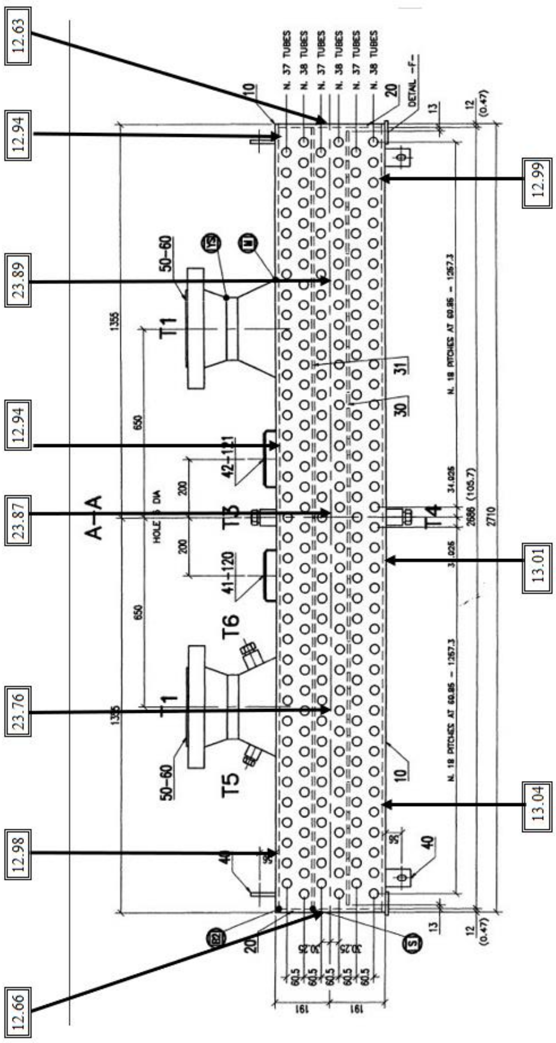

Figure 5. Results of UT thickness measurements

4. CONCLUSION

All of the essential sections/components of the air cooled heat exchanger are safe to operate until next scheduled inspection.
Next external inspection, internal inspection and ultrasonic thicknesses measurements at the same position should be performed within next five years.
All of the essential sections/components of vessel are safe to operate until next scheduled inspection.

REFERENCES

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[2]API 570 Piping inspection code;

[3] API 572 Inspection practice for ;ressure vessels

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[6] API 661 Petroleum, Petrochemical, and Natural Gas Industries Air-Cooled Heat Exchangers

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HERB DRYING AT DIFFERENT TEMPERATURES

Nina Đapić[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: nina.djapic@tfzr.rs

Abstract: This work represents an attempt to find out the influence of drying temperature on the water loss and the pigments chlorophyll *a* and *b* content changes during the drying process in *Petroselinum crispum*, Apiaceae leaves. The aim of the research was to evaluate the water loss and chlorophylls content in *P. crispum* leaves dried at different temperatures (40°C, 50°C and 60°C). The chlorophylls composition was measured by the spectrophotometric method. The analysis showed significant decrease in chlorophylls content with the increase of the drying temperature.
Key words: drying, herb, water loss

INTRODUCTION

Drying or dehydration is a technological operation that involves the removal of moisture for the purpose of obtaining a dry product. Dehydration is a complex physical process that simultaneously involves the transfer of heat and moisture. Drying of a complex system including herbal material refers to the removal of almost all moisture by evaporation or sublimation with the introduction of heat under controlled conditions. The goal of this operation is the preservation of herbal material and it is based on the principle of anabiosis or xeroanabiosis, where the activity of microorganisms is suppressed or limited by removing moisture. The processed herbal material can be used at a time when it is not available fresh in the form of a semi-finished product or a final product.

The advantage of dried herbal material compared to herbal material preserved by other methods is the reduction of mass and volume, which facilitates handling and use, with lower storage and transportation costs. However, during drying, undesirable changes occur in the dried herbal material: browning, loss or degradation of individual components and many other changes. The main goals of such an effort are to obtain the herbal material with a porous structure, good rehydration properties and with small changes in organoleptic and nutritional properties compared to the starting raw material.

Drying is a physical process that involves the transfer of energy and matter. The transfer of energy from the heat source to the drying herb material can be based on conduction and convection. In convection drying, heat transfer is direct using a heated air or gas medium, while in conduction drying, heat transfer is indirect *via* a metal surface. Convection drying with the use of heated air as a medium is most often used in drying herbs. In this drying method, the heat transfer depends on the properties of the heated air: temperature, humidity, flow speed and pressure. The drying of herbs can also be by solar-hot air drying, microwave-vacuum drying and hot air-low humidity drying [12].

In most cases, plant tissue is subjected to various processing methods before the actual drying is carried out in order to reduce the changes caused by the preparation of herbal material, the drying process and the changes that occur during their storage. The methods used to stop unwanted metabolic processes and improve drying kinetics of damaged plant tissues can be classified into two groups: chemical and non-chemical methods [7]. Undesirable changes that may occur during the process are: enzymatic and non-enzymatic browning, surface hardening with deposition of soluble ingredients, shrinking, loss of taste and smell.

A large number of processes are used: blanching, freezing, osmotic water removal, sulphurization, sulfating and immersion in ascorbic acid, citric acid, calcium chloride solutions in the pretreatment of herbal materials intended for drying.

Peeling and cutting causes significant changes in plant tissues, which are primarily manifested in increased respiration, ethylene production and various reactions of phenolic compounds. The color, texture and aroma of damaged plant tissues, among other things, are the result of the influence of the synthesis and polymerization of phenolic compounds [10].

The loss of sugar and other soluble substances during processing can affect the loss of aroma, which leads to a decrease in the quality of dried products [5].
The goal of preparing herbal materials is to improve the quality of the final product and to improve the kinetics of drying. One part of the pretreatment methods is aimed at general operations, while the other part is aimed at improving the dehydration process itself.
Osmotic removal of water in most studies gives unfavorable results regarding the reconstitution properties of herbal materials. Osmotic water removal in combination with convection drying results in significant changes in the tissue structure of herbal materials, which also affect the mechanical properties of the dried products [1]. Blanching is one of the most widespread methods of herbal materials pre-treatment. Blanching attempts to cause denaturation or inhibition of enzymes that are responsible for reducing product quality through enzymatic browning, lipid oxidation and many other degradative reactions. The blanching has a significant effect on shortening the drying time, removing air from the intercellular space, and softening the texture of herbal materials [7].
Herbal materials soften during heating, which is a consequence of the drop in turgor pressure and complex changes within the polysaccharide matrix of the cell wall. The reduction of cohesive forces within the polysaccharide matrix and the drop in adhesion within the cell results in an increase in the adsorption and reconstitution properties of the herbal material [7]. Furthermore, cell tissues lose their strength due to enzymatic activity leading to depolymerization of cellulosic and pectin substances within the cell wall [11].
The implementation of the blanching procedure can be continuous or discontinuous. The temperature of the water used for blanching can range between 75 °C and 100 °C, and the time of blanching can range from 20 seconds to 15 minutes.
Numerous tests have been conducted on the influence of different methods of blanching on the dynamics of drying and the quality of dehydrated products. Which herbal material blanching procedure will be applied depends primarily on the type and composition of the specific biological material intended for drying [4].
The color of vegetables is one of the most important quality parameters. Products that are not satisfactory in terms of color are often not accepted by consumers, despite their good taste and aroma.
During the preparation, processing and storage of herb material, the development of desirable and undesirable changes can occur, among which the most important property is the color change. This property is a product of browning reactions that affect the following characteristics of herbal material: nutritional value, aroma and stability during storage. Browning reactions can be divided into enzymatic and non-enzymatic browning. The prevention of color change is important because of the preservation of organoleptic properties.
The herbs and spices green color is due to the chlorophyll *a* and *b* content [3]. The chlorophylls are important aroma precursors influencing appearance and quality of *P. crispum* leaves. The dried green *P. crispum* leaves color is related to the content of chlorophylls [6], [13]. These pigments decompose during the drying leaves technological process [9], [2]. Except the visual evaluation of leaves color, the chemical analysis of chlorophylls content is useful and important. Therefore, the determination of chlorophylls content in dried *P. crispum* leaves at three different temperatures was done and the quantity was determined by the spectrophotometric method.

MATERIAL AND METHODS

Fresh material

The *P. crispum*, Apiaceae leaves were obtained from the local small farm. After stabilization at the ambient temperature, the *P. crispum*, Apiaceae leaves were manually cut into disc shaped samples.

Drying equipment

Drying was performed in a tray dryer. The dryer operated in the thermo-gravimetric way. The dryer was equipped with the temperature and airflow velocity controllers. Air was drawn into the duct through a diffuser by a motor driven axial flow air impeller. In the tunnel of the dryer were carriers for trays with samples, which were connected to a balance. The balance was placed outside the dryer, continuously determining and displaying the sample weight. A digital anemometer measured the airflow velocity at the end of the tunnel.

Drying procedure

The drying temperatures applied for *P. crispum*, Apiaceae leaves were 40°C, 50°C, and 60°C. The dryer operated at the air velocity of 1.5 m/s. The air streamed parallel to the horizontal drying surfaces of the samples. The drying process started when the drying conditions had been achieved. The *P. crispum*, Apiaceae leaves samples were placed on the trays into the tunnel of the dryer. The probes were placed into the drying chamber and used to measure the relative humidity and drying air temperature. The airflow velocity was measured every five minutes with a digital anemometer that was placed at the end of the tunnel. The dried samples were used for the determination of the chlorophyll content.

Determination of water loss

Dry matter content of the samples was determined by drying the samples (1 g) for 1 h at 105±0.5°C. Analyses were done in triplicates. The average water loss, expressed in percent, was calculated.
The chlorophyll *a* and *b* were determined according by the spectrophotometric method, with the 80% acetone extraction and absorbance measured at 470, 646, 663 nm [13]. The spectrophotometer used was DR 6000UV Hach Lange GmbH, Düsseldorf, Germany.

Statistic analysis

The data are expressed as means standard deviation. The experiments were replicated three times for statistical purposes.

Table 1. Chlorophyll *a* and *b* content and water loss during drying *P. crispum* leaves

Temperature [°C]	Chlorophyll *a* [mg/g]	Chlorophyll *b* [mg/g]	Water loss rate [%]
40	129.52±0.61	12.65±0.21	18.95±0.28
50	110.17±0.42	11.16±0.12	21.37±0.16
60	80.70±0.10	9.92±0.18	25.95±0.14

RESULTS AND DISCUSSION

The determination of chlorophyll *a* and *b* content in dried *P. crispum* was done by the spectrophotometric method, with the 80% acetone extraction and absorbance measured at 470, 646, 663 nm [8]. The influence of different temperatures on *P. crispum* leaves chlorophyll *a* and chlorophyll *b* content is presented in Table 1. It can be seen from the table that in terms of the chlorophyll *a* quantity the highest is when the leaves are dried at 40°C. The chlorophyll *a* represented the highest content in leaves dried at 40°C, successively followed by the leaves dried at 50°C. Compared with the leaves dried at 60°C, the contents of chlorophyll *a* significantly dropped. A significant difference was observed in the content of the chlorophyll *a* when the temperature was 60°C compared to drying at 40°C and 50°C. The highest chlorophyll *b* content in dried leaves was observed when the leaves were dried at 40°C. The chlorophyll *b* quantity was higher in leaves dried at 50°C than in those dried at 60°C. Comparing the chlorophyll *b* quantity, the content of the plastid pigment significantly reduced with increasing the temperature from 50°C to 60°C. To be specific, the contents of the chlorophyll *b* decreased from 11.16 mg/g to 9.92 mg/, meaning the content of the plastid pigment reduced for 11.11%. The content of the plastid pigments investigated showed a reduction.
Chlorophylls are not the main composition of plastid pigments, they have some kind of the aroma. The pigment degradation in the drying process directly influences the change of appearance, color and influences the generation and transformation of aroma components.

CONCLUSION

The research results revealed that with the increase of drying temperature the contents of chlorophyll *a* and *b* decline. The reason is that the corresponding temperature and humidity offered in the drying process enabled occurrence of enzymatic browning and non-enzymatic browning of leaves. The content of the nitrogen compounds, chlorophyll *a* and *b*, is lowered, so nitrogen was lost to some extent. The transformation of pigments under drying process can be further explored. In the future research, different temperatures can be applied.

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BIOMASS PYROLYSIS AND GASIFICATION MODELING WITH COCO SIMULATOR

Emilija Dejanoska[1], Filip Todorovski[1], Andrej Senegačnik[1], Mihael Sekavčnik[1], Boštjan Drobnič[1]
[1]University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia
e-mail: emilija.dejanoska@fs.uni-lj.si

Abstract: Biomass is a renewable energy source and represents an efficient and sustainable alternative to fossil fuels. The environmental benefits from the use of biomass are the global impact, represented by negative CO_2 emissions in the atmosphere, and the local impact represented by the absorption of heavy metals from polluted soils. With the help of energy crops planted on the polluted areas, which absorb the heavy metals from the soil, contaminated areas can be cleaned and, in the end, can be treated as recovered for food production. Further processing of energy crops with pyrolysis, gasification and additional passivation of biochar leads to safe storage of heavy metals.

Pyrolysis is a complex thermo-chemical decomposition of a substance that takes place at temperatures above 300 °C in an inert atmosphere. The usefulness of biomass as a carbon-neutral energy source or raw material for further processing is increased if biomass is converted by pyrolysis into three characteristic products bio-char, bio-oil and bio-gas. A model of rapid pyrolysis of lignocellulosic biomass has been developed in the freely accessible COCO simulator. The simulation model is one-step with one stoichiometric equation taken from the literature. The quality of the simulation model was verified by comparing the computational and experimental results given in literature. The temperature range of the simulation was extended to an interval of (400-550 °C) in our own model, performed in the MS Excel. Furthermore, the process of gasification of biochar obtained from the process of pyrolysis of pine wood was simulated. The analysis of the composition of the syngas as a gasification product was performed in the temperature range (650-1400 °C), the reactor volume size (0.5-75 m^3) and the steam to carbon ratio (0.1-4.5).

Key words: pyrolysis, gasification, biomass, renewable energy, COCO simulator

INTRODUCTION

The most alarming problems on earth, which affects the future of the entire civilization, are air and land pollution. The first causes the greenhouse effect resulting in global warming, and the second increasing of a number of contaminated lands around the world. Carbon dioxide represents the largest share of all greenhouse gases, and its amount in the atmosphere is at its highest level so far. Conversion of the biomass produced at contaminated land to passive biochar which can be safely stored underground is an attractive idea which can be used for simultaneous improvement of land and reduction of CO_2 amount in the atmosphere. Biomass is first subjected to pyrolysis process. Pyrolysis is the process of decomposition of organic matter in the absolute absence of an oxidant. Process temperatures range from medium (300-800 °C) to high (800-1300 °C) temperatures. The initial pyrolysis product consists of condensable gases and solid char. Condensable gases can be further broken down into non-condensable gases (CO, CO_2, H_2 and CH_4), tars and char [1]. During pyrolysis, the large complex hydrocarbon molecules of biomass are broken down into relatively smaller and simpler gas, liquid and char molecules. This decomposition occurs partly due to homogeneous reactions in the gas phase and partly due to heterogeneous thermal reactions in the gas-solid phase. The final products of the process are biochar, biogas and bio-oil. The product yields are influenced by many factors such as: temperature, residence time, heating rate, biomass particle size, etc. In the next phase biochar is subjected to gasification, in which biochar is partly transformed into a mixture of H_2, CO, CH_4, CO_2, water vapor, N_2, as well as char, ash, soot, tar, alkalis, nitrogen compounds, sulfur and chlorine compounds, etc. Gasification agent is needed, such as steam, enriched air, O_2, CO_2 or their combination at a temperature range (600-1500 °C) [2]. The biggest influence in the gasification process has the temperature, on which depends the concentration of various compounds in the product gas [3], [4]. The product biochar is activated, while heavy metal compounds stay in the solid phase. The activated char is than contacted with pyrolysis gas and passivation process occurs which is based on coking of tar compounds at the surface of activated char. Schematic view of the process is shown in fig 1.

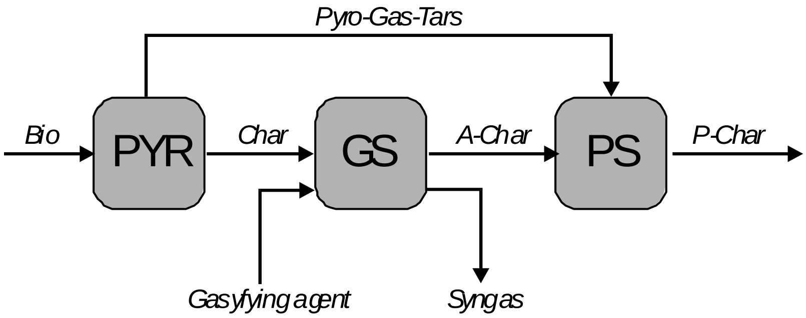

Fig. 3. Passive biochar and syngas production process scheme

MATERIAL AND METHODS

First two phases of the process have been modeled with COCO simulator and further extended on the bases of comparison the COCO results with the available literature results [5], [6]. Experimental data was used with the aim of obtaining all the necessary information about the chemical background of the process [7-10].

Pyrolysis

Pyrolysis is a complex process, the understanding of which requires various engineering skills and tools. The two most used approaches are conducting experiments and creating computer models. Computer models are usually designed based on the performed experiments, then later used for multi-parameter analyzes of various cases. COCO (CAPE-OPEN to CAPE-OPEN) is a free simulation environment that enables the simulation of time-independent chemical processes. The COCO "TEA" thermodynamic library and its chemical compound database are based on ChemSep LITE. The pyrolysis process is modeled with COCO simulator [11]. A one-step, one-reaction model is made based on the experimental results from literature [7], and can be used for any other type of pyrolysis where the stoichiometry and process conditions are known.
In the papers published so far in this field [5], [6], [12], [13], [14] the products are determined on the basis of experimental results and it can be seen that they change considerably. The products compounds are highly dependent on the type of biomass and the process conditions. Often the products contain compounds whose physical and chemical properties are not publicly available, and some are even completely unstudied [15] . Because of this property, pyrolysis is not a process for which a universal model can be made, but modeling is necessary after the experiment has been conducted. The purpose of modeling is a broader field of research, not independent determination of products for different types of biomass and different operating conditions. In the COCO model, the first stage is drying the biomass. It is performed with the mixing of the biomass with dry air, heating in the heat exchanger with condensation heat of the steam and finally separation of the vapor phases from the other phases present in the system. Dried biomass continues in the next stage of the process – heating, provided with hot sand. The heat flux entering the reactor is therefore the sum of the heat fluxes of sand and preheated biomass. The temperature of the sand is much higher than the temperature of the biomass. A fixed conversion reactor is a simplified reactor model. One or more chemical reactions must be defined. A predetermined reaction package is assigned to the reactor. A mixture of solid bio-char, sand, condensable and non-condensable gases exit the pyrolizer. For their quantification, we must separate them with a model element, i.e. separators. The first separator separates the solid phase from the gas phase. The second separator separates condensable gases from non-condensable gases. Main assumptions in the model are: no pressure drops in the elements, isothermal process in the reactor, maximum theoretical heat transfer in the heat exchangers and ideal mixing in the mixers. Considering the complexity of pyrolysis and the diversity of its products, most of the compounds were not found in the library and were thus additionally added with ChemSep

software, including biomass itself. Model was further extended using experimental data [7] for a wider temperature range.

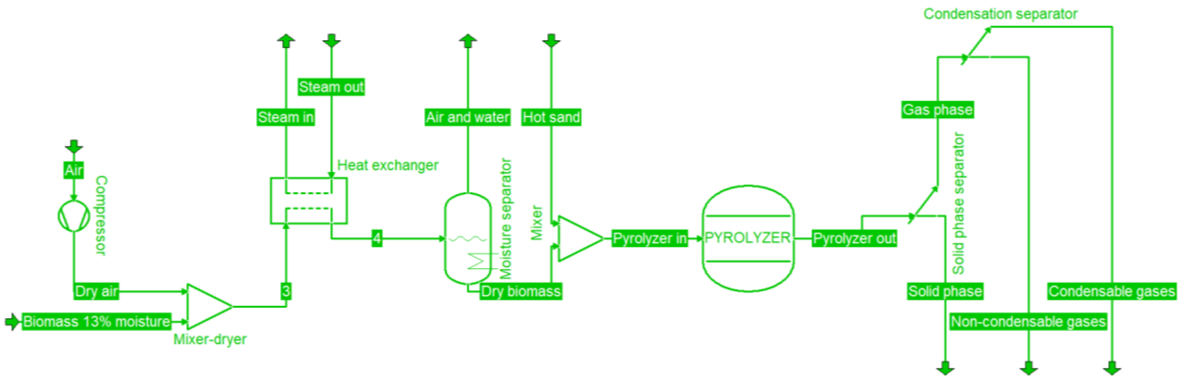

Fig. 4. Pyrolysis model in COCO simulator

Gasification

Biochar from the pyrolysis is used as an input value in the gasification process. It is not necessarily pure carbon, but also contains a certain amount of hydrogen and oxygen. The first stage after pyrolysis is the combustion of biochar, after which the actual gasification process begins. Gasification is a thermo-chemical process in which biochar is transformed into a mixture of H_2, CO, CH_4, CO_2, water vapor, N_2, as well as char, ash, soot, tars, alkalis, nitrogen compounds, sulfur and chlorine compounds, etc. Gasification agent is needed, such as steam, enriched air, O_2, CO_2 or their combination.

For the modeling of the gasification process in COCO the following elements are used: a heat exchanger, a mixer and a CST reactor. In the drying phase of the pyrolysis biomass steam is used for heating. This steam is also used to heat the mixture of the extracted moisture, oxygen and nitrogen obtained from the biomass drying process. This mixture is then used in the gasification process. Two mixers are used in the model. The first allows the mixing of water, oxygen and nitrogen with the gaseous pyrolysis products. In the second their total flow is mixed with the biochar. These two adiabatic mixers unite all input elements of the gasification process in one inlet stream. Three reactors with continuous mixing are used. The entire biochar gasification process is divided into two zones: biochar combustion (one CST reactor) and biochar gasification (two SCT reactors). The dependence between activation energy and temperature is given with the Arrhenius equation. This equation states that a minimum amount of energy, called activation energy, is required to convert reactants into products. Reaction rates are for all chemical reactions used [16] are taken from the literature [8-10]. The rate constant and activation energy are determined experimentally for each chemical reaction separately.

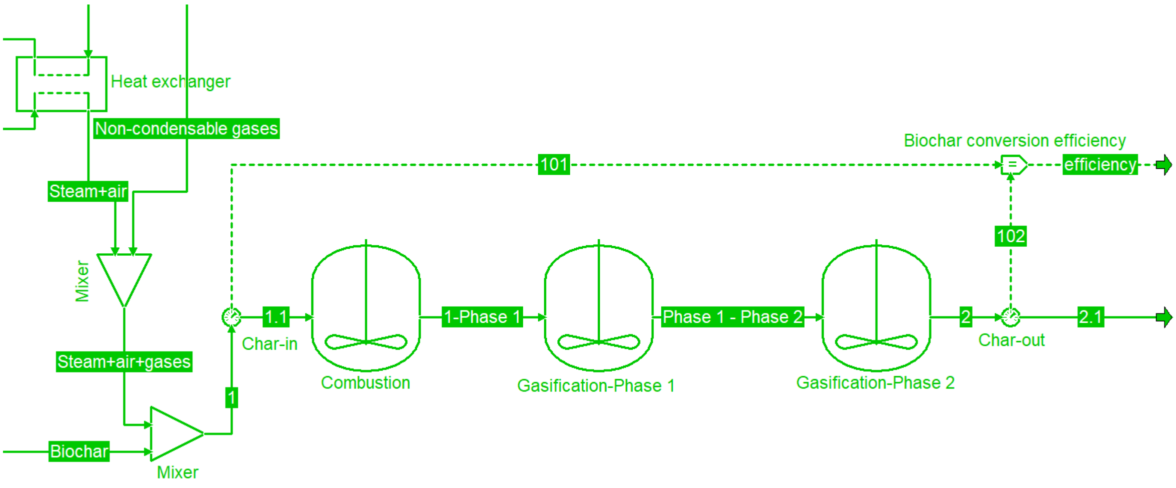

Fig. 5. Gasification model in COCO simulator

RESULTS AND DISCUSSION

The model is made for the fast pyrolysis of dry pine wood with the chemical equation $CH_{1,5}\,O_{0,66}$. The model calculates the product yields in the temperature range of (400-550 °C). It also predicts the biogas composition (assuming the biogas composition is mixture of CO, CO_2 and CH_4).

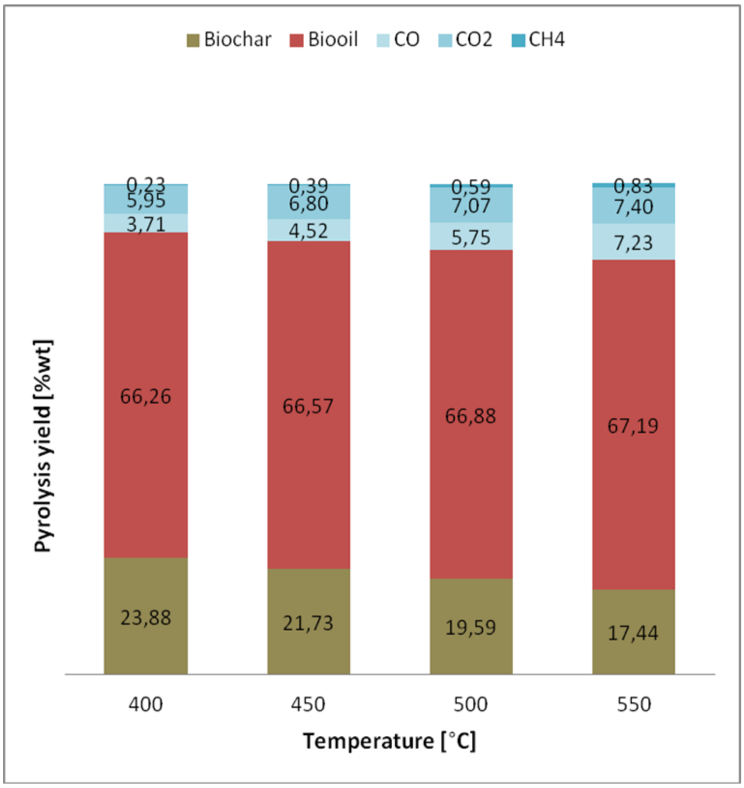

Fig. 6. The effect of temperature on the yields of bio-oil, biochar and biogas and the biogas composition (400–550 °C) for fast pyrolysis of dry pine wood [11]

The bio-oil and biogas yield slightly increase with the temperature increasing, while biochar yield decreases. The composition of biogas is approximately constant. There is a small deviation of constancy for CO and CO_2. The content of CO increases with increasing temperature, while the content of CO_2 decreases. The oxidation (combustion) zone of the solid product of pyrolysis - biochar was modeled with two oxidation reactions for partial and complete oxidation. The final product of biomass gasification is synthesis gas and activated biochar. The gasification process was modeled with four reactions that determine the ratios between the products under certain process conditions. At temperatures above 1100 °C (depending on the reactor volume), the proportion of hydrogen in the synthesis gas decreases due to the equilibrium nature of the steam reforming reaction.

The composition of synthesis gas is also strongly influenced by the steam/biochar ratio. For higher ratios the content of hydrogen increases, while the content of CO and CH_4 decrease. Figure 5 shows that as temperature increases, the conversion efficiency also increases, since the rate of combustion reactions in the Arrhenius equation is proportional to temperature. This means that when the temperature is higher and the other conditions are constant, the conversion of biochar into syngas increases. Residence time also affects the conversion efficiency. The larger the volume, the faster the maximum efficiency area is reached. This is still limited by the amount of steam that enters the gasification process as a gasification agent. The maximum value of biochar conversion efficiency is reached at a temperature of 1100 °C and a volume of 75 m^3 and is 49%.

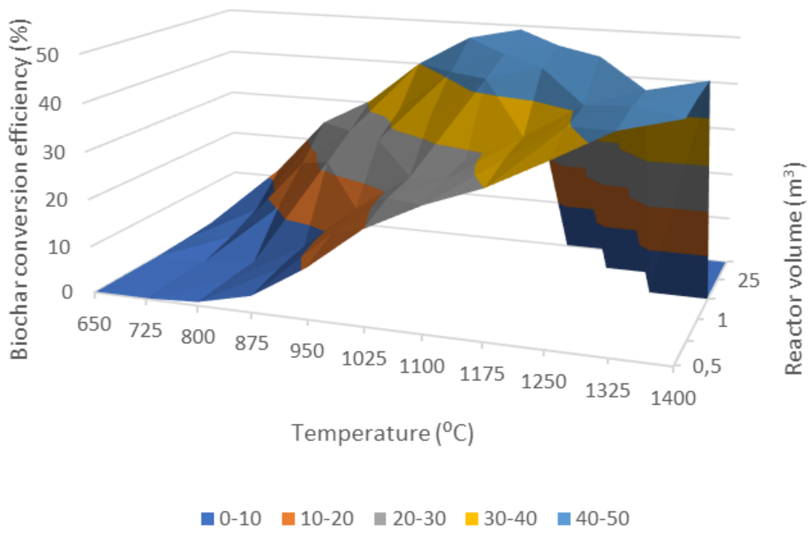

Fig. 7. The effect of the temperature and reactor volume on the biochar conversion efficiency [16]

CONCLUSION

A biomass pyrolysis model in the COCO simulator was designed, which is able to calculate the products yields for fast pyrolysis of dry pine wood in the range from 400 °C to 550 °C. It also predicts the biogas composition, so the authors were able to evaluate the nature of the process. The model is single-step global and is based on the previously experimentally specified stoichiometric equation. The complexity of the chemical process of pyrolysis and the limitations of the freely available COCO simulator were the biggest challenges. A major disadvantage of using free software is the lack of a solid database. Pyrolysis products are highly diverse, strongly depending on the type of biomass and reaction conditions. Compounds appearing in the product mixture proved to be the biggest difficulty of this work, because of their inaccessible or even undetermined properties. The entire field of biomass use as a fuel is underexplored in comparison with the fossil fuels. The gasification part of the model generated a clear view and many parametric analyses were performed – the impact of the temperature and the residence time on the syngas composition and the biochar conversion efficiency [16]. Gasification process was modelled with four reactions that determine the ratios between the products under certain process conditions: water vapor, hydrogen, carbon monoxide, carbon dioxide and methane. Steam reforming and methanation reactions are key in the production of hydrogen in synthesis gas, where process parameters such as temperature and the influence of the catalyst used must also be taken into account.

At temperatures above 1100 °C (depending on the reactor volume), the proportion of hydrogen in the synthesis gas decreases due to the equilibrium nature of the steam reforming reaction. The composition of synthesis gas is also strongly influenced by the ratio between water vapor and biochar. By increasing the water vapor flow, the share of H_2 increases, while the share of CO and CH_4 decrease, thereby increasing the efficiency of the conversion of biochar into synthesis gas with a higher hydrogen content.

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ENVIRONMENTAL IMPACT ASSESSMENT OF PROTON EXCHANGE MEMBRANE FUEL CELL WITH ECO-DESIGN STRATEGIES FOR REALISTIC SHORT-TERM CONCEPT

Rok Stropnik[1], Felipe Campos-Carriedo[2], Jure Gramc[1], Andrej Lotrič[1], Laurent Rey[3], Eleonora Bargiacchi[2], Diego Iribarren[2], Javier Dufour[2], Mitja Mori[1]
[1]University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia
[2]IMDEA Energy, Systems Analysis Unit, E-28935 Móstoles, Spain
[3]SYMBIO, F-73370 Le Bourget-du-Lac, France
e-mail: rok.stropnik@fs.uni-lj.si

Abstract: The presented work is done within the eGHOST project, which aims to support the whole Fuel Cells and Hydrogen (FCH) sector industry in how to address the new eco-(re)design of Proton-Exchange Membrane Fuel Cells (PEMFC) stack, in such a way that sustainable design criteria can be incorporated since the earliest stages of the product development. The presented preliminary results are a little stone in the mosaic of project results and a small milestone that will help with further development of eco-design criteria in the EU hydrogen sector and will go a step beyond the current state of the art in eco-design. The results show that total GHG emissions are reduced by 43.3% in the realistic short-term PEMFC case, corresponding to 680 kgCO_2 eq. per PEMFC stack production with eco-design actions, compared to 1200 kgCO_2 eq. emissions for the reference 48kW$_{el}$ PEMFC case production.
Key words: Environmental LCA assessment, Eco-design, PEMFC, FCH technologies, Sustainability

INTRODUCTION

The European Union (EU) has set an ambitious target to reduce net greenhouse gas emissions to zero by 2050, while at the same time ensuring economic and social sustainability. One of the key documents is the European Green Deal [1], which lays out a path towards achieving this overall target, by accelerating a variety of policy changes that concerns many aspects of the EU economy and society. EU concerns on climate change and natural resource depletion have raised interest in fuel cells and hydrogen (FCH) technologies to provide sustainable ways for hydrogen production and use. Furthermore, the European Commission considers eco-design as a key factor to meet its commitment to a carbon neutral and circular economy by 2050. The current Eco-design Directive 2009/125/EC [2] has a long track record of delivering benefits to businesses, consumers, and the environment. In 2021 alone, the impact of the current eco-design measures, covering 31 product groups, saved 120 billion EUR in energy expenditure for EU consumers and led to a 10% lower annual energy consumption by the products in scope [3]. Therefore, the sustainability performance of FCH systems must be assessed in a holistic approach embracing environmental, economic, and social aspects. Within this scope, the EU project eGHOST [4] will contribute to developing the first preparatory study of FCH products, under the principles of the Eco-design Directive will improve the understanding of FCH technologies as sustainable investment and will include a full life cycle sustainability assessment of a PEMFC stack and Solid oxide Electrolyzes (SOE) stack.
In the presented study, the focus is on environmental impact comparison of reference and realistic short-term PEMFC stack case, for which detailed environmental LCA was performed and analyzed. The main plan is to present the eco-design principle and to show how the eco-(re)design strategies applied could contribute to the more sustainable products with lower environmental impacts. The evaluated reference PEMFC case is a 48 kW$_{el}$ PEMFC stack that is used in the automotive industry for light fuel cell electric vehicles (FCEV).

METHODOLOGY

Environmental Life Cycle Assessment

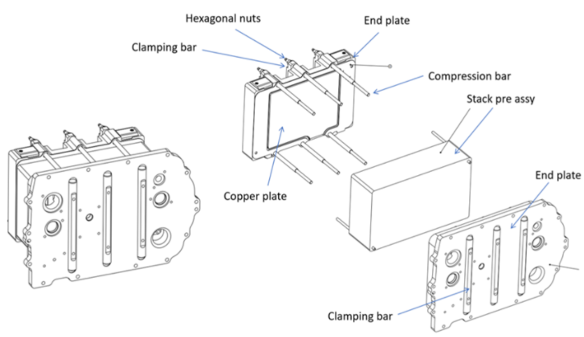
Life Cycle Assessment methodology is standardized according to the ISO standards 14040 [5] and 14044 [6] and includes four phases (i) goal and scope, (ii) life cycle inventory (LCI) analysis, (iii) life cycle impact assessment (LCIA) and (iv) interpretation of the results. The study also considers International Reference Life Cycle Data System (ILCD) guidelines [7] and the guidance document for performing an LCA on FCH technologies by HyGuide [8].

All the LCA modelling and environmental assessment calculation are made in GaBi software with Ecoinvent and Gabi professional databases. The main goal of this LCA analysis is to evaluate the environmental impacts of the 48kW PEMFC stack (reference case and realistic short-term case) according to the EF 3.0 LCIA method. The scope of the study is ‘cradle to gate’ excluding the use and end-of-life phase. The functional unit (FU) quantifies the function of the product system and provides a reference unit. The choice of the FU can strongly affect the conclusions of the study (especially in comparative studies). For this study, FU is one PEMFC stack with 48 kW electrical power output.

System boundaries: The foreground system comprises all processes related to the production of the PEMFC stack itself. In the presented case, this includes the main production processes for the main components, such as the manufacturing of the catalyst coated membrane (CCM), sub-gaskets and gas diffusion layers (GDL) which comprise the membrane electrode assembly (MEA). Additionally, manufacturing processes for gaskets, bipolar plates (BPP), current collectors, screws, springs, and end plates are also included in the PEMFC stack manufacturing. The background system supports the foreground system described above and its processes. It deals with almost all material and energy flows going to and coming from the foreground system. As for secondary data, a high-quality database Ecoinvent v3.7 [9] and GaBi Professional [10] is used for the background system.

The reference PEMFC case under evaluation and presented in this study is a 48 kW_{el} PEMFC stack (SYMBIO [11]), which is used in light vehicles (single or multiple stack units). The detailed technical specifications and list of materials (BoM) were provided by the industrial partner from France SYMBIO, from which the needed material and energy flows were identified to produce 1pcs of reference PEMFC stack.The automotive PEMFC stack consists of 280 MEA (membrane electrode assembly) units with an active area of 200 cm^2 each. The amount of platinum in the 48 kW_{el} PEMFC stack is 0.5425 g/kW with a power density of 1.36 kW/kg. The reference PEMFC technology definition is presented in Table 7, where the main boundary conditions and limitations are summarised.

Table 7. Reference PEMFC stack technology definition [11]

PEMFC technology definition and boundary conditions	
Technical Drawings of the reference PEMFC stack	
Technical Perimeter	Stack only
Life Cycle Perimeter/scope	‘’Cradle to gate’’ (Manufacturing phase)
Size of the system (El. Power)	48 kW_{el} (1.36kW/kg)
Technology	Representative PEMFC stack design

Application	Light vehicles (FCEV)
Timeline	Current technology (prospective approach to 5 years envisaged)

The LCI is presented in Table 8 with all the materials and energy required to produce a reference PEMFC stack, and the final LCA model constructed in GaBi Software is presented in Fig. 1.

Table 8. LCI of the 48 kWel PEMFC stack used for the base case study

Input flow	Total Amount	Amount per kW_{el}	Share [w%]	Process
Silicone	1.265 kg	26.34 g	3.60%	EU-28: Silicone sealing compound (EN15804 A1-A3) Sphera
Stainless steel	21.623 kg	450.47 g	61.48%	DE: Stainless Steel slab (X6CrNi17) Sphera <p-agg>
Carbon cloth. fibres	1.249 kg	26.02 g	3.55%	EU-28: Polyacrylonitrile Fibres (PAN) Sphera
PEN or PET film with thermo active glue	1.82 kg	37.92 g	5.17%	EU-28: Polyethylene terephthalate fibres (PET) Sphera
Platinum	0.026 kg	0.54 g	0.074%	GLO: Platinum mix ts
Carbon black	0.039 kg	0.81 g	0.11%	DE: Carbon black (furnace black; general purpose) Sphera
PFSA (Nafion)	0.018 kg	0.38 g	0.052%	CA: Nafion - for use in fuel cell ts
Water	0.49 kg	10.21 g	1.39%	EU-28: Water (desalinated; deionised) Sphera
Alcohol	0.22 kg	4.58 g	0.63%	EU-28: C12-15 Alcohol (petro) Ethoxylate, 7 moles EO ERASM
Glass reinforced thermoplastic	3.800 kg	79.17 g	10.80%	RER: glass fibre reinforced plastic production, polyamide, injection moulded ecoinvent 3.7.1
Chromium steel	0.852 kg	17.75 g	2.42%	RER: steel production, chromium steel 18/8, hot rolled ecoinvent 3.7.1
Copper	0.950 kg	19.79 g	2.70%	EU-28: Copper Wire Mix (Europe 2015) DKI/ECI
Steel product	2.820 kg	58.75 g	8.02%	DE: EAF Steel billet / Slab / Bloom Sphera <p-agg>
Electricity	410.2 kWh	8.5 kWh	/	EU-28: Electricity grid mix Sphera

The Environmental Footprint 3.0 (EF3.0) LCIA method will be used to evaluate selected environmental impact categories. The EF3.0 method includes 16 environmental impact indicators, from which in this study seven will be included in the analysis (See Table 9) with more in detail the Climate Change indicator, which is one of the most used in EU legislation and widely used in other studies.

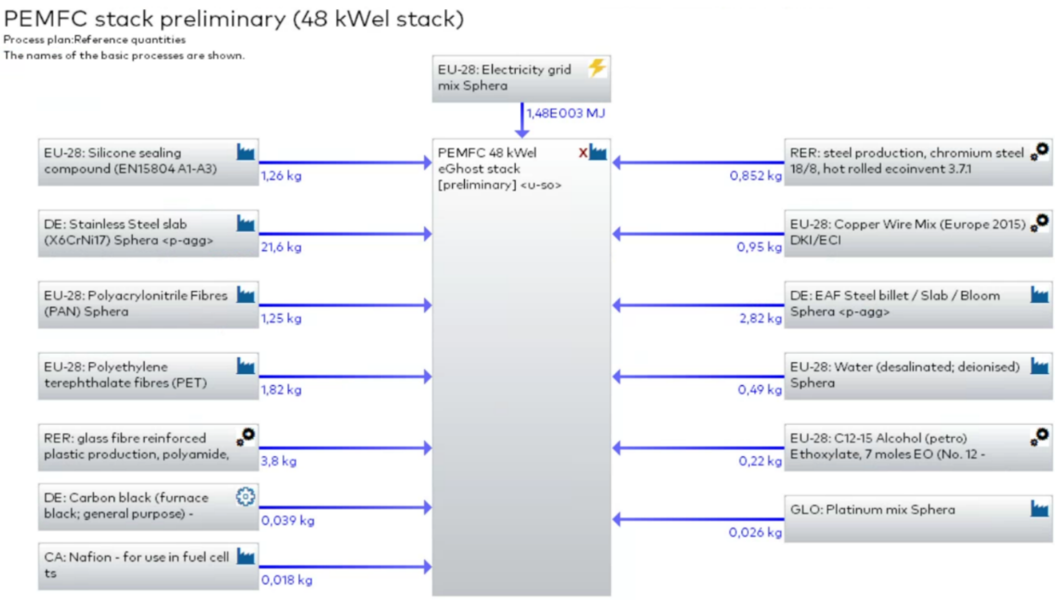


Fig.1. LCA model of 48 kW PEMFC stack (reference PEMFC case)

Table 9. Indicators from EF 3.0 LCIA methodology used in the study

EF impact category	Indicator	Unit
Climate change	Global Warming Impact Potential (GWP)	kg CO_2 eq.
Acidification	Accumulated Exceedance (AE)	mol H+ eq.
Eutrophication, Terrestrial	Accumulated Exceedance (AE)	mol N eq.
Eutrophication, aquatic freshwater	Fraction of nutrients reaching freshwater and compartment (P)	kg P eq.
Eutrophication, aquatic marine	Fraction of nutrients reaching marine and compartment (N)	kg N eq.
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq.
Resource use, energy carriers	Abiotic resource depletion – fossil fuels (ADP-fossil)	MJ

Eco-design approach

Eco-design strategies consist of integrating environmental/sustainability protection criteria over a service or a product life cycle. The main goal of eco-design is to anticipate and minimize negative environmental impacts (of manufacturing, use and end-of-life of products). Simultaneously, eco-design also keeps a product quality level according to its ideal usage and at the same time does not compromise its functionality. The principles can be found in ISO/TR14062 [12]. Eco-design is a “multi-step” and “multi-criteria” approach that supports a product’s entire life cycle in a circular economy perspective by saving and recycling maximum of natural resources.

Eco-design actions address different product levels: i) Product Component Level, with a selection of low-impact materials and/or reduction of material used. ii) Product Structure Level, with optimization of production techniques, optimization of the distribution system and reduction of impacts during the use phase and iii) Product System Level, with optimization of lifetime and optimization of the end-of-life system. The main approach for the generation and categorization of eco-design ideas to create product concepts of PEMFC was the brainstorming sessions of experts and industry partners within the EU eGHOST project according to the eco-design strategy wheel (Fig. 2.).

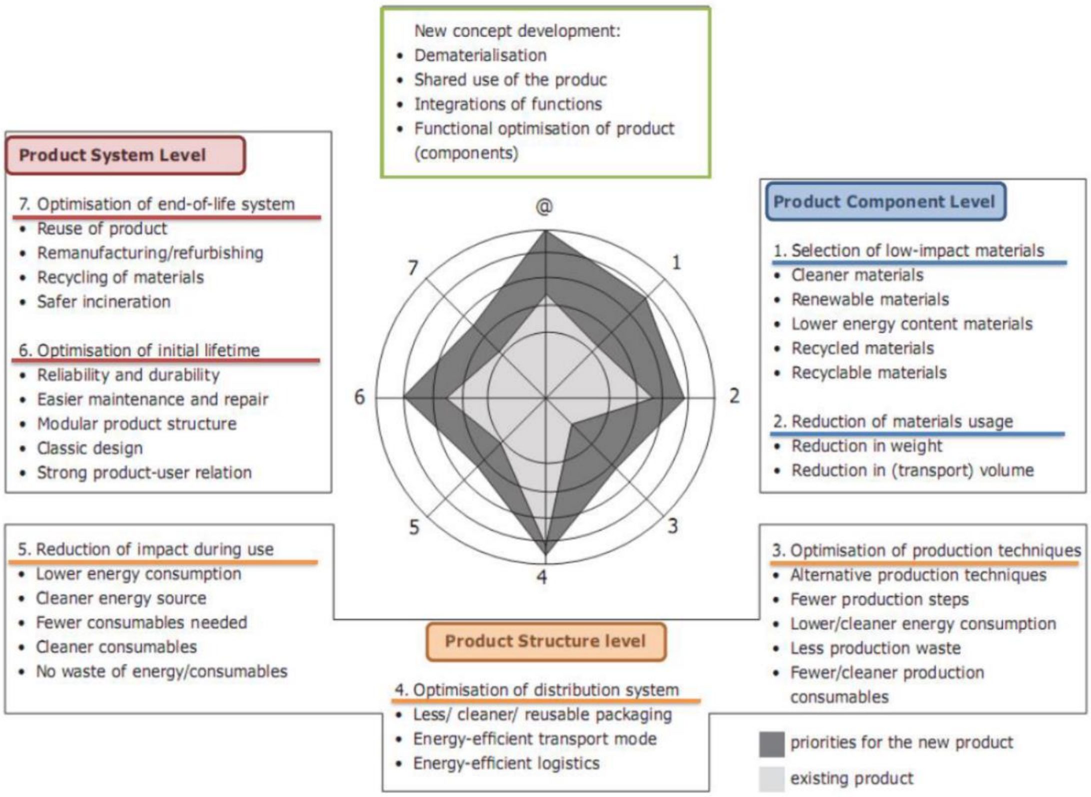


Fig. 2. Eco-design strategy wheel [13]

Based on these sessions and identified Eco-design action for each axis, four product concepts were proposed for the PEMFC system: Realistic short-term concept, Realistic medium-to-long-term concept, Optimistic product concept and Disruptive product concept. In this comparative study realistic short-term concept is presented and results are benchmarked to the reference PEMFC case. All addressed actions for realistic short-term concept are described and presented in Table 10 as new LCI for Realistic short-term PEMFC concept.

Additional actions, which are not explicitly addressed under description of action in Table 10 are, (axis 3) optimized catalyst coating on MEA (action 3.1), with the smallest possible material loss during the coating process. Action 3.4 addresses the rejection rate of components that must be minimized by improving defect detection technologies. In distribution optimization (axis 4) actions 4.1 and 4.2 are included; they address the packing material that should be sustainable (wood), reusable and recycled (recycled corrugated cardboard box). Realistically, most FC systems are equipped with a battery pack. As a recommendation, by optimizing the integration and battery-stack hybridization strategy the lifetime of the system can be prolonged (axis 6). According to presented actions and mass and energy balances for the product concept the LCA model of a realistic short-term 48kW PEMFC stack is presented in Fig. 3.

Table 10. LCI of the 48kW realistic short-term PEMFC stack concept with eco-design actions

Input flow	Mass [kg]	Mass/P_{el} [g/kW]	Share [total w%]	Description of Action
Silicone	1.204	25.09	3.90%	
Stainless steel	18.379	382.90	59.57%	BPP mass reduction - 15% reduction in thickness
Carbon cloth. fibres	0.687	14.31	2.23%	GDL mass reduction – Thickness reduction from avg.150-300 μm to 110 μm (45% reduction).
PEN or PET film with thermo active glue	1.733	36.11	5.62%	
Platinum (30% Rec Pt)	0.013	0.27	0.04%	A1.1 - Rec Pt use (30% Rec Pt, 70% Virgin Pt); A2.1 Pt loading reduction - from reference (0,465mgPt/cm^2 to 0,235mgPt/cm2 [14]), A2.2 optimized triple phase boundary (5% Pel)
Carbon black	0.037	0.77	0.12%	
PFSA (Nafion)	0.101	2.10	0.33%	Membrane mass reduction - Thickness reduction from avg.15-20 μm to 12 μm (30% reduction).
Water	0.467	9.72	1.51%	
Alcohol	0.210	4.37	0.68%	
Glass reinforced thermoplastic	3.619	75.40	11.73%	
Chromium steel	0.811	16.90	2.63%	
Copper	0.905	18.85	2.93%	
Steel product	2.686	55.95	8.71%	
Electricity [kWh]	390.7	8.1	/	

RESULTS AND DISCUSSION

In the first part of the results, the total environmental impacts of the manufacturing phase are presented for reference PEMFC case with an additional relative contribution for each component (material used) of the 48 kWel PEMFC stack. In the second part of results, comparative analysis of environmental impact indicators of the reference vs realistic short-term PEMFC case is presented to assess the impact of eco-design actions used for the realistic short-term product concept.

In Table 11 the total absolute values of the environmental indicators for acidification, climate change, eutrophication, and resource consumption are presented for the manufacturing phase of the reference PEMFC stack. For a more detailed presentation of the relative contribution of electricity and materials to the total environmental impacts of the 48 kWel PEMFC stack the table is coloured with the contribution shares in parentheses, namely red colour represents very high impact and green colour represents low impact.

From results the summary and conclusions related to the reference PEMFC case are, that the main hotspot of reference PEMFC case is Pt, despite the total mass share of Pt in the whole PEMFC stack is only 0.074% (Pt is according to the EU Criticality methodology [15] very critical raw material). Furthermore, the total GHG emissions of the 48 kW_{el} PEMFC stack manufacturing is 1200 kg CO_2 eq., which is equal to 25 kg CO_2eq. per kW power.

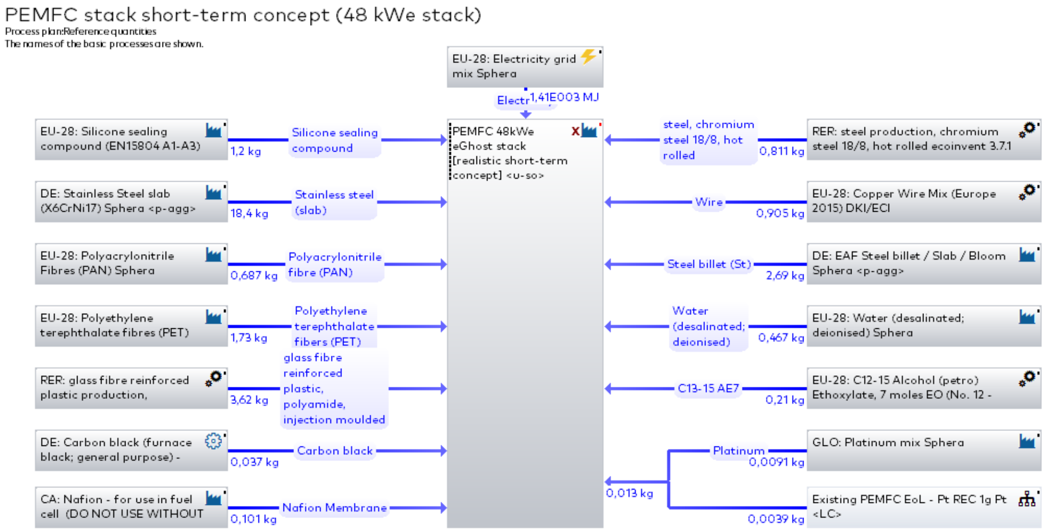


Fig. 3. LCA model of 48 kW PEMFC stack (realistic short-term PEMFC case)

Table 11. E-LCA results with the relative contribution of electricity and materials to the entire environmental impact of the reference PEMFC case

	EF 3.0 Acidification [mol H^+ eq.]	EF 3.0 Climate Change total [kg CO_2 eq.]	EF 3.0 Eutrophication freshwater [kg P eq.]	EF 3.0 Eutrophication marine [kg N eq.]	EF 3.0 Eutrophication terrestrial [mol N eq.]	EF 3.0 Resource use, fossils [MJ]	EF 3.0 Resource use, Min.&met. [kg Sb eq.]
48 kW_{el} PEMFC stack (100 %) (Reference PEMFC case)	**21.5**	**1200**	**0.005**	**1.58**	**17**	**14100**	**0.052**
Electricity	1.6%	13.8%	8.6%	5.1%	5.0%	20.6%	0.1%
Platinum	94.9%	73.6%	1.5%	86.7%	88.2%	65.5%	86.3%
Nafion	0.0%	1.4%	0.0%	0.0%	0.0%	0.4%	0.0%
Carbon black	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Steel	0.0%	0.1%	0.1%	0.0%	0.0%	0.1%	0.0%
Stainless steel	2.5%	6.1%	1.7%	3.6%	3.7%	5.7%	9.4%
Alcohol	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Copper	0.2%	0.3%	0.4%	0.3%	0.3%	0.3%	3.6%
Polyacrylonitrile fibres (PAN)	0.1%	0.5%	0.2%	0.4%	0.4%	1.0%	0.0%
Polyethylene terephthalate fibres (PET)	0.0%	0.5%	0.4%	0.2%	0.2%	1.1%	0.0%
Silicone	0.1%	0.8%	0.3%	0.4%	0.4%	1.0%	0.3%
Water (desalinated; deionised)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Glass fibre reinforced plastic	0.6%	2.8%	60.8%	2.8%	1.3%	3.7%	0.1%
Chromium steel	0.1%	0.3%	26.1%	0.3%	0.3%	0.4%	0.3%

Electricity and Pt production have the highest contribution to the Climate Change environmental indicator, namely Pt represents 73.6% and electricity represents 13.8% of total climate change impact. For the Resource use mineral and metals environmental indicator, the highest impact comes from Pt (86.3%) followed by stainless steel (9.4%) and copper (3.6%). For the Acidification environmental indicator, most of the impact comes from platinum production (94.9%), followed by stainless steel (2.5%) and electricity (1.6%). Glass fibre reinforced plastic has the highest impact contribution to freshwater Eutrophication, with 60.8% followed by chromium steel (26.1%) and electricity (8.6%).

Table 6 shows the absolute values of the environmental indicators for the reference case and the realistic short-term case. Fig. 4. shows the relative reduction of each environmental indicator compared to the reference PEMFC case. The results of the eco-design strategies show that with the presented measures according to the eco-design wheel described in Table 4, a significant reduction is possible with the re/design approach of the PEMFC stack by 43.2% on average.

Looking more in detail at the individual indicators, the highest reduction in environmental impact due to acidification (EF 3.0 Acidification) is 62.7% compared to the reference scenario. There is an almost negligible decrease in the indicator EF 3.0 Eutrophication freshwater (0.6%), and a higher decrease in the indicator Eutrophication is recorded for marine and terrestrial eutrophication compared to the reference scenario. There is also a significant decrease in natural resource depletion (EF 3.0 Resource use minerals and metals), which amounts 57.3 %. This is the result of measures A1.1 and A2.1 (see Table 4), which affect a lower amount of Pt (hotspot for Resource use). In the case for greenhouse gas emissions reduction (EF 3.0 Climate change) due to addressed eco-design actions, the reduction of CO_2 eq. emissions by 43.3% or 520 kgCO_2 eq. for a 48 kW PEMFC stack (10.83 kgCO_2 eq /kW). The realistic short term PEMFC concept have the total 680 kgCO_2 eq. emissions for manufacturing phase, which corresponds to 14,17 kgCO_2eq. per kW power.

Table 12. Total values of environmental for reference and realistic short-term 48 kW_{el} PEMFC case

48 kW_{el} PEMFC stack	**EF 3.0 Acidification [mol H^+ eq.]**	**EF 3.0 Climate Change total [kg CO_2 eq.]**	**EF 3.0 Eutrophication. freshwater [kg P eq.]**	**EF 3.0 Eutrophication. marine [kg N eq.]**	**EF 3.0 Eutrophication. terrestrial [mol N eq.]**	**EF 3.0 Resource use. fossils [MJ]**	**EF 3.0 Resource use. Min.&met. [kg Sb eq.]**
Reference PEMFC case	**21.5**	**1200**	**0.005**	**1.58**	**17**	**14100**	**0.052**
Realistic short-term PEMFC case	**8.02**	**680**	**0.00507**	**0.65**	**6.8**	**10700**	**0.0221**

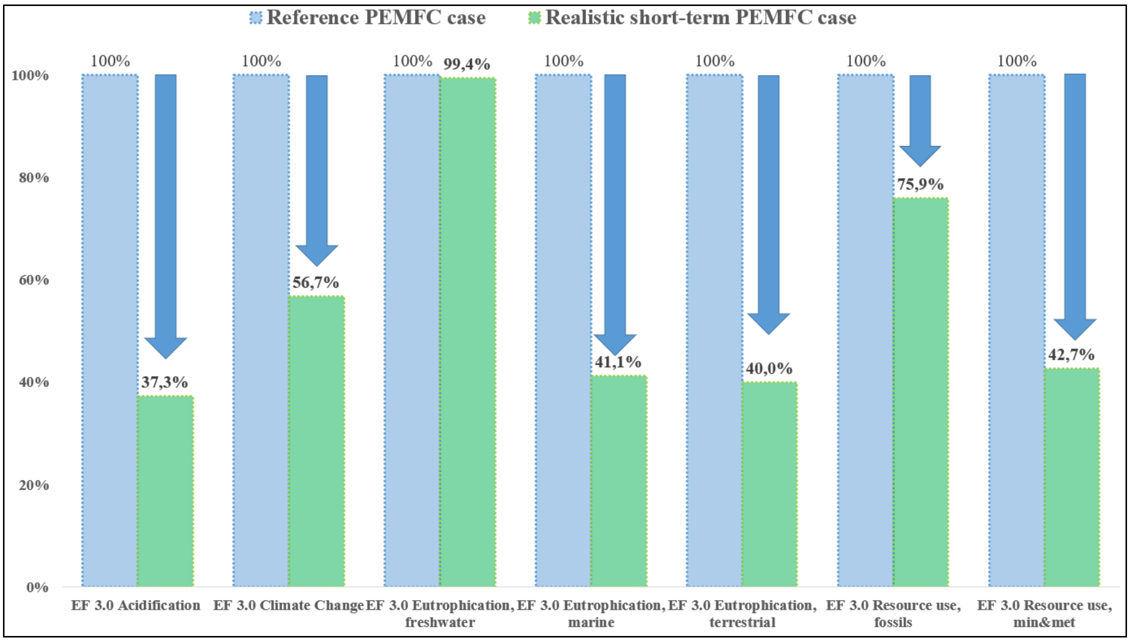


Fig. 4. Relative reduction of environmental indicators for realistic short-term PEMFC concept compared to reference PEMFC case (100%)

CONCLUSIONS

The work presented here, as part of the EU eGHOST project, demonstrates the importance of potentially reducing the environmental footprint using eco-(re)design strategies for fuel cell and hydrogen technologies, which will serve as a starting point for further guidelines. A realistic short-term concept designed for 48 kWel PEMFC reference stack is presented, and the comparative analysis of the environmental impact indicators of the reference and realistic short-term PEMFC cases is evaluated with the environmental life cycle assessment. The main hotspot in the reference PEMFC case is Pt and the Pt-related measures addressed, highlighting the importance of using a low Pt loading and the new opportunities for recovering Pt from end-of-life FCH technologies. The environmental impact indicators are significantly reduced by an average of 43.2% for the realistic short-term PEMFC case compared to the reference case (current state of the art). The total CO2 eq. emissions were reduced by 43.3% or 520 kgCO2 eq., which in the end amounts to 680 kgCO2 eq. per PEMFC stack, compared to 1200 kgCO2 eq. for the reference PEMFC stack. The results presented in this paper show great opportunities and example of how eco-design for PEMFC products can be envisaged and incorporated at early stages of product development.

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Session 3

Designing and Maintenance

CONNECTION AND COMMUNICATION IN THE CLUSTER OF BUILDINGS AND MECHANIZATIONS MAINTENANCE FOR THE REGIONAL COOPERATION

Krešimir Lacković[1], Zlatko Lacković[2], Milan Ivanović[2]
[1] University of North, Centre Koprivnica – Croatia
[2] Panon – think tank for strategic studies, Osijek – Croatia
e-mail: kresimir.lackovic@unin.hr

Abstract: The paper discusses the possibility of information and communication links between activities related to maintenance in the construction sector in the Western Balkans. However, the precondition for this connection is the organization of clusters at the national level so that as many companies as possible are involved in regional cooperation. The development of information technologies enables local and regional connections. The common goal is to inform each other for the purpose of business development and competitiveness. In the regional sense, the areas of interest are parts of the Bosnia and Herzegovina, the Republic of Croatia and Republic of Serbia. In practical terms, an information and communication model of regional cooperation with clear objectives is proposed.
Key words: Information, Cluster, Maintenance, Construction

INTRODUCTION

In the global economic world, there is a tendency for information to connect different actors for the purpose of sustainable development and competitiveness. In this sense, groups already established in most European countries are known as clusters. On this occasion, the starting point of research is maintenance activities that have their place in all economic systems. In essence, these are economic activities, mainly technical occupations that deal with ensuring the functioning of various technical systems. This primarily refers to the maintenance of machinery and equipment, electrical appliances, installations and complex systems, agricultural machinery and machinery, buildings and machinery, and information hardware and software and other technical systems. In the teaching text, special attention will be paid to the maintenance of buildings. The reason for this starts from similarity of business problem and technical characteristics provide the conditions in construction, and thus in maintenance.

With the development of technique and technology, there is a need to improve maintenance activities. Such tendencies favor certain legal solutions in all European economies that enable groups of similar goals and problems, ie clusters. For now, there is no evidence of the existence of clusters from the maintenance business, so this is becoming an increasingly interesting area of research. Special emphasis should be placed on the fact that these activities are not competitive in a regional, non-national sense with regard to the market in different systems. In this case, it refers to the markets of Slavonia and Baranja - within the Republic of Croatia, the market of Vojvodina within the RS and the northern part of Bosnia and Herzegovina. Namely, the companies that deal with maintenance are of a local character, so they are not in direct competitive relations, so there are no obstacles to cooperation in mutual information and development.

Research shows that the formation of clusters, especially in the Republic of Croatia and the RS, has reached a solid organizational and legal regulation, so there is a basic prerequisite for the formation of regional clusters in this case from technical maintenance. Of course, the goal should be in the organizational sense something absolutely of common interest, and that is certainly mutual information and development of activities. Therefore, this paper deals with maintenance activities and their specifics, information system and common information point where all economic entities are able to communicate and inform each other, and there are technical possibilities for this. Defining the organization and functioning of information and communication activities sets the technical and organizational solution for regional cooperation in the field of maintenance.

In the next part of this paper, special attention will be paid to the basic elements of maintenance of buildings and machinery, clusters as institutional aspects of regional cooperation and information system for joint relationships with clients and other business partners and all companies in maintenance. It is the common information system that can contribute to the intensification of research and application of new achievements in the development of techniques and technologies, as well as applications in the field of maintenance.
Different scientific methods have been used in the research and definition, and as a result, an information system is proposed that uses various development achievements in the field of information and communication sciences.

SPECIAL MAINTENANCE FEATURES OF BUILDINGS

The maintenance of buildings is regulated in all countries of the region by certain similar legal regulations, and in the Republic of Croatia, according to the Ordinance on maintenance, the maintenance of buildings includes:

1) Regular inspections of the building or its parts, at intervals and in manner determined by project of building and a written statement of contractor on work performed and conditions of the building maintenance, this Ordinance and /or special regulations adopted in accordance with the Construction Act, devices and installations and other and with a service plan within the deadlines prescribed in the guarantees of the manufacturer of installed products,
2) Extraordinary inspections of building or its parts after an extraordinary event or after an inspection,
3) Performance of works by which the building or its part is retained or returned to the technical and / or functional condition determined by the project of the building or regulations and acts for construction in accordance with which the building was built,
4) Keeping and keeping documentation on maintenance of the building: in the continuity of ordinal numbers listed and compiled on the day of creation records with attachments on regular and extraordinary inspections and work performed in order to preserve the designed basic requirements for construction, functionality and safety of the building in use [1].

Assuming that this matter is regulated by appropriate regulations in Serbia and Bosnia and Herzegovina, similar problems arise in the maintenance of buildings as well as types of work. In addition, the maintenance of buildings is usually organized either independently or with the help of a company that is at a shorter geographical distance. In addition, such companies in the region are not burdened with mutual competition, so this creates opportunities for communication and information in order to develop and increase quality. In this sense, it is necessary to set up an organization of information and communication system through which to communicate. This communication would have two basic common goals. This primarily refers to mutual communication for the presentation of new maintenance methods, the use of new technologies in terms of means of work, equipment and materials. Another extremely valuable activity is public relations in order to inform users in the region about all innovation achievements in the region. In the era of high level of informatization, a common way of informing and communicating should be devised, i.e. the organization of the information and communication system of the cluster should be set up.

CLUSTERS-RESEARCHED EXPERIENCES

A cluster is a form of strategic alliance or group of related companies or associations of producers from one branch, including producers of raw materials, as well as governmental and NGO and scientific and educational institutions that solve common problems and improve business above-average competitiveness and promotion at home and abroad [2]. Analyzing the above definition, it can be concluded that the following reasons for the formation of the cluster are:

- Affinity of the company in terms of type of activity.
- Solving common problems.
- Improving business through innovation.
- Increasing competitiveness.
- Promotion through information and communication relations, especially in relations with the rest of the public.

Analyzing the stated reasons for formation of cluster, goals of participants in cluster can be identified, such as increasing competitiveness and better use of own resources. Support for companies by scientific and educational institutions and links with development finance funds should also be added. Given this cluster formation is a strategic move oriented to the global market. In order to consider a topic, it is necessary to explore certain experiences related to clusters in the region to which this applies. In this sense, there are already some regional experiences. According to information from a specialized conference held on the island of Brač clusters are tools through which small and medium-sized companies become more competitive in foreign markets [3]. At the conference, participants from the region (Croatia, Serbia and Bosnia and Herzegovina) presented a number of interesting analyzes, criticisms and proposals, highlighting the following:

- Tomislav Radoš, Vice President of the Croatian Chamber of Commerce for Industry and Information Technology, believes that the main problem in Croatian clusters is poor communication and noted that the establishment of 13 clusters has just been launched in order to increase competitiveness.
- Danka Milojković, director of the Cluster House from Niš, pointed out that the sustainability of the cluster depends on; sustainability of members, managerial management and public sector support, but also on national economic strategy.
- Marko Šantić, President of the Chamber of Commerce of Bosnia and Herzegovina, says that there are no clear state strategic documents there in order to organize and support clusters.
- Jacques Viseur Communication Manager from the Laboreuropean Cluster Collaboration Platform stressed the importance of clusters in national economies but also the need for international communication and cooperation for development and competitiveness.

In other countries of the wider region there is some experience in organizing clusters, such as in Slovenia it is the approach of "dynamic concentric circles" or grouping smaller companies around large companies. Similar gatherings are taking place in Hungary around the world's multinational companies. Slovakia's goal is to explore the possibilities of local connections of related smaller companies. In Poland, a special goal and interest is to connect with world high-tech centers for the purpose of developing products and services [4].
From the previous information it is evident that there is a desire and need for cluster organization and their international connection, especially when there is a high degree of similarity in product type, organization and the need for mutual information for development and competitiveness. Therefore, on this occasion, the activity of maintenance of buildings was chosen, especially for group housing and other infrastructural activities. Such buildings in the region have similar maintenance problems and can exchange knowledge and experience through information and communication links in order to increase the quality of activities. The common interest of construction maintenance activities is certainly mutual information and communication. This means that an information and communication system should be set up, and a common approach to the relations between clusters and their partners should be built on that.

INFORMATION AND COMMUNICATION SYSTEM OF CLUSTERS FOR MAINTENANCE OF BUILDINGS

Organization of information and communication process

Maintenance of buildings in particular is an activity that has a tendency to long-term cooperation with customers or clients. This stems from the need for the maintainer of the facility to be well acquainted with all its characteristics, because only in this way can an efficient service be provided. In order for each maintainer to be able to communicate effectively and permanently with clients, he must establish a minimum information system or organize an information process with his business environment. In modern conditions, Figure 1 shows one possibility of a communication system that is suitable for the maintenance of buildings. A developed web or portal is the main starting point from which the user starts when connecting to the Internet, so opening a web portal is the minimum that every entrepreneur

should do [5]. Once the market segment or group of clients with whom it will cooperate in the long term is determined, we move on to personalizing the website. This means that information important to each other will be delivered to each important client. Once the clients for long-term cooperation have been defined, a blog is opened that enables constant asynchronous information with relevant information. Modern dynamic blogs are interactive that allow visitors to leave their comments [6]
The information process can be extended through an application known as a forum. Forums perform a function similar to that in bulletin board systems, which were first created in the late 1970s. Early web forums date back to 1994; so many alternatives have been created. A sense of virtual community often develops around forums that have regular users with a large number of topics. [7] This enables the exchange of written information between each entrepreneur and his clients as well as the general public. This is followed by a video conference that connects individuals and groups through telecommunications networks and video technology so that people have the impression of attending meetings simultaneously in the form of a live video link on a computer monitor. [8] Defining video conferencing enables discussion with several participants, and with the help of social networks, the information and communication process is professionally developed in accordance with the needs of clients. As the highest level of communication and management with clients, a set of methods and business processes called CRM (Customer Relationship Management). [9] In technical terms, this is done through the organization of a single contact center that has the following functions: [9]

- Providing marketing information and answering inquiries.
- Receiving requests for services.
- Receiving problem reports, complaints and customer complaints.
- Providing insight into the status of customer orders.

In order to better connect with their clients and the rest of the public, every entrepreneur-maintainer can open one of the social networks. In that sense, Facebook, as the most downloaded mobile application of the decade, from 2010 to 2019, enables better connection of immediate participants in maintenance. [10] In addition, opening Instagram can help promote commercial products and services. It can be distinguished from other social media platforms by its focus on visual communication. Instagram marketing is an effective way to advertise a product, given that an image is said to speak a thousand words. The platform can also help commercial entities save on branding costs, as it can be used for free even for commercial purposes. [11] There is also specialized software for this kind of professional communication - e.g. Trello (Fig. 1).

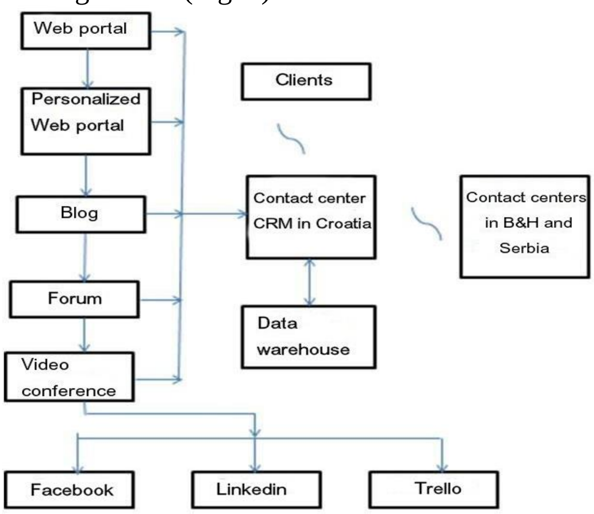

Fig. 1.

Cluster-public relations

Given that there are information and technical possibilities for connecting contact centers in the region, regional information and communication cooperation can be achieved. Figure 2 shows three contact centers that can connect three companies or three or more national clusters. A higher level of integration is the harmonization of national regulations and the formation of an interregional cluster (Fig. 2).

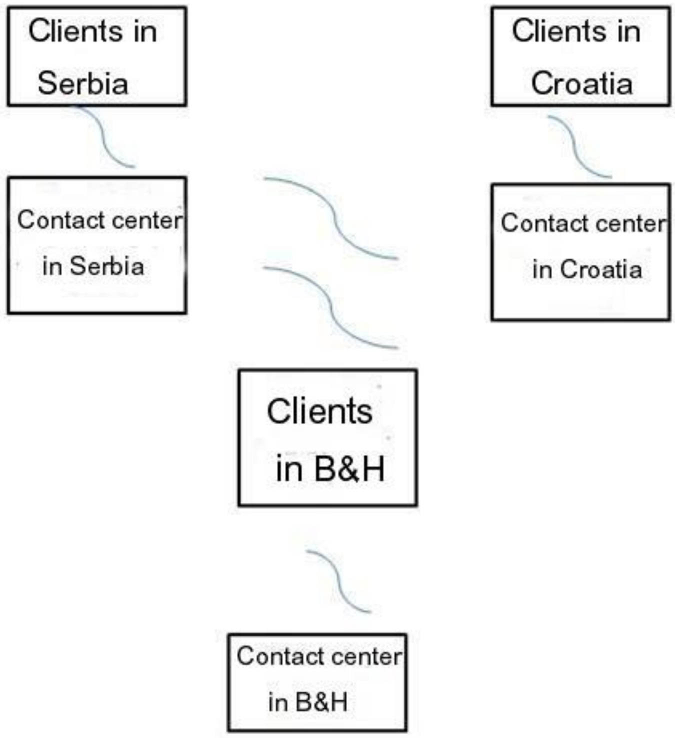

Fig. 2.

There are no obstacles to regional cooperation, given that companies in the field of maintenance of construction facilities are of a local character and are not in direct competition. The main reasons for such regional cooperation are the following:

- Mutual information on all innovations in terms of new tools, materials and working methods of common interest.
- Increasing labor productivity and quality levels.
- Harmonization of national regulations with international regulations in the field of maintenance.
- Analysis and harmonization of working conditions of related companies in the region.
- Mutual exchange of other relevant information related to the wishes and problems of clients in the region.

CONCLUSION

Previous considerations show that there is a need but also technical possibilities for connecting economic entities in the region. In order to increase the representation, it is proposed to first form a cluster for the maintenance of buildings, because these are companies that are local type and are not in conflict with strong competition. After such grouping, the next phase is to connect clusters in the region (Croatia, RS and BiH) and their common interest is to inform and develop activities. Given the possibilities of the mentioned CRM, there are no obstacles to regional cooperation. Thus, all companies retain legal personality as well as clusters in individual countries, but the possibility of cooperation opens up where topics of common interest are discussed. In this way, interregional cooperation is achieved, which can make a certain economic contribution and a small political and regional incentive for cooperation.

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APPROACH TO DEVELOPMENT OF THE LEAN CONCEPT PROJECT

Bogdan Marić[1], Vlado Medaković[1]
[1]University of East Sarajevo, Faculty of Mechanical Engineering East Sarajevo, East Sarajevo, Bosnia & Herzegovina
e-mail:maricbogdan@ues.rs.ba, vlado.medakovic@ues.rs.ba,

Abstract: We are on the threshold of joining the European Union (EU) and our business environment is experiencing a severe economic and financial crisis, which is a part of the global crisis. Based on the fact that mental and technological creativity grows just in times of crisis, the Lean concept is gaining recognition and becoming a challenge to future scientists, researchers and entrepreneurs in our country. Inspired by the Japanese automotive industry, it is synonymous with a good way to get out of the crisis. The time of crisis in giving us the best time to develop the strategies of work process improvement and the application of Lean concept. The crisis facilitates the use of new paradigms with completely new mental models in the business of organizational systems. This concept provides a focus on people, their training in work processes, teamwork and continuous improvement. They are crucial for the efficiency level in the use of key resources: people, techniques, property or capital invested in human labour performance.
Key words: Lean concept, principles, methods, tools, effectiveness, efficiency, project of lean concept

INTRODUCTION

We live in a time of crisis and economic recession when all companies, of all sizes and shapes, from industrial giants, medium and small enterprises, to the micro-organization of companies, are faced with challenges to their own survival. In these difficult and complex times of recession and financial crisis, the usual actions of management in leading a company are to reduce costs and waste in all its forms. Therefore, company managers do not usually choose new business programs nor accelerate programs that are under development.
Major changes in the management have resulted from the crisis, affected by large and developed countries, modern scientific and technological progress in the field of computer science, new technologies, new materials, energy development, and communication development, directly influencing each company. Thus, we can no longer talk about running business under stable conditions for a long period of time, but the business in terms of constant changes.
Today's management structure and managers should first know how the company generates profit and then redesign those activities. Toyota's struggle for survival has resulted in the discovery of appropriate programs, principles, methods and tools for the implementation of the Lean concept. Recently, during the crisis, the Lean concept has become the philosophy of efficient business and has increased the interest of businessmen and scientists in the processes of its introduction and implementation. Through systematic and continuous Lean programs and establishment of business under the Lean environment conditions, we achieve: flexibility and willingness to start production to the demands of customers – the market; better utilization of space resources – layout; better utilization of human resources; continuous increase of knowledge and understanding; the change of the organizational culture and faster identification of workers with work processes and the company and so on [3,4,6,14].
In times of crisis, Lean implies abandoning the reactive management style in which time is spent dealing with emergencies and it totally accepts the proactive management style in which all available time is devoted to solving the root causes of the inefficiency of systems and processes. It takes a lot of effort for an enterprise to become Lean – long-term, flexible and vital in providing the customer with the full value of products or services. The customer wants the product or service with the highest efficiency, lowest cost of procurement and maintenance during exploitation. It is necessary to establish a continuous process of constant systemic identification and elimination of unnecessary work processes and business waste, everything that does not represent a value from the customer's perspective. The constant systemic elimination of activities that do not create new or additional value

to a product or service is a challenge to the survival of any organizational system. Because of all this, it is becoming a challenge for human resource management studies, and the Lean concept holds all the answers.

LEAN CONCEPT

Over the last few decades of the 20th century, Lean production as a source of improvement of effectiveness in work processes was getting more and more importance day by day. Lean production has initiated the development of this kind of approach and has generally been a breakthrough into more significant process analyses towards the improvement of production and factory layout in which products are being manufactured. It has changed the way the participants in the work process think and behave and created a state (environment) where the work management is done: the work process, waste elimination in the process of work, constant training of employees at all levels and functions in order to achieve shorter delivery times and cheaper products. In this way, the companies create an environment that represents the Lean concept or doctrine in the way of organizing and managing businesses.

In the late 1980's, the Massachusetts Technology Institute (MIT) studied the International Program on motor vehicles. In this research, it analysed automakers comparing the United States, Europe and Japan. The book “The Machine that Changed the World” [11] was based on this project. It practically presented the term ‘Lean manufacturing’ in America. The authors concluded that in Japan, streamline processes and ways of organizing production systems were credited for its success. They found that a mixed system based on keeping minimum stocks and maintaining high quality was the basis for the success of Japanese manufacturers, particularly Toyota. Babson [1] noted that there are similarities with TQM, although many analysts had already pointed to it. Even though they popularized the term “Lean” to describe the Toyota production system, authors of the MIT study initially presented many of these ideas to the West. In fact, many books written before Womack's represented different characteristics of the concept. For example, Ohno, Japanese architect of the Toyota production system, wrote “Toyota Production System: Beyond Large-Scale Production” [9]; Shingoe’s Study of Toyota production system from the perspective of industrial engineering [8]; Goldrat and Cox published the first edition of “The Goal” (1984); Schonberger wrote “World Class Manufacturing” [7] and so on. However, the book "The Machine that Changed the World" was very popular with executives and highly sought after document for Lean production systems. Another book written by authors Womack and Jones, “Lean thinking” [12], offered an alternative way of applying Lean production. It deals with companies outside the automotive sector which have successfully implemented this principle.

Lean Manufacturing: Tools, Techniques, and How to Use Them [10] is based mainly on designing efficient and effective operation of manufacturing processes that are applicable, flexible, consistent and sustainable in time and space. The labour force was foreseeable and entrepreneurial. Lean production creates a system based on real customer’s needs and continuous improvements in all work processes. In this way, the labour force is being developed and trained in the use of Lean tools and methods necessary for the achievement of the objective function of the production system and its rise to the world class level.

Womack argues that the Lean concept must be a meaningful concept adopted in the enterprise, in all functions, to see improvement and maintain a system of designed objective functions. A segment or organizational-functional understanding of the application of Lean concepts, principles and its actions lead only to a small improvement compared to the effects of comprehensive application.

THE PRINCIPLES AND TOOLS OF LEAN CONCEPT

In their book “Lean Thinking” [12], move further from the specific functional approach in the design of production systems and establish the five principles of Lean manufacturing:

- Value - focus on customers (the ability or possibility to meet customer’s requirements at the right time and for a reasonable price)
- Value stream - effective and efficient work processes (the specific activities necessary for designing, commissioning and provision of certain products from concept to production, from

order to delivery, from raw materials to the customer's hands. It is, in fact, the flow encumbrance profile, i.e. process from an idea to finished product to buyers in the market),

- Flow - continuous flow (the full realization of tasks during the “value stream” work process, so that the product passes the process from design to its launch on the market, from order to delivery, from raw materials to customer’s hands, without stopping, without scrap, poor quality and without overloading the work process)
- Pull – starting the production to costumer’s request (production and delivery of products to customer’s request, in which case there will not be any production without their previous request,
- Perfection - perfection in work (complete elimination of waste where high values are achieved during the “value stream”). Today, many companies include these principles, but usually only in some of the functions, and less frequently in all functions. These five principles lead the companies to the understanding of the Lean approach because their common use of all production system functions can significantly increase production.

To enable the implementation of the whole Lean concept, there is a set of tools (Figure 1) which have to be used within the company. Besides the tools shown in the figure, it is possible to create and design other tools that for certain conditions provide better results (with tools and methods, for a more detailed description of lean tools and methods see [2] and [13]). If we represent the tools used in the procedures of Lean concept design as a house – a firm creation of human work, and if we should explain the Lean concept as parts of the house, then the supporting pillars would be Just-In-Time and Jidoka (or making quality at source).

The foundations of such a house would be Lean philosophy, visual system control, stable and standardized processes, and balanced production. The house would be held by teams through teamwork with the aim of continuous business improvement.

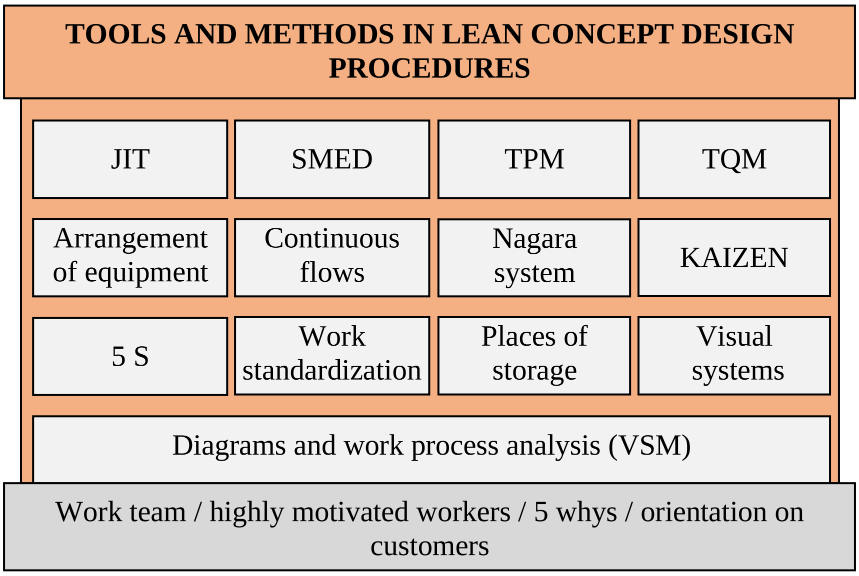


Fig. 1. Tools in Lean concept design

FROM AN IDEA TO PROJECT LEAN CONCEPT

Design of a Lean concept starts after the management's decision that work processes within systems must be changed in order to achieve greater competitiveness in the market. Its design is a complex process of state analysis and synthesis of those elements into a whole that will bring the greatest benefit to the industrial system. The design procedure consists of the following stages:

The first stage: *preparation for designing*. This is the stage where as a result of sets of activities we make certain proposals, conclusions and decisions:

- identification of key losses, errors, problems and guidelines for their solving,
- defining the terms of reference and their goals,

- time framework for the completion of all activities,
- the appointment of a team to implement the whole project,
- the decision of management to introduce the Lean concept.

In fact, it is the process of assessing the need to switch to the Lean concept and determining the current state of the industrial system. States and views on the necessity and importance of the changes must be critically represented. After the changes had been introduced, the next step is to publically present the expected results.

They motivate (drive) employees to pun in greater effort. Motivation, persistence and management of change-inducing processes play a key role in the successful development of the Lean concept. If individuals or most employees are not motivated to change, if there are no signs for the next steps after the changes and if, above all, there is no persistence to endure the great challenges in the way of building the Lean concept, it is better not to start at all.

The second stage: *diagnosis of the current state*. This is the stage in which output documents of the previous stage are used as input, and concrete suggestions and conclusions compiled in a diagnostic study of the current state are considered outputs. This study should include:

- the diagnosis of the application degree of Lean principles, methods and tools,
- the possibility of the Lean concept implementation,
- the strategy of the Lean concept implementation: terms of reference with all proposals and activities and a detailed timetable.

The terms of reference need to define the objectives and results, while the timetable should identify the main stages of the project, the planned deadline for their execution, and many other details related to the realization of the defined framework. The team also need to skilfully use modern information technologies and application software that support the planning and scheduling of the individual stages of the project. Thus, individual project stages or segments can be entrusted to one part of the formed team.

The terms of reference and the timetable should also be accompanied by the following supporting documents (they are considered to be an essential part of good project practice):

- the framework chart of the required steps and work procedures with objective deadlines for implementing the Lean concept,
- project protocol (timetable for team meetings, place, duration),
- organization and project team members,
- established rules and responsibilities,
- ways to identify and address potential risks,
- teamwork rules,
- terms of reference (efficiency indicators, list of financial costs),
- table of results (catalogue of project results, actions, deadlines),
- the team register.

Terms of reference and the timetable created by the team are the first documents of the plan for the Lean concept introduction. These documents should be approved and signed by the top management to minimize the risk of failing to carry out the implementation process of such a project. Therefore, the announcement should be represented at all meetings of the industrial system functions.

The third stage: *design of the Lean concept model.* This is the stage where the team from a set of activities creates a study that includes specific variants of the model and financial costs of its implementation. The study should include:

- general assessment of the future economic conditions,
- deficiencies in the existing activities and concepts of loss reduction,
- application of the principles, methods and tools across the Lean concept elements (procedures and instructions),
- economic analysis assessments of the application effects of principles, methods and tools, the financial plan for the implementation of the whole project.

This stage is the most complex part of the project. Here, the state assessment and observing are done in a more detailed way in order to shape certain models of the Lean concept.

The first step: state assessment for Lean concept introduction (Figure 2). It is a process of state identification by individual work processes and one by one production program from the standpoint of the Lean concept. At this stage, the team should try to identify where the suitable areas and business focal points are. They start by writing a plan that includes methods and contents of work in all elements of the Lean concept that improve business.

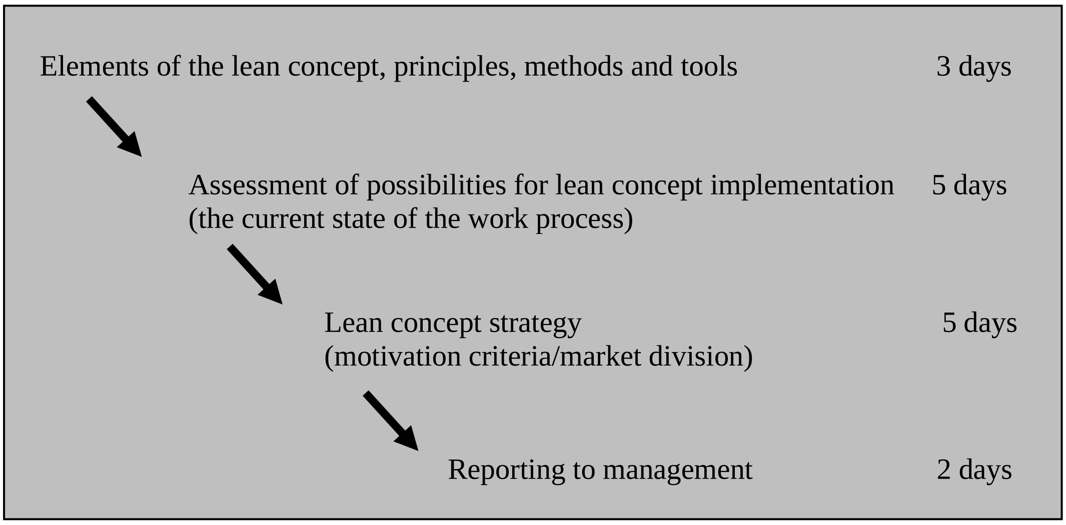


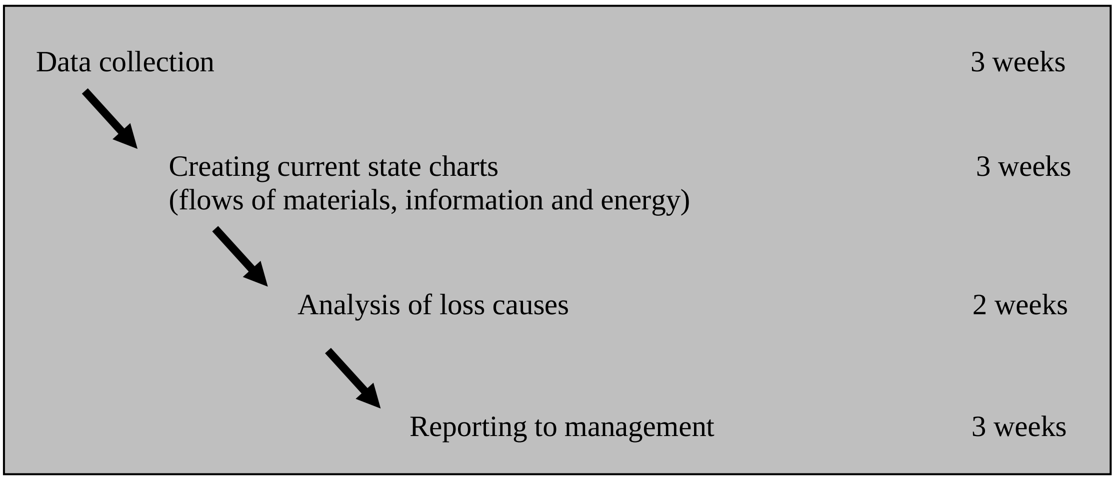
Fig. 2. The first step: The assessment of possibilities for Lean concept introduction

The team must have the strength to use all five principles of the Lean concept in all five of its elements: flows, organization, control, measurements and logistics. In each element, Lean principles are analyzed: identifying the value that the customer considers to be important (value), identifying the section of flow loads (value stream), homogeneous flows of materials, information and energy (flow) and process perfection (perfection).

The second step: system state recording (Figure 3). The recording provides a basic assessment of where the system is currently.

At this step, the team:

- conduct the analysis of the process value,
- analyze the process linking through flows of materials, information and energy,
- make charts of the work process,
- assess where there are opportunities to eliminate wasted time,
- shape the planning criteria to market requirements,
- create a sketch of the supply chain (supplier-input-process-output-customer - SIPOC), charts of all major work processes to understand the relationship customer/supplier and required inputs and outputs that activate these processes,
- analyze the levels of current losses and errors and perceive opportunities to eliminate what is unnecessary,
- develop a list of quick actions for short-term progress and demonstrate activities that will provide rationalization.



Fig, 3. The second step: State recording

The third step: shaping the future state. This project step begins after the acceptance of the management report on step 2. It is based on shaping the future state that gives greater effects (Figure 4). This process usually takes two to three weeks and includes:

- identifying the groups of products that are profitable and competitive on the market,
- harmonization of system conditions with the project,
- analyzing the range of product requirements and the flow of materials and information,
- team training of employees in the use of tools and methods of the Lean concept,
- process development of the new management requirements for the performance of other functions of industrial system in terms of logistics for the Lean production.

When the proposal of one part of the project relating to the future state is approved, the team focuses on the other part of this step for another three to four weeks, i.e. the formation of Lean concept details. The formation of details includes the following:

- staff plans in all functions across the industrial system,
- presentation of work units in the schedule,
- actions to be performed during the transitional period,
- the implementation plan of activities with short-term and long-term effects of the planned improvements,
- the role of layout reconfiguration and accountability for its consistent implementation,
- charts and tables of the effects on notice-boards,
- a plan for training employees to implement the work process,
- a plan of communications in the industrial system.

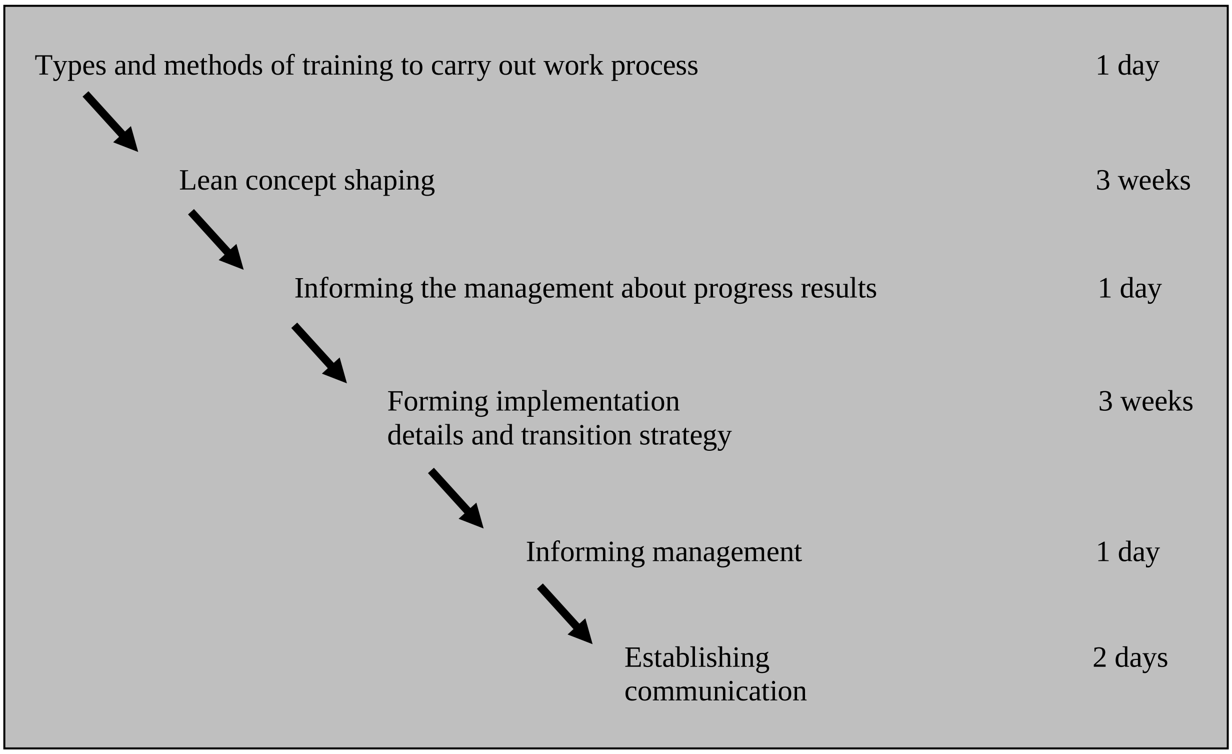


Fig. 4. The third step: Shaping the future state

This plan of the future state is presented to the management for approval. The conversation in terms of plan implementation has to be done with all employees, explaining what was observed, who is involved, what was decided, what the aims of the organization are and what all employees involved in are. At this point the project team reach the fourth step.

The fourth stage: *application of the designed model.* This is the stage related to the introduction of the Lean concept project into the system. It contains the following activities:

- financing the activities defined in the study,
- direct application and the establishment of work process standards to eliminate losses through the principles, methods and tools,
- establishing communication and training of employees,
- measurements and monitoring procedures for the selected characteristics,
- shaping the final work process standards.

CONCLUSION

The Lean concept represents a group of efficient and rational procedures in the systematic use of principles, methods and tools in industrial systems on finding and eliminating wasteful activities (losses and errors) in the working processes, thereby creating the necessary conditions for harmonious activities of functions in a company in the given time and in the existing conditions of the environment. Its implementation leads to efficient and effective procedures in working processes which have to be improved, standardized and accepted as models in performing working processes leading to the achievement of high competitiveness and business excellence in work. This contributes to the TQM system by establishing and integrating standard management systems, as well as applying adequate tools for increasing efficiency.

To implement the Lean concept in industrial systems, a number of evaluations provided by the management are required. Its implementation depends on people, i.e. the team selected by the management. To make any team successful in its task of developing and introducing the Lean concept, the management must answer the following questions:

- Is it possible to hire three to eight people for the period of six to nine months?

- Is it possible to handle failures and mistakes before achieving success and complete the implementation of improved production through the Lean concept?
- Is it possible to maintain work team members' participation even when they do not see significant results after two months?
- Is it possible to maintain the engagement of employees in work teams to the final implementation of the project?
- Is it possible to stabilize production in one, two or three weeks?

Additionally, the management should ensure: the time required for project implementation, funds for the project, personnel, full-time project team (team focused on the task), full performance control of certain stages and steps of the project and approving the following activities of the team.
By establishing the Lean concept, the very principles, methods and tools which contribute to efficiency and effectiveness of working processes are being affirmed. It creates a productive climate in industrial systems and a good foundation for further improvements of TQM. The final result is overall satisfaction of employees, users of products or services and society in general.

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REPAIR PROCEDURE OF CORE CASTING MACHINE-SHALCO U180

Eleonora Desnica[1], Dragan Brkin[2], Mića Đurđev[1], Ivan Palinkaš[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
[2]Metalotehnika Group DOO, Kikinda, Serbia
e-mail: desnica@tfzr.uns.ac.rs

Abstract: This paper presents a procedure in overhaul of casting machine Shalco U180. The machine was dismantled. All key elements of the machine have been carefully inspected. Reparation was done on all elements it needed. Parts that have been damaged and cannot be repaired have been replaced. After assembling, tests for its functionality has been done to ensure full operational state of machine.
Key words: Shalco U180, core cast, disassembly, reparation

INTRODUCTION

There are many machines in the casting industry whose interruption can affect the operation of other machines. For example, when considering foundries that cast aluminum, we have aluminum melting furnaces, furnaces for maintaining aluminum in liquid state, casting machines, sand core making machines, etc. Due to the interdependence of machines, as well as smooth production, maintaining them is crucial. [1,2] Maintenance in casting factories or foundries can be divided into:

- Preventive maintenance
- Regular overhaul
- Emergency overhaul or intervention.

Preventive maintenance involves the regular monitoring of the condition of machines and tools in order to eliminate possible malfunctions and damage in advance. This type of maintenance is performed on a daily basis, with shifts when production is reduced. [3,4]
When the casting of a particular batch of castings is completed, a planned, regular overhaul of the machine can be started. Regular overhauling is performed to replace worn out assemblies in order to bring the machine into a fully functional state safely for operation. Scheduled overhaul is usually done once a month, but if preventive maintenance is effective then regular overhaul is done annually or once in few years. The length of the overhaul depends on:

- complexity of worn-out elements and assemblies,
- the time that takes to build a new one, if it's not available on stock,
- time required for disassembly and assembly,
- the time it takes to bring the machine to a safe state for repair (e.g. melting furnaces). [5]

An emergency overhaul involves an immediate intervention of the fault. Whether or not due to preventive maintenance failure, there can be various malfunctions that stop the casting process. As longer the break in casting process the losses increase, it is critical to eliminate the failure as soon as possible. At best, a replacement part can be found in spare part warehouse, and the failure is eliminated quickly and efficiently. The worst case is when there is no replacement part and it is necessary to make a new one. In this case, production stops for a given batch of castings and a new one is started to minimize the cost of stopping the casting. [6,7]

SHALCO - MODEL U180

Shalco U180 is machine designed for making small and medium sized sand cores. There are two basic types of machine model:

- model with electrical heaters, and
- model with gas heaters

The main difference between the models is the way the tool is heated. One, as the name explains, uses electricity to heat tool, while the other model uses gas.

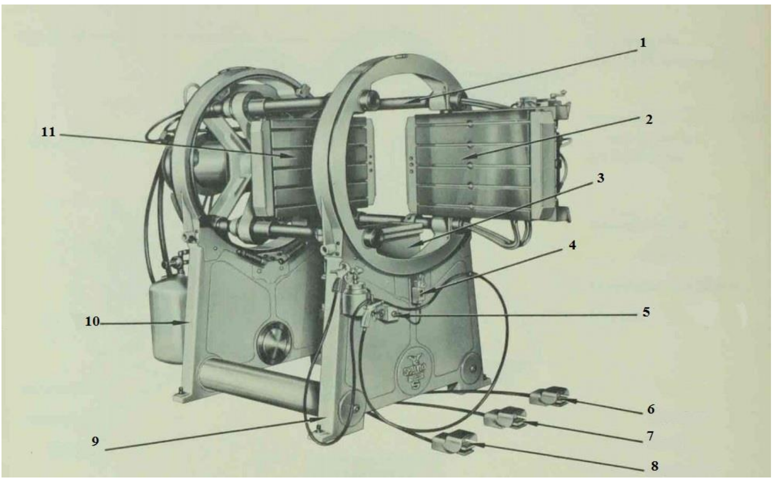

Fig. 1. Shalco U180 from operators side– taken from the manufacturer's catalog [8]
(1. Guide axles; 2. Door with the heating plate; 3. Sand mixture chamber; 4. Air pressure limit switch; 5. Emergency stop switch; 6. Foot switch for vibrator – not always used; 7. Foot switch for start cycle; 8. Foot switch for extruders; 9. Front base stand; 10. Back base stand; 11. Moving heating plate)

The principle of operation of the core making machine Shalco U180

The principle of operation of the Shalco U180 core making machine will be explained through the explanation of one cycle of operation. Core build cycle:

1. The door with one half of the tool is closed first;
2. Then, using the two pneumatic cylinders, the door locks;
3. As the door are locked then the other half of the tool, mounted on the movable heating plate, is pressed on. For this tool closure large pnaumatic cylinder is used;
4. After the tool has been closed, a tank of sand mixture for making the core, is raised, which is also tightly connected to the tool;
5. The rotation around 180° of the horizontal axis of the tool follows;
6. When the actuator is activated, it activates a solenoid valve that releases compressed air in the sand tank, injecting that sand mixture into the tool by filling the pressurized material firstly on the walls of the tool, following all the tool cavities;
7. When the sand is accelerated in the tool, the baking core begins to rotate and the tool rotates around its horizontal axis in its original position, ie. 0°;
8. After completion of the baking cycle, the tank is separated from the tool;
9. Then, using large pneumatic cylinders, one half of the tool opens, keeping the core in the other half of the tool;
10. When the moving heating plate reaches its end possition – tool fully open, then it is opened, then the door, on which the second heating plate is located, unlocks and it’s possible to open it;
11. By opening the doors of the machines, using the foot - switch, the ejectors are activated to push out cores from the tool so that the operator can easily and safely remove them;
12. Making the finished cores from the tool is followed with the cleaning of the tool with clean compressed air, and this complete cycle is repeated. [8]

OVERHAUL CORE CASTING MACHINE SHALCO U180 WITH EXTERNAL SAND RESERVOIR

A complete overhaul is a complete repair of all damaged assemblies and machine elements to restore the machine to a fully functional state. After the overhaul, the machine must be safe for the operator to operate and function smoothly and properly.

Dismantling core casting machine Shalco U180 with external sand reservoir [9]

Dismantling is carried out in the machine repair rooms, where all the equipment necessary for dismantling all the elements and assemblies of the machine is located. First, all the accessories connected to the machine are released. In this case it is an additional sand tank. The machine is then washed to remove all dirt and impurities. After detailed washing of the machine, complete dismantling of the assemblies and elements is ensured, which includes: dismantling of the protective armor; dismantling of electrical and pneumatic installations; dismantling the door with the heating plate; dismantling the rotating frame with guides; dismantling the sand tank; disassembly of gearboxes and electric motors.
After each assembly is dismantled and thoroughly cleaned, the technician starts the defect. First a visual inspection is performed, followed by a dimensional inspection, and the measurements are recorded in the checklists. The engineers responsible for overhauling a given machine, by comparing the expected and measured values, as well as by visual inspection of each element, determines the further course of operations. If possible, repair the damaged element. In the other case, the engineers give the order to create a new one, replacement element. Whether the old part can be repaired depends on the type and extent of its damage.

Dismantling of an additional sand tank

After the additional tank is released from the machine, an analysis of its elements follows. Visual inspection revealed that there was damage to the pneumatic cylinder acting as a valve. By running this cylinder, sand is passed to the tank of the machine. After disassembly of the pneumatic cylinder, damage to the sealing package was observed, which was caused by impurity and probably some sand content in the compressed air that drives the said cylinder.

Dismantling of the electrical and pneumatic installations

As the machine is freed from additional elements, it is followed by disassembly of the electrical and pneumatic installations, so that the machine subassemblies are easier to dismantle and later assemble. When dismantling the electrical installation, all the elements are carefully analyzed and those that need to be replaced are marked. Damages that occur on electrical installations of the machine are usually:

- broken or damaged power cable,
- broken or damaged control cable,
- damaged pressure switch,
- damaged inductive or capacitive sensor, i.e. switch,
- damaged solenoid valve.

Damages occurring in pneumatic installations are most commonly:

- damaged or clogged hose,
- damaged quick pneumatic clutch,
- damaged compressed air filter and regulator, i.e. preparation group.

Figure 2 shows the machine after dismantling the electrical installation.

Fig. 2. Machine after dismantling the electrical installation [9]

Disassembly machines door with heating plate

Figure 3a shows the heating plate on the machine door before disassembly. Visual inspection clearly shows damage to the gas nozzles. After dismantling the door, it was determined by physical measurement of the elements of this assembly that deformation had occurred due to uneven heating of the tool. Uneven tool heating is a factor contributing to the production of damaged cores.

Disassembly of the rotation frame with its guides

As previously explained, one heating plate is located on the door of the machine, while the other moves on the guides, ie. axles driven by a pneumatic cylinder (Figure 3b). The holder of that heating plate is tied to the bushes, one bushing per axle. Inside the bushing is a Teflon (PTFE) bearing, while at each end of the bushing is a wiper. The wiper serves to wipe away any impurities from the shaft along which the sleeve moves. If the wiper is damaged for any reason, then the sand comes in contact with the Teflon bearing. In that case, when the Teflon bearing is constantly influenced by sand, fine dust and temperature, causes damage to it.
When the Teflon layer is damaged, the Teflon bearing becomes a steel bushing which impairs or impedes the normal functioning of the machine, along the way causing damage to the shaft on which it moves.

a) b)

Fig. 3. a) Heating plate on the door of the machine b) Heating plate bracket on guide axles [9]

Disassembly built-in reservoir for sand mixture

Figure 4 shows the reservoir before disassembly. Visual inspection revealed physical damage to the guides, which led to uneven lifting, ie attachment of the tank with the tool. If the reservoir is not pressed tightly against the tool, there is a possibility that a mixture for making sand cores, will not reach every part of the tool cavity and thus cause debris.

Fig. 4. Built-in reservoir before dismantling [9]

The reason for producing bad cores in this case is extremely trivial. The pressure, the amount of air and the sand mixture are predetermined and if there is any gap between the tank and the tool, then there is a high possibility that leakage from the tool will occur when injecting the mixture into it. Then two possibilities arise:

- a smaller amount of the mixture was injected, which is less likely because the amount of sand required for the sand core is less than the amount of sand contained in the reservoir,
- the mixture does not reach every part of the tool cavity due to pressure drop before the start of the sand core making cycle.

Disassembly of gearing box and electric motor

Visual inspection revealed that there was little physical damage to the electric motor. Subsequent detailed inspection, after dismantling the electric motors and gearboxes, determined that the output speed was not in line with the value declared by the manufacturer. If the turning speed of the tool increases above the permitted limit, there is a high likelihood of damage to the steel chain, which was the case here.

Reparation, replacement and assembly [9]

In this specific case of overhaul the following was done:

- reparation of additional sand reservoir;
- replacement of rotating frame guides;
- reparation of heating plates;
- replacement of rotating frame steel chain;
- repair of sand tank on machine;
- replacement of gearboxes and motor of rotating frame drive;

As noted above, repairs are only possible over certain elements of the machine subassemblies. Certain elements must be replaced with new ones when damaged, eg. damaged bearing, steel chain, damage shaft, etc.

Reparation additional reservoir for the sand mixture

A detailed defect revealed the wear of the pneumatic cylinder sealing package, and the damaged package was replaced with a new one. The tank was sandblasted and then painted in the required color. After assembly of each element of this assembly, testing is performed to verify the correctness of the elements and the functionality of the assembly (Figure 5).

a)

b)

Fig. 5. Additional reservoir for sand a) before and b) after reparation [9]

Replacement of the rotating frame guides

A detailed defect revealed the wear of the sliding Teflon bearings inside the bushes were damage. As the worn bearing friction damaged the guide axles, it was necessary to replace all the axles. The construction of new axles has begun, as damage exceeds the tolerance limits. New Teflon bearings and wipers have been inserted into the bushes, the damage of which precedes the damage of these bearings.

Reparation and replacement of heating nozzle

A detailed inspection revealed the clogging of the gas nozzles, which are responsible for uneven heating of the tool, and therefore the bad sand core. Nozzle clogging is caused by impurities in the air, because gas is used in the mixture with air to heat to achieve a higher temperature.

Replacement of steel chain of rotating frame

A detailed defect revealed damage to the steel chain and replaced the old one with a new one (Figure 6).

Fig 6. Replaced steel chain [9]

Reparation of built-in reservoir for sand mixture

All visually observed cracks on the steel structure of the sand reservoir are repaired by treating the damaged spots with a manual angle grinder and then filling the crack by welding the material. Flange, mounted on the mouth of the tank, which is attached to the tool, is machined by grinding with a tolerance of up to 0.02mm.

Replacing and testing a electric motor for tool rotation

Testing of electric motors is carried out in several stages:

- First, the motor is visually inspected by a technician to determine if there is any physical damage to it. Physical damage may be minor, e.g. scratches or slight damage to the shield of the propeller, etc.;
- The motor shaft is then examined;
- When it is determined that the physical condition of the motor is within the permissible limits of normal and safe operation, it shall proceed to the motor insulation test;
- If the insulation is OK, then the phase ratio is determined, i.e. are the phases in balance. If the phases are not in balance, this means that the coils are not the same for each phase, which may, and may not, lead to the motor warming up and overheating at load;
- Upon successful completion of all tests and test run, the electric motor is paired with the gear unit, after which the electric motor and gear unit are ready for assembly (Figure 7).

It is also mandatory to replace the steel wheels on which the rotating frame moves.


a)


b)

Fig. 7. a) Electric motor with gear box before dismantling; b) Assembly of electric motor and the gear box [9]

Evaluation of repaired machine [9]

After the assembly of all assemblies and machine components has been completed, the installation of pneumatic and electrical lines is followed. This is followed by testing the correctness and functionality of all elements to avoid any omission.
After the machine has been tested, output documentation is compiled and the machine shipped. The output documentation lists all repaired and replaced parts with measuring lists.

Fig. 8. Shalco U180 after reparation [9]

CONCLUSION

The type and magnitude of malfunctioning of casting machines is highly dependent on the operators operating the machine. Preventive maintenance also has an impact, which should eliminate any malfunction that may occur in a timely manner so that production line does not stop.

The duration of the overhaul depends on the level of expertise and experience of the personnel, technicians and engineers performing the overhaul. Experience and a good supply of tools and spare parts speed up the process of disassembly and assembly of parts. A good team of experienced technicians and engineers often in the field without dismantling the entire assembly can eliminate many on-site failures, reducing costs due to production interruptions.

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BASIC ASPECTS OF DESIGNING EXPLOITATION AND MAINTENANCE OF GRAIN STORAGE

Jasna Tolmac[1], Slavica Prvulovic[1], Vladimir Sinik[1], Milan Markovic[1]
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e–mail: jasnatolmac@yahoo.com

Abstract: The paper presents the results of testing and analysis of the functionality of grain storage. The following parameters were identified: transport capacity, specific energy consumption, grain breakage, dust emissions, as well as system reliability. The aim of the paper is to indicate the key parameters and their influence on the functionality of grain storage plants. The paper presents groups and units of drive equipment for storages for granular materials, methods in the operation of modern (automated) storages, problems of occupational safety and environmental protection. The paper discusses the technological process of a real storage with three silos, each with a volume of 8300 m^3. The silos are equipped with conveyors for loading and unloading with a capacity of 300 t/h. Based on the test results, an analysis of the interdependencies of key parameters such as: transport capacity, specific energy consumption, reliability of system operation, dust emission and losses due to breakage of cereal grains was given.
Key words: grain storage, functionality analysis, transport capacity, designing, exploitation, maintenance.

INTRODUCTION

Grain storage is important for the processing industry and food production. In addition to the basic functions of preserving the quantity and quality of grain products, grain storage also performs a number of other functions:

- bridges the gap between the seasonal character of production and the continuous character of industrial processing,
- homogenizes and standardizes the stored quantities, thereby creating a marketable product of a defined quality level, etc.

Accordingly, it is necessary to design technical – technological systems for storage and transport that meet all legal and technological standards. The development of technology has conditioned the automation of the system, and therefore the increasing application of elements of industrial automation in capacities [1].

In this paper is given an analysis of the grain storage and transportation system. The operation of the storage is automated with elements of industrial automation.

The historical path of development of storage capacities in Serbia conditioned that the most of storage spaces were built and developed as auxiliary plants for processing capacities – mills, oil mills, starch mills, malting plants, and soybean processing capacities.

Such development trends have resulted in a situation where most storages place a dominant emphasis on the technical–technological function of the storage with the primary goal of providing a raw material base for processing industrial capacities.

In Serbia, there are built significant storage capacities for grain crops, which are well distributed in relation to the raw material market and the sales market [2].

MATERIAL AND METHODS

According to [3, 4], the drive equipment of the storage for granular materials (in addition to the completeness and functional layout of the equipment itself) must also satisfy a number of conditions related to its functionality, so that the storage system can function without downtime and interruption. The basic functional condition that the drive equipment for transport should have that it does not damage, i.e. that it does not break and scatter granular materials, as well as that it does not create a high

level of dust in the air when it is put into operation.
According to [5, 6], all machines and equipment should work within the range of operating parameters that are provided for that machine. All equipment should be set up, installed and put into operation according to the specification and operating instructions obtained from the equipment manufacturer, without any deviations, so as not to reduce the functionality of the equipment.
Display of groups and units of drive equipment for storages for granular materials is shown in Table 1 [3], [7].

Table 1. Display of groups and units of drive equipment for warehouses for granular materials

Loading equipment	• Fill in bag for road vehicles • Fill in bag for means of railway transport • Equipment for loading from means of water transport
Transport equipment	• Chain conveyor • Belt conveyors • Spiral conveyors • Elevators
Cleaning equipment	• Silo aspirator • Separators of ferromagnetic impurities • Rotary separator
Dryers	• On gas • On solid fuel • On liquid fuel
Measuring equipment	• Truck scales • Flow scales • Silo thermometers
Aspiration equipment	• Pipeline system • Fan • Cyclone
Unloading equipment	• Unloading cells

Methods in the operation of modern (automated) storages

According to [5], [8], the basic methods in the operation of automated storages are as follows:
- Sampling methods
- Laboratory methods
- Process control methods
- Methods of measuring quantities
- Computer methods

Laboratory methods

According to [2], [9], methods for determining the quality of granular materials are applied:
- When receiving the granulated mass in the warehouse
- During the actual storage in order to check the condition of the stored grain
- When delivering granular mass, with the aim of determining the quality class, forming the price or determining adequate procedures for safe storage.

Determination of moisture content

According to [10], water content is a critical parameter of granular materials quality. If the water content of the grain is high, there is a risk of a decrease in the quality of the grain materials or of losses during storage. On the other hand, excessive drying can also affect the quality of granular materials. The methods used in practice to determine the moisture content are as follows:
• Direct methods (methods based on extracting moisture at a certain temperature to dry matter – drying)
• Indirect methods (methods based on the measurement of some physical quantities that depend on the moisture content – electrical conductivity, capacitance, absorption).

Sensory evaluation of granular mass

According to [11, 12], sensory evaluation is the fastest and most effective way to identify many potential defects in the quality of granular materials. The sensory properties of granular mass are determined by the senses of sight, smell and taste.
Based on the visual assessment of the condition of the granular mass, it is possible to obtain a whole series of data on the size, shape, color and appearance of the surface of the grain itself. For a visual inspection of granular materials, 10 to 15 minutes per sample is necessary. The main disadvantage of this method is that the inspector–analyst has a subjective feeling.

Occupational safety, security and environmental protection

According to [7], [13], during occupational safety, the requirements for explosion protection and fire protection must be met. Dust that is created in the technological process itself in granular materials, which is dispersed in the air, can cause a fire if it comes into contact with an ignition source. Whether the mixture will ignite or detonate depends on the dust concentration, particle size, moisture and ignition temperature of the mixture. The destructive force of 1 m^2 of dust in the air represents an explosive mixture equal to 300 kg of TNT. Areas of fire sectors are given in Table 2.

Table 2. Presentation of the maximum allowed values of the area of fire sectors in closed storages [5], [14].

Types of materials	**Allowed area of fire sectors in m^2, without installation for automatic fire detection**	**Allowed area of fire sectors in m^2, with installation for automatic fire detection**
Flammable powdery matter	up to 400	up to 800
Solid components of flammable matter with an ignition temperature of up to 300˚C	up to 2000	up to 3000
Solid compact matter with an ignition temperature above 300 ˚C	up to 3000	up to 4500

In the literature, there is relatively little data obtained from specific grain storage plants. The paper provides an analysis of the functionality of the storage based on the following identification parameters: transport capacity, specific energy consumption, grain breakage, dust emissions, as well as system reliability. The aim of the paper is to indicate important parameters and their influence on the efficiency of grain storage plants.

Storage technology

With classic technology, the material is delivered to the location for storage and drying to the receiving place (the so–called bunker), as shown in Fig. 1. It is sent for purification by appropriate transport devices, temporarily stored and then sent for drying. The humidity of the material at the entrance can be very different (and over 30%), and at the exit there must always be an equilibrium humidity, which is exactly the prescribed value for each agricultural crop. The characteristic of the classic technological scheme is that the material is dried only in one pass through the drying device. After that, it is sent to the storage where it is stored until the moment of use [15]. The technology of storage with the possibility of re–drying the grain is most often used. For example, if corn or wheat with a moisture content of 28% is delivered, they are first dried to 18% moisture content, and after a certain time they are re–dried to an equilibrium moisture content of 14%.

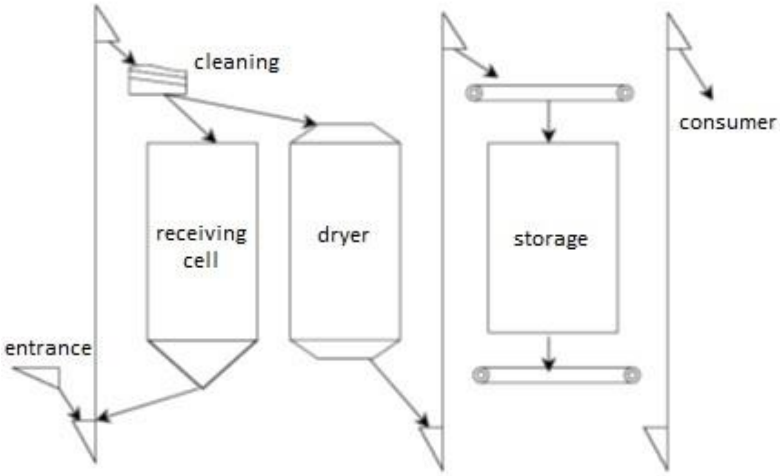

Fig. 1. Classical storage technology

Examples of realized grain storage silos are given in Fig. 2 and Fig. 3, according to [16].

Fig. 2. Examples of realized grain storage silos

Fig. 3. Examples of realized grain storage silos (silos with a capacity of 5000 t of wheat, transport capacity of 60 t/h), Dryer capacity 18 t of grain 24/14% moisture.

Silo cells (Fig. 4.) are used for temporary storage of grain before the drying process and in the case of two–phase drying, to return the grain to the dryer for re–drying to equilibrium moisture, [16].

Fig. 4. Dryer with silo cells

Technological process

The paper considered a storage with three silos, each with a volume of 8300 m^3. The silos are equipped with conveyors for loading and unloading, as well as elements of industrial automation – sensors for indicating the level and temperature, etc. [17]. There are two grain receiving lines, each with a capacity of 150 t/h. The maximum transport capacity when filling and emptying the silo is 300 t/h. Chain conveyors are used for horizontal transport and elevators with buckets are used for vertical transport. Machines and equipment are equipped with all the necessary sensors, in order to fully automate the process, using a process computer. The silos are equipped with a minimum and maximum level indicator and a radar level measurer. Chain conveyors are equipped with overload sensor and rotation sensor, while elevators are equipped with rotation sensor, belt alignment sensor, bearing temperature sensor and explosion pressure relief panel. Two–way switches and sliding shutter are equipped with position sensors. The installed power of electric motors for driving machines and equipment is 482 kW. The storage capacity with three silos is $3 \cdot 8300 = 24900$ m^3.

RESULTS AND DISCUSSION

The storage and transport system are equipped with loading and unloading conveyors, as well as elements of industrial automation, which ensure the functionality of the system. The transport capacity is 150 – 300 t/h. Based on the test, the results of interdependencies of transport capacity, specific energy consumption, grain breakage, dust emission, working hours and reliability were obtained, shown in Table 3.

Table 3. Dependencies of transport capacity, specific energy consumption, grain breakage, dust emissions, working hours and reliability

Transport capacity (t/h)	150	200	250	300
Specific energy consumption (kWh/t)	2,8	2,3	1,6	1,2
Grain breakage (%)	0,30	0,35	0,40	0,50
Dust emissions (mg/m^3)	10	12	15	18
Working hours (h)	2000	4000	6000	8000
Reliability (%)	98	96	94	92

One of the important indicators in the operation of the storage system is the specific energy consumption. The operation of the storage is automated with elements of industrial automation by installing sensors. The specific energy consumption was 1,2 – 2,8 kWh/t, Table 3. It was calculated with a coefficient of simultaneous operation of 0,8. According to [3], [18,19], specific energy consumption in grain storages ranges from 1,2 to 3 kWh/t. Based on that, the obtained results are in accordance with the literature source.

In the operation of production plants, storages and other plants, one of the indicators is reliability. Reliability is the probability that the system will function without failure for a specified time, in the designed manner under specified environmental conditions. Based on the results of the research, a reliability of 92 – 98% was obtained, Table 3. According to [8], [20], the reliability in the operation of the storage is 85% and more.

Grain breakage and grain dissipation are one of the inevitable occurrences in grain storages. This can cause direct losses of stored grain i.e. and financial negative effects. Grain breakage occurs during transport by chain conveyors and elevators. Based on the obtained test results, grain breakage was 0,3 – 0,5%, Table 3. Grain breakage is less than 0,5% if the velocity of the chains is less than 0,5 m/s, and the elevator belts are about 2 m/s, where chain conveyors are used for horizontal transport and bucket elevators for vertical transport [17], [21]. According to [2], [10], [22], breakage and dissipation of grain in storages ranges from 0,3 to 1 %.

The creation of dust due to the operation of transport machines in the storage is inevitable. In order to protect the environment, it is desirable to reduce the concentration of dust within the permitted limits. Based on the obtained test results, the emission of dust into the atmosphere ranged from 10 to 18 mg/m^3, Table 3. According to [1], [23], the permitted value of dust emission is 20 mg/m^3. For the operation of the storage, it is necessary to provide a certain number of workers. During the operation of the automated storage, 3 workers are needed (weigher, lab technician, operator). According to [7], [13], 3–5 workers are needed to work in storages with similar capacities.

CONCLUSION

Correct storage of grains is of great importance for preserving quality, considering that grains are used for human and animal nutrition and as a raw material in the food industry – alcoholic drinks, biofuels, pharmaceutical products, chemical products, etc.

In order to successfully preserve grains during storage, it is necessary to ensure the functionality and reliability of the storage, reduce losses due to grain breakage and grain dissipation, achieve the required level of fire safety in accordance with applicable regulations and laws, etc.

Problems related to functionality and efficiency in the operation of storages are at the same time among the most attractive and difficult problems that can be faced by the designer of such systems.

During the exploitation process, storage systems are exposed to conditions of wear and aging, which leads to a change in their working capabilities.

Within this paper, the results of research on a real grain storage are presented. An analysis of the functionality of the storage was performed based on the following identification parameters: transport capacity, specific energy consumption, grain breakage, dust emissions, as well as system reliability.

Based on the results of testing and analysis of the functionality of grain storages, the following was determined:

- specific energy consumption at the maximum transport capacity of 300 t/h was 1,2 kWh/t
- for an automated warehouse with elements of industrial automation, a reliability of 92 – 98% was obtained
- grain breakage was 0,3 – 0,5%
- the emission of dust into the atmosphere ranged from 10 to 18 mg/m^3, which is below the upper limit value of 20 mg/m^3
- during the operation of the automated storage, 3 workers are needed (weigher, lab technician, operator).

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ACTIVE SAFETY OF MODERN TRUCKS AND EXAMPLES OF INCIDENTS

Ervin Molnar[1], Jovan Dorić[1]
[1]University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
e-mail: molnar.ervin.ki@gmail.com

Abstract: This work represents active safety from the aspect of vehicles includes primarily preventive measures, which the vehicle designer must include in the design phase of the vehicle, and which relate to the driver-vehicle-environment system in order to avoid conflict situations. Studies which are made for active safety, show that there are several active systems on the market that can prevent and detect truck incident. The most common incident are made by drivers without relying on active safety systems.
Key words: *active safety, vehicle, driver, incident situations*

INTRODUCTION

Due to the increased demand and use of trucks nowadays, the need for active safety is becoming more and more frequent. Measures that are most important are driving safety, safety of operation and handling, conditional security and observations while driving. The driver is the most important link in any transport task. A driver who loves his job and who feels good does a better job, which directly affects traffic safety, as well as labor costs and the environment. In order for the driver to perform his job as the most important link with minimal fatigue, it is necessary to pay special attention to his working environment, which are cabin interior and visibility, mirrors, noise reduction in the cabin, comfortable seats, ergonomically placed controls.

MATERIAL AND METHODS

Electronic vehicle stability control systems

Electronic vehicle stability control systems are of high importance. Devices for automatic regulation of vehicle movement are a set of systems which, without the influence of the driver, enable the proper maintenance of the stability of vehicle movement, regardless of the road conditions. The main function of such systems is to help the driver to react and maintain stable vehicle movement with some delay, given that the current state of technology and "intelligence" of the system does not allow complete "exclusion" of the driver in the decision-making process.

ABS (Anti-Lock Braking System)

In critical situations, such as wet and slippery roads, the driver often reflexively applies the brakes. In this case, there is a risk of the wheels locking due to reduced friction on vehicles with ordinary brakes. Such a vehicle can no longer be driven and it usually slides and drifts uncontrollably, and often lands off the road. This allows the driver to continue to control the movement of the vehicle and to avoid skidding and slipping, however, despite the undoubted advantages, the driver must also get used to the reaction of the ABS. ABS system, controlling the speed of rotation of individual wheels, without the will of the driver acts to reduce the pressure in the braking system on individual wheels, which maintains their rotation (prevents blocking the rotation of the wheels) and prevents slipping of wheels and vehicles during braking and thus maintains desired trajectory . Tests have shown that in cases of blocked wheels, in their sliding, there is no possibility of controlled steering, but the vehicle moves by inertia. In addition, the braking track of vehicles with locked wheels is significantly longer than those in the rolling state but at the slip limit.

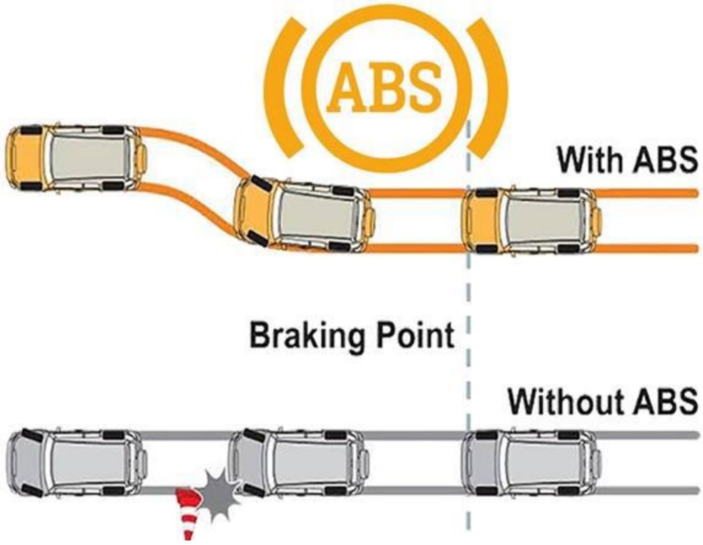

Fig. 1. ABS system

ASR (Anti Slip Regulation)

Full transmission of torque to the drive wheels is possible only in terms of quality traction of the wheels for the road to the slip limit
In order to reduce large slippage of drive wheels, ASR system, which:

- improves power transmission conditions and maintains wheel rolling
- improves driving safety in conditions when the driving force on the wheels is greater than the adhesion
- automatically adjusts the torque distribution to non-slip conditions
- provides information to the driver on the achievement of dynamic limit grip conditions.

Very effective system during sudden braking at low and high speeds.

ESP – (Electronic Stability Program)

ESP increases control of the vehicle in borderline driving situations, such as speeding. ESP expands the function of ABS, in fact combines the ABS and ASR program system and dynamic vehicle stability and reduces the risk of vehicle skidding on all types of surfaces. For optimal monitoring of vehicle stability, intervention is not only through the braking system, but also through engine management, acceleration of the drive wheels.

ACC (Active Cruise Control)

ACC tries to drive "alone". It allows the driver, when he reaches the desired speed, to activate the ACC and the system takes further care of the vehicle's speed. This is where this system acts as a cruise control. When a vehicle with ACC activated encounters an obstacle, is a vehicle in front of it and goes at a lower speed, the ACC slows down the vehicle to the speed of the vehicle in front and holds it until the driver in front increases speed or changes lane, after which ACC accelerates to required speed. In some versions, it is possible to define automatic distance keeping, at which distance the system starts to react and regulate the speed of movement. ACC systems use radar or a laser to track vehicles in front of it. The data processed from radar, ABS, ESP and ASR are processed by the system and a decision is made on how to react next. When the radar detects the vehicle in front of it, it measures its speed, then compares it with its own speed and further applies measures to adjust the speed of the vehicle in front of it.

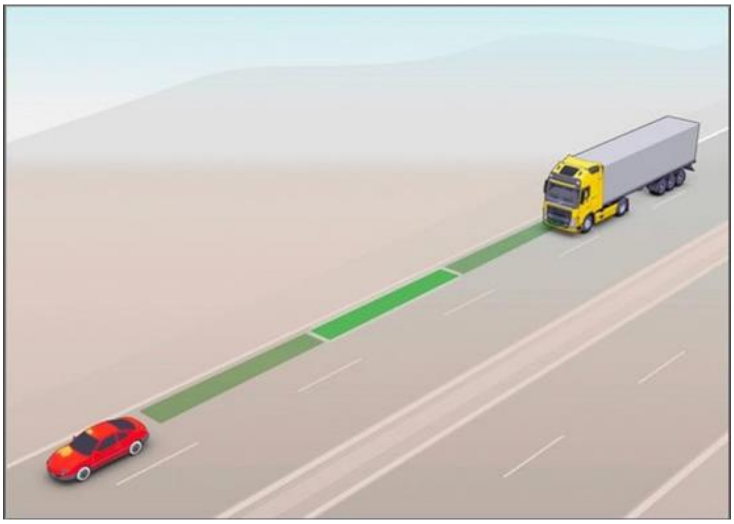

Fig. 2. ACC in work

LDWS (Lane Departure Warning System)

Its main task is to detect undesirable crossings over the lines that mark individual lanes at speeds higher than 80 km / h. The system is activated when the vehicle crosses or steps on the line. There are two vibrating motors built into the seat. One is on the left side, and one on the right side, and they light up depending on which side of the line crossing it is. LDWS uses six infrared sensors to detect unwanted line crossings. The sensors are located in the front bumper of the vehicle, three pieces on each side.

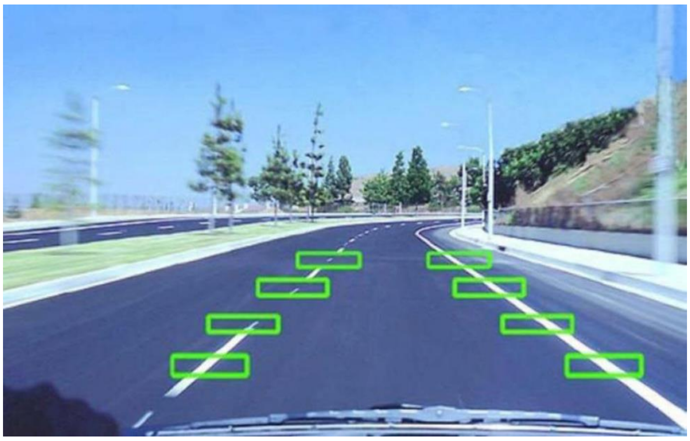

Fig. 3. ACC in work

Incident situations

Truck drivers are often blamed for accidents with large platforms or other large commercial trucks. The most common problems caused by drivers of cars that collide with large trucks are ignorance of the speed, size and braking ability of the truck.
Some of the most common incidents:

Truck overturning - The accident when the truck overturned is one of the most catastrophic. Trucks have a much higher center of gravity than standard passenger cars. If drivers turn too sharply or drive too fast for defined road conditions, the trailer can overturn and overturn the entire truck to one side, creating a dangerous and deadly danger for everyone on the road. In some cases, rollover accidents occur because truck drivers behave recklessly or carelessly, speeding, driving distracted or tired, or under the influence of narcotics.

Collisions from the back - When truck drivers are distracted, speeding or moving through doors, their negligence can lead to devastating accidents in the back with other vehicles. Impaired driving and driver fatigue are also common causes of rear-end accidents. Inexperienced truck drivers - or those in a hurry - who do not respect distances, also create dangers when they do not leave themselves enough time and space to slow down or stop.

Frontal collision - The truck may collide head-on with another vehicle for a variety of reasons. The truck driver may be tired from long hours trying to meet demanding quotas and slowly gravitate to the opposite lanes while nodding his head. Drivers can also drive under the influence of alcohol or illegal drugs. They may experience mental breakdown after excessive use of OTC (Over The Counter) stimulants and accidentally stray towards oncoming traffic. Tires that usually lead to rollover accidents can also cause drivers to lose control and turn unexpectedly into other lanes.

Side impact - In many cases, side-impact accidents between trucks and passenger cars occur when commercial drivers fail to adequately check their many deadlocks before changing lanes or engaging in traffic. Truck drivers may lose control of their vehicles due to flat tires, roadblocks, strong winds or other weather conditions. Distracted, drunk, drugged or tired drivers can also simply lose focus on the road and crash into nearby cars in adjacent lanes. These accidents are especially dangerous because a car that is thrown to the side can be forced sideways into other lanes of parallel traffic, causing the accumulation of more vehicles and even greater damage.

T side impact - Accidents, also known as side impacts or side collisions, most often occur at intersections. Truck trailers and other large trucks traveling through intersections at vertical angles sometimes go through red lights, ignore stop signs or otherwise violate the real advantage and eventually collide with the sides of other cars, creating a "T" shape. Truck drivers who are fast, distracted, sleepy or under the influence of alcohol can illegally pass through intersections and cause T-bone wreckage. A T-bone collision can also occur when a truck driver turns incorrectly over one or more traffic lanes, causing other vehicles to hit the side of the cab or trailer.

Wide turns - Right turns are usually firmer than left turns, so truck drivers must move these maneuvers with special caution. Sometimes, truckers try to turn right by first swinging the cab wide to the left and then circling through the right turn to avoid the "right turn pressure" that occurs when trailers do not have enough space to turn right. he turns. However, this creates a dangerous situation for vehicles in adjacent lanes, which can crash into a trailer or even get caught under a truck as it swings to the left.

Jackknife Accidents - Jackknife accidents occur when large trucks with articulated joints between the tractor and its attached trailer make improper turns or braking maneuvers, and the resulting force causes the trailer to swing wide around its pivot point to create a shape like a folding jackknife. This type of wreck is especially dangerous due to the sheer unpredictability of a skidding trailer, which may strike nearby vehicles and carry them along as the truck bulldozes its way through traffic. The most common cause of jackknife accidents is truck drivers braking improperly. When truck drivers brake too quickly or too hard in inclement weather conditions, the tractor can slow down faster than the trailer it is towing. This can result in a fishtailing motion by the trailer. The back of the trailer may then skid out to one side and cause a jackknife. Taking turns too quickly can lead to similar situations. Even if a jackknifed trailer manages to avoid colliding with other vehicles before it comes to a stop.

Fig. 4. Most common incident situations

RESULTS AND DISCUSSION

Active systems give the driver more control in dangerous situations. Simply put, active safety systems avoid or mitigate an accident pre-impact – so before it happens or contact is made. Approximately 80-90% of the trucks on Europe's roads come equipped with technologies such as ABS, ASR, ESP, ACC and LDWS. Some of the most common incident situations that have been recorded in practice are truck overturning, collisions from the back, frontal collision, side impact, t side impact, wide turns and jackknife accidents.

CONCLUSION

In general, the biggest incident situations that occur are driver error, inexperience, fatigue, misjudgments, talking on the phone, moving at high speeds, turning sharply to the right, consumption of alcohol and other psychoactive substances. With the development of technology, active safety systems are becoming increasingly common in all vehicles, increasing the safety of drivers, passengers and the environment. Modern trucks today cannot be imagined without an active system. By applying active systems and constant driver training on driving safety, the number of incident situations should decrease. Although it is not a physically difficult job to be a truck driver, a small number of women, about 5%, decide to take up this profession, the vast majority are men.

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METHODS OF CALCULATING THE VOLUME OF THE PRESSURE TANK FOR THE PROTECTION OF PIPELINES AGAINST HYDRAULIC IMPACT

Jovana Radnović[1], Ljiljana Radovanović[2], Ivan Palinkaš[2], Jasmina Perišić[3]
[1]MUP R. Srbije, PPU Zrenjanin
[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
[3]Faculty of Informatics and Computer science, Belgrade, Serbia
e-mail: ljiljana.radovanovic@tfzr.rs

Abstract: The research problem of this work is focused on the analysis of the phenomenon of hydraulic shock as the main cause of difficult regulation and control of pipeline operation during transitional regimes, as well as damage to the pipeline itself and the equipment in it. The research subject of this paper is related to the calculation of the volume of the pressure reservoir according to Spar, as well as the calculation of the volume of the pressure reservoir using the Combes and Barot diagrams in order to protect against hydraulic shock.
Using these calculations would optimize the operation of the pumps and create insignificant losses. There would be a reduction of the overpressure to a size that corresponds to the maximum allowable pressure in the pipeline, thus preventing the occurrence of a hydraulic shock.
The research was based on the assumption that the use of the pressure tank volume calculation method affects the protection of pipelines against hydraulic shock.
Keywords: hydraulic shock, pipeline, pressure reservoir

INTRODUCTION

Consideration of transient regimes in pipelines is one of the most complex problems in hydraulics. A sudden change in the flow in the pipeline, caused either by a sudden closing of the pipeline, or by a sudden stop of the pump, leads to oscillatory amplification and weakening of the pressure, which is manifested by a series of impacts on the pipe wall. Impacts can be noticed both by the sound and by the load on the pipe, and their effect can also cause the breakdown of the pipeline [7].
In order to choose the right solution for protection against hydraulic shock, the designer should have a good knowledge of the operating regimes of the pipeline, as well as the principles and reliability of the functioning of all facilities on the pipeline. He also needs to know the advantages, disadvantages and reliability of all means of protection against hydraulic shock that he intends to use [1]. The most important part of the work in determining protection against hydraulic shock is the identification of dangerous situations and the choice of the protection concept [2].
The Russian scientist Zhukovsky called the series of phenomena that occur in the pipeline due to a sudden change in flow speed hydraulic shock. Zhukovsky was the first (in 1889) to theoretically describe the phenomenon of hydraulic shock, that is, he set up differential equations and found their solutions. Because of the large pressure changes that occur during hydraulic shock, both the compressibility of the liquid and the elasticity of the pipeline must be taken into account. The movement of the liquid during hydraulic shock is oscillatory, and thanks to the existence of friction due to the roughness of the pipeline and local resistances, the oscillations are dampened and disappear over time [2].
When the pump stops working suddenly, the pressure rises or falls very quickly and sometimes the pump or pipeline bursts. In some cases, the same phenomenon occurs when the discharge valve suddenly opens simultaneously with the start of the pump. Hydraulic shock is a phenomenon that occurs when pressures change due to a change in flow rate in the period between two stable states, as previously stated [3].
When designing hydrotechnical systems under pressure, the possible causes of hydraulic shock are divided into two groups, depending on the situation in which they occur: cases that occur within the normal operation of the system, and which can be avoided by prescribing (and following) procedures for safe operation of the system. Sudden events that cannot be influenced by the designer (loss of

electricity, failure of measuring and regulation equipment), as well as events due to unprofessional handling. These include outages of all pumps, errors of pressure and flow indicators in the system, etc. [4].
An outage or intentional shutdown of one pump leads to a drop in pressure in the system. In the event of a pump station outage, a vacuum is expected, and in the event of an open valve on the pressure pipeline, a backflow of water is also possible. Each closing of the shutter leads to the appearance of a hydraulic shock on the system. During the sudden closing of the shutter in front of the tank, large pressure oscillations are expected, above all a greater increase in pressure above the working pressure [4].

MODELING OF TRANSIENT REGIMES IN A PIPELINE

Solving hydraulic problems involves several stages [1]. The first stage includes a logical description of the problem and the identification of relevant elements and their connections. The next stage is the idealization of the problem description, which usually involves the creation of a mathematical model.
Mathematical models in hydraulics are arrived at by adapting the basic laws of fluid mechanics (laws of conservation of mass, momentum and energy) to the specific conditions of water movement in certain flow areas (open flows, pressurized flows, porous media) and writing them in the form of algebraic, differential or integral equations. The resulting equations describe the idealized current field at each point and at each instant. Changes in the current field defined in this way depend on the initial state (initial conditions), the state at the borders of the flow area (boundary conditions), as well as on the values of the current field parameters [4].
The movement of water in pipes is always unstable due to the constant change in flow boundary conditions and the inability of water to instantly adapt to those changes. In addition to water inertia and viscosity, i.e. friction, the elasticity of the fluid and pipe walls often play a significant role [4].
Any change in the speed of the fluid in the pipe causes a certain change in pressure, as well as a change in density. When the pressure change is significant and the velocity change along the pipe must be taken into account, the hydraulic shock model is used. This is a true linear model of flow in pipes. It is assumed that the deformations of the fluid and the pipe are small and that the relationship between stress and deformation is linear, so the name elastic impact is used. With a sudden change in speed, the disturbance propagates through the pipe as a wave with a steep front, with final, although quite high-speed a. Pressure or velocity changes at pipe boundaries can be very rapid [4].

HYDROPHORIC CONTAINER AS HYDRAULIC IMPACT SHOCK ABSORBER

Calculation of the pressure tank volume according to Spar

Based on Zhukovsky's scientific works, Spar established a formula by which the tank volume can be calculated [3]:

$$\frac{1}{n} = \frac{g}{\gamma}\left[\frac{LA(Hp + Pa)}{gV}\right]^{0.5} \tag{1}$$

$$n = \frac{p}{Pmax - Hp} \tag{2}$$

$$LA = \sum LiAi, \qquad m^3 \tag{3}$$

$$p = \frac{a v_{sr} \gamma}{g}, \qquad bar \tag{4}$$

$$v_{sr} = \left(\frac{\sum LiAiv_i^2}{\sum LiAi}\right)^{0.5}, \qquad m/s \tag{5}$$

n - pressure reduction amplitude;
L, A, m^3 - volume of water in the pressure pipeline;
Hp, mVS - manometric lift height;
Pa, mVS - atmospheric pressure (≈ 10.33 mVS);
$v,\ m^3$ - the volume of the container;
p, bar - hydraulic shock pressure;
$a, m/s$ - shock wave propagation speed;
$v_{sr}, m/s$ - mean flow velocity in the pressure pipeline, calculated from the energy balance;
$Pmax, bar$ - the maximum pressure that the pump can deliver.

This kind of calculation has shown in practice that the volumes are larger than required, so the volume can be determined by a more accurate method.

Calculation of pressure tank volume using Combes and Barot diagrams

In order to reduce the total required volume of the pressure container, it is planned to install a check valve with bypass water on the pressure pipeline, immediately before the entrance to the container. During the optimal operation of the pump, when the flow is in the direction of the pressure tank, this connection creates insignificant losses, and during the return flow from the pressure tank to the container under pressure, the valve closes and the water flows at a higher speed through the bypass line into the container under pressure and creates considerable losses. These losses are determined by reducing the overpressure to a size that corresponds to the maximum allowable pressure in the pipeline.
The maximum resistance that can be created in the bypass line (through the aperture and similar), for the case of flow towards the pressure container (shock wave) is [3]:

$$h_{wd} = H_{max} - H_p + H_{wp}, \qquad mVS \tag{6}$$

h_{wd}, mVS - loss in bypass pipe-choke;
H_{max}, mVS - maximum allowable pressure in the pipeline (taken for zero pump flow);
H_p, mVS - manometric lift height;
H_{wp}, mVS - losses in the pressure pipeline at maximum flow.

This is the maximum loss that can be realized given the value H_{max}.

$$H_s = H_p + p_a, \qquad mVS \tag{7}$$

p_a, mVS - atmospheric pressure;

$$H_{wpd} = H_{wp} + h_{wd}, \qquad mVS \tag{8}$$

h_{wd}, mVS - total loss in the pressure pipeline at maximum flow, including the choke in the bypass line.

To read the parameters from the image diagram, it is necessary to calculate the ratios: $\frac{H_{max}}{H_s}; \frac{H_{wp}}{H_s}; \frac{H_{wpd}}{H_s}$

From the diagram of Combes and Barot, the value for n and $\frac{H_{max}}{H_s}$ is read.

$$n = \frac{v_{sr}^2 LA}{2gC} \tag{9}$$

$v_{sr}, m/s$ - mean flow velocity calculated according to the equation;
L, A, m^3 - volume of water in the pressure pipeline;
C, m^4 - pressure container characteristic.

The container characteristic can be calculated from the equation:

$$C = \frac{v_{sr}^2 LA}{2gn} \tag{10}$$

Since the characteristic of the pressure container is $C = H_s V_k$, then the volume of the container follows:

$$V_k = \frac{C}{H_s}, m^3 \tag{11}$$

$$V_{k\,max} = \frac{V_k}{\frac{H_{min}}{H_s}}, m^3 \tag{12}$$

$$V_{k\,min} = \frac{V_k}{\frac{H_{max}}{H_s}}, m^3 \tag{13}$$

Since the maximum losses and the maximum pressure of the pipeline are taken into account during the calculation, the maximum volume of the container $V_{k\,max}$ is relevant. For the isothermal change of state during hydraulic impact, the characteristic volume of the adopted container will be:

$$V_k = V_{k\,max} \frac{H_{min}}{H_s}, m^3 \tag{14}$$

$$V_{k\,min} = V_k \frac{H_s}{H_{max}}, m^3 \tag{15}$$

CONSTRUCTIVE ELEMENTS OF THE CONTAINER

Diameter of the bypass line

If we start from the losses h_{wd} in the bypass line (local and line) [3]:

$$h_{wd} = \sum \xi \frac{v^2}{2g}; v = \frac{4Q}{\pi d^2} \tag{16}$$

$v, m/s$ - flow rate in the bypass line when flowing from the pressure tank to the pressure container;

$\sum \xi$ - resistance coefficient (local and line);
$Q, m^3/s$ - maximum pump flow.

$$h_{wd} = \frac{\sum \xi}{2g} \left(\frac{4Q}{\pi d^2} \right)^2 \tag{17}$$

The diameter of the bypass line can be calculated:

$$d = \left(\frac{8Q^2 \sum \xi}{\pi h_{wd} g} \right), m \tag{18}$$

DIMENSIONS FOR INSTALLING WATER LEVEL GLASS

Based on the calculated volume $V_{k\,max}$, a standard container is chosen (one or more, if a large $V_{k\,max}$ is obtained), and its diameter is thus defined [3]:
The cross-sectional area of the container (Fig. 1) is:

$$A_p = \frac{D_p^2 \pi}{4}, m^2 \tag{19}$$

And the required heights are calculated from the ratio:

$$h_1 = \frac{V_{k\,min}}{A} + 0.1, m \tag{20}$$

$$h_2 = \frac{V_k - V_{k\,min}}{A}, m \tag{21}$$

$$h_3 = \frac{V_{k\,max} - V_0}{A}, m \tag{22}$$

$$h_4 = 0.8, m \tag{23}$$

The total height of the pressure container is $H = h_1 + h_2 + h_3 + h_4, m$.

The volume of air at atmospheric pressure is often not sufficient to provide the necessary gas volume when the system is under pressure. In order to solve this problem from the previous equations, it was found that it is possible to increase the total volume of the container or ensure the supply of compressed air to the container and thus protect the pipeline from negative phenomena that occur as a result of hydraulic shock. Based on the equations presented in the paper, engineers can easily dimension the container, determine the required air volume and the dimensions of the inlet and outlet pipe connections. These methods are easy to use and give accurate results.

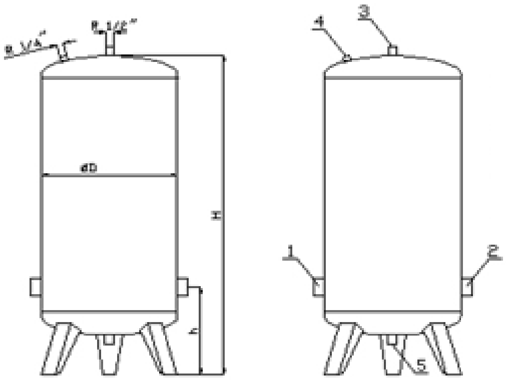

Fig. 1. Hydraulic shock absorber tank [8]
1. Water input; 2. Water output; 3. Pressure gauge connection; 4. Switch connection; 5. Water discharge

EXAMPLE OF A HYDRAULIC IMPACT AMORTIZATION CALCULATION

For a pumping system with the following characteristics [3]:

Optimal flow $Q = 1000\, L/s$; geodetic height $Hg = 90\, mVS$; pressure gauge height $H_p = 103.5\, mVS$; losses in the pressure pipeline $H_{wp} = 13.5\, mVS$; maximum effort of the pump at zero flow $p_{max} = H_{max} = 160\, mVS$. The pressure pipeline has a diameter of $DN\, 700\, mm$, wall thickness $\delta = 7.1\, mm$, length $L = 1370\, m$.
Using Spar and Combes and Barot's procedure, the pressure container volume was calculated for hydraulic shock absorption.

a) Procedure according to Spar

Shock wave propagation speed:

$$a = \frac{C_0}{\sqrt{1 + \frac{10E_w D}{E\delta}}} = 1003.6\, m/s$$

Mean flow velocity in the pressure pipeline:

$$v_{sr} = \frac{4Q}{\pi D^2} = 2.62\, m/s$$

Hydraulic impact pressure:

$$p = \frac{a v_{sr} \gamma}{g} = 26.8\, bar$$

Amplitude of pressure reduction:

$$n = \frac{p}{p_{max} - H_p} = 4.74$$

Container volume:

$$V = g\left(\frac{n}{\gamma}\right)^2 LA\left(H_p + p_a\right) = 13.11 m^3$$

which is slightly more than 2% of the pipeline volume.
Two containers of $7\, m^3$ are selected.

b) Procedure according to Combes and Barot

Loss in the bypass line:

$h_{wd} = H_{max} - H_p + H_{wp} = 70\, mVS$

$H_s = H_p + p_a = 113.83\, mVS$

$H_{wpd} = H_{wp} + h_{wd} = 83.5\, mVS$

$\frac{H_{max}}{H_s} = 1.40$

$\frac{H_{wp}}{H_s} = 0.1186$

$\frac{H_{wpd}}{H_s} = 0.73355$

From the diagram for these values it can be read:

$n = 0.43;\ \frac{H_{min}}{H_s} = 0.44$

The characteristic of the container is:

$C = \frac{v_{sr}^2 LA}{2gn} = 425.3$

Container volume:

$V_k = \frac{C}{H_s} = 3.74\, m^3$

$V_{k\,max} = \frac{V_k}{\frac{H_{min}}{H_s}} = 8.5\, m^3$

$V_{k\,min} = \frac{V_k}{\frac{H_{max}}{H_s}} = 2.67\, m^3$

A container with a volume of $V_{k\,max} =$ 9 m^3 is selected, that is, two containers of 4.5 m^3 each.

CONCLUSION

The occurrence of hydraulic shock is described by the momentum conservation equation for compressible fluids. Since it is a non-stationary nonlinear partial differential equation, its solution is possible only by applying numerical methods. For the analysis of hydraulic shocks, the method of characteristics is most often used, by means of which partial differential equations are reduced to ordinary differential equations [6].

Numerical analyzes can take into account the effect of friction within the pipeline, fluid flow discontinuity, fluid evaporation, wave propagation speed, pump inertia, and the effect of various hydraulic shock protection systems.

As part of the research in this paper, the procedure for calculating the volume of the pressure tank according to Spar, as well as the calculation of the volume of the pressure tank using the Combes and Barot diagrams, which represent suitable methods for protecting pipelines from negative phenomena arising as a result of hydraulic shock, were considered.

The paper discusses the effect of a container for preventing hydraulic shock in a pumping station on a pressure pipeline. The results of the analysis showed that the volume of the container is a key

parameter that determines the effectiveness of protection against hydraulic shock. The maximum pressure in the system decreases with increasing container volume. With a fixed container volume, the shape of the container and the method of installation on the pipeline (horizontal or vertical container) have no significant effect on the occurrence of damping of the hydraulic shock. In order to achieve maximum effectiveness of the protection, the container should be as close as possible to the discharge pipe of the pump.
A simplified analysis can be carried out by solving the momentum conservation differential equation for incompressible fluids. A sudden stoppage of a pump in a pipeline that is not protected by some system results in a sudden drop in pressure, with a shock wave traveling upstream and downstream within the pipeline for a period of time. In the case of pipelines to which containers are connected to protect against hydraulic shock, pressure oscillations are significantly slower and less intense. In this sense, the theory of incompressible flow is sometimes sufficient for analysis. The number of variables that need to be taken into account is significantly reduced so that a more general analysis can be applied in a dimensionless form that can be used to calculate the container volume.

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Session 4

Health and Environmental Protection

EVALUATION OF AZOLLA AQUATIC MACROPHYTE POTENTIAL IN PYRENE AND PHENANTHRENE ACCUMULATION AND PHYTOREMEDIATION IN CONTAMINATED WATERS

Mohammad Ali Zazouli [1], Alireza Ala[2†], Somayeh Asghari [3], Esmaeil Babanezhad [1]
[1]Department of Environmental Health Engineering, Faculty of Public Health, Mazandaran University of Medical Sciences, Sari, Iran
[2]Health Sciences Research Center, Student Research Committee, Mazandaran University of Medical Sciences, Sari, Iran
[3]Health Sciences Research Center, Mazandaran University of Medical Sciences, Sari, Iran
e-mail: ala_alireza@yahoo.com

Abstract: Polycyclic aromatic hydrocarbons (PAHs) are a serious threat to the health of the environment. Considering the importance of phytoremediation, in this study, the potential of *Azolla* macrophyte for uptake, accumulation, and biodegradation of phenanthrene and pyrene has been investigated. By designing phytoremediation experiments after 10 days of treating *Azolla* macrophytes with concentrations of 10 and 30 mg $L^{-1}$of pyrene and phenanthrene, the amount of accumulation of these substances in *Azolla*, the side compounds resulting from the decomposition of these substances in the plant tissue, and cultural environment and the effect of the desired compounds on the growth parameters. The plant (fresh weight, dry weight, RFN, photosynthetic pigment) were measured using high-performance liquid chromatography (HPLC), gas chromatography (GC-MS) and spectrophotometry. Data analysis was done by ANOVA statistical analysis by SPSS version 25 software. Accumulation in *Azolla* tissue at concentrations of 10 and 30 mg $L^{-1}$was 95% and 50% for pyrene and 75% and 40% for phenanthrene, respectively. 10 compounds were identified from the decomposition of the desired hydrocarbons in the plant tissue. Aggregation capacity, fresh weight, dry weight, number of pigments, and RFN at 10 mg concentration were higher than the treatment for *Azolla* and there was a significant difference (PV<0.05).
Key words: Aquatic macrophytes, Phytoremediation, Aromatic hydrocarbons, Azolla, Bioaccumulation, Biosorption

INTRODUCTION

Polycyclic organic hydrocarbons (PAH_S) are an important group of organic compounds that have a compact structure of two or more aromatic rings, with variable physical and chemical properties, and have a high risk of carcinogenicity and toxicity for aquatic organisms and humans. Based on the studies conducted, there is clear evidence that shows that exposure to PAH_S in concentrations higher than the permissible limit causes DNA damage, genotoxic effects, and serious problems in humans. Water, air, fish and other food contaminated with organic hydrocarbons are sources of their entry into the human body [1]. Therefore, in 1984, USEPA included them in the list of priority pollutants [2, 3]. PAH_S enter the environment through natural sources as well as anthropogenic sources. Benzopyrene is one of the five-ring aromatic hydrocarbons, exposure to which has a large contribution to carcinogenesis [4, 5]. Organic hydrocarbons are hydrophobic and after entering organic sources, they tend to bind with particles and eventually lead to sediments [6]. The usual concentration range for total PAHs in drinking water, based on the World Health Organization (WHO) standard, is about 1 nanogram per liter to 11 micrograms per liter [7]. In phytoremediation, plants, as the first links of food chains, can receive PHA compounds from polluted areas and convert them into less harmful or harmless compounds with low energy consumption [9]. Among the various processes that exist to remove pollutants from polluted waters, the use of aquatic macrophytes is very significant due to their high potential in absorbing and accumulating pollutants, and using direct and indirect pollution absorption mechanisms. Transferred from the root to the branch and create a stable cycle in aquatic ecosystems. Therefore, the use of macrophytes as biological indicators is very useful in determining and monitoring water pollution and waste management [10]. *Azolla* macrophyte is a small aquatic fern that floats freely on the surface of the water, but does not have roots in the sediment, and moves freely with wind and water currents [11]. *Azolla* is used as an environmentally friendly and effective option in the phytoremediation of polluted water sources due to its high pollutant accumulation capability [12]. *Azolla* and macrophytes in general have been proposed as an effective candidate for removing pollutants from wastewater due to their simple and low-cost growth conditions, high absorption ability, and no environmental pollution. Therefore, the potential of aquatic macrophytes for the removal of polyaromatic hydrocarbons should be of interest to phytoremediation specialists [13, 14]. Phytoremediation is a practical and practical technology for purifying places contaminated with pollutants [15]. Considering the importance of the effect of phytoremediation in removing pollutants from the environment and maintaining the health of the environment, to develop research in this field and investigate the potential of *Azolla* macrophytes in absorbing and accumulating pyrene and phenanthrene and phytoremediation in polluted waters, in this study the effectiveness of removing hydrocarbons Polycyclic aromatics were evaluated in polluted waters using *Azolla* aquatic macrophytes in the scope of a case study in the laboratory.

MATERIAL AND METHODS

Plant collection and culture conditions

The *Azolla* plant was harvested from the old reservoir of Aghamshahd village, Sari city, Mazandaran province. The plants were collected in appropriate containers and were transferred to the research laboratory of the Health Sciences Research Center of Mazandaran University of Medical Sciences in the shortest possible time to carry out the cultivation procedures under the relevant environmental conditions. *Azolla* plants were harvested from the reservoir at the end of winter and their color was almost red at this point. Seasonal changes are effective on the composition of *Azolla* plant pigments [16]. After washing with distilled water to remove unwanted particles and organisms, the plants were disinfected with 0.5% hypochlorite solution for 2 minutes. Then by transferring into a glass tank containing a solution of one gram per liter of Albert (10.6% N, 9.3% P, 16.3% K, 11% Ca, 2.25% Mg, mg/kg B35, 35 mg/kg Cu, 660 mg/kg Fe, 130 mg/kg Mn, 140 mg/kg Zn and 20 mg/kg Mo) [17], which was made with distilled water were cultured. The materials used in the preparation of the culture medium were obtained from Merck, Germany. The photoperiod and temperature for the growth of plants were set as 16/8 hours (light/dark) and 20-25 °C respectively. After increasing the number of plants and their growth, the solution containing the culture medium was aerated once a day for 0.5 hours. Also, to strengthen and grow the plants better, the culture medium was changed every week. The *Azolla* plants grew and their color changed to green.

Experimental design

We prepared 250 ml flasks containing 100 ml culture medium of 1 g/L Albert solution. After conducting initial tests to find suitable and tolerable concentrations of phenanthrene (≥97% German Merck) and pyrene (≥96% German Merck) concentrations of 10 and 30 mg $L^{-1}$of analytes (using a stock solution of 1000 mg per liter of PAH_S in acetone) was selected for phytoremediation by *Azolla* plants. After complete evaporation of acetone (≥96% German Merck), the prepared culture mediums of *Azolla* plants were exposed to the culture medium for 10 days and used for different assays. The tests were repeated 3 times for control samples (solution containing plants and no PAH_S) and treated samples.

Evaluation of growth rate

The growth rate of *Azolla* plants that were exposed to 10 and 30 mg L^{-1} PAH_S environments was estimated by calculating the relative frond number (RFN), fresh weight, and dry weight. 50 *Azolla* plants with almost equal sizes and an initial fresh weight of 0.07 grams were placed in each concentration to measure fresh and dry weight. In addition, 20 isometric plants with an initial fresh weight of 0.3 g were used to measure RFN. After ten days, the fresh weight and dry weight of the samples (after drying in an oven at 50 °C for 24 hours) were measured. The RFN of *Azolla* plants was determined by counting the leaves during ten days, on days 0, 2, 4, 6, 8, and 10 using the following formula [18].

RFN = (frond N1 - frond N0)/frond (N0) (1)

N1 and N0 represent frond numbers at day N and 0, respectively

Evaluation of Photosynthetic Pigments

One of the methods of investigating seedling growth disorders, which leads to a decrease in the plant's competitive power, the use of environmental facilities, and the ability to tolerate adverse environmental conditions, is to measure the amount of chlorophyll, which reflects the plant's photochemical status [19, 20]. The photosynthetic pigments of chlorophylls and carotenoids belong to the group of paranoid plant lipids, which were named prenyl lipids by Goodwin and Lichtenthaler in 1976 [21]. *Azolla* plants were exposed to concentrations of 10 and 30 mg L^{-1} PAH_S for ten days for phytoremediation. After ten days, one fresh plant weighing 0.07 grams from each treatment separately in 100 ml of 100% acetone to measure the number of plant photosynthetic pigments (chlorophylls a(ca), b(cb), and total carotenoids (Cx+c) was homogenized. The homogenates were centrifuged at 5000 rpm for 10 minutes. The absorbance of the supernatant was measured spectroscopically at 470, 645, and 662 nm by recording the spectrum (in a UV-260 Shimadzu spectrometer). The amounts of photosynthetic pigments were measured using the descriptive methods of Lichtenthaler (1987) [22].

Phytoremediation Estimation

Azolla plants were harvested after ten days of treatment exposed to concentrations of 10 and 30 mg L^{-1} PAH_S and phytotherapy. Analytes of pyrene and phenanthrene were extracted from organic extracts of *Azolla* plants treated with concentrations of 10 and 30 mg L^{-1} of aromatic hydrocarbons (PAH_S) and *Azolla* plants' growth in media (water culture medium) with a concentration of 30 mg L^{-1}. To extract the desired analytes from the plant tissue, *Azolla* plants were collected in each of the desired concentrations and homogenized separately in mortars containing 4 ml of 2-propanol (99.9% - Merck, Germany). Then 10 mL of n-hexane (95% - Merck, Germany) was added to the homogenates and mixed thoroughly. After the complete evaporation of n-hexane, the contents of the remaining organic compounds were dissolved and concentrated in one milliliter of methanol (99.9% - Merck, Germany) [23]. Phenanthrene and pyrene in plant organic extract and plant growth medium using high-performance liquid chromatography (HPLC) with fluorescence detector and reverse phase C18 column 300 x 1/4 mm (Φ 4.1 x 300 mm reverse phase C18 column) were measured. The wavelength of the fluorescence detector was set for pyrene EX=260 and EM=420 nm and phenanthrene EX=260 and EM=352 nm. GC-MS analysis of organic extracts extracted from treatments containing 30 mg L^{-1} concentration of PHA_S (phenanthrene and Pyrene) was done separately to identify intermediate products resulting from biodegradation of PAH_S in phytoremediation by *Azolla*. Chromatographic analyzes were performed on GC–MS (Agilent Technologies 7890A, 5975c inert MSD detector).

RESULTS AND DISCUSSION

Effect of PAHs on the Growth of the Plant

The calculated RFN of *Azolla* plants that were exposed for 10 days to each of the concentrations of 10 and 30 mg L^{-1} PAH_S separately showed that the plant growth is response to specific concentrations of the desired aromatic organic hydrocarbons, and has decreased significantly (Figure 1).

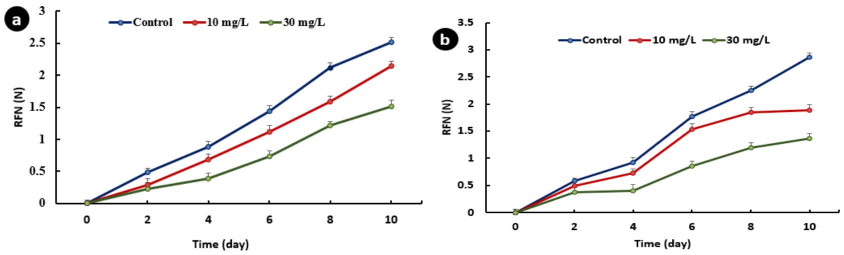

Fig. 1. The effect of various concentrations of phenanthrene (a) and pyrene (b) on *Azolla* by the means of RFN, on the 2nd, 4th, 6th, 8th, and 10th days after treatment.

This calculation for each of the concentrations of 10 and 30 mg L^{-1} of PAH_S shows 42.5% and 64.2% for phenanthrene and 48.4% and 57.8% for pyrene, respectively, reducing the RFN of *Azolla* plants compared to the control. (Figure 1-(a), (b)). Also, in the fresh weight of plants, it has been observed that exposure to each of the concentrations of 10 and 30 mg L^{-1} of phenanthrene and pyrene significantly increased the weight (Figure 2 -(a)) and dry weight (Figure 2-(b)) of the target plants and has decreased compared to the control sample (P<0.05). Overall, the results of this study have shown that the response of plants that were exposed to higher concentrations of PAH_S was more intense and more evident, and higher concentrations of phenanthrene and pyrene could have a greater effect on reducing the growth rate of *Azolla* plants. The results of the previous research also show an almost similar effect to the effect of aromatic organic hydrocarbons (phenanthrene and pyrene) on the blue lentil plant (L. minor) [14]. A comparison of the growth of these two plants (*L. minor* and *Azolla*) in response to Exposure to concentrations of 10 mg L^{-1} of PAH_S (phenanthrene and pyrene) does not show a significant difference (P>0.05). The findings of this research confirm the results of previous studies which showed that concentrations of 25 to 100 mg L^{-1} of pyrene and phenanthrene had a significant reduction in growth, including stem and root length, fresh and dry weight of some species of aquatic organisms, and also corn plants [24, 25]. PAH_S toxicity causes stressful conditions in the environment so that plants will reduce growth in response to these conditions by restricting photosynthesis and oxidative stress [26].

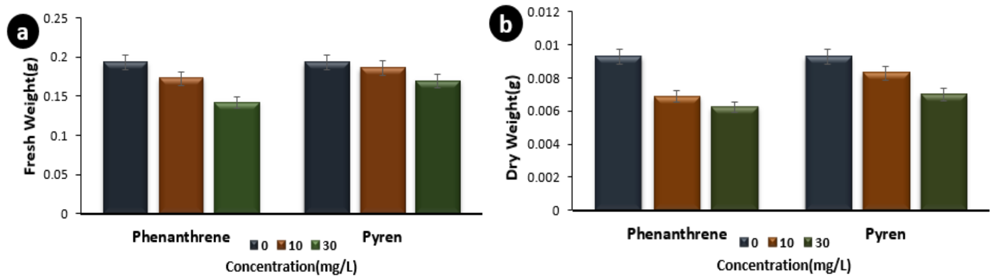

Fig. 2. The effect of various concentrations of phenanthrene and pyrene on *Azolla* by the means of fresh weight (a) and dry weight (b) after 10 days of exposure. Different letters indicate significant differences (P < 0.05).

Effect of PAHs on Photosynthetic Pigment Contents

Measuring the number of pigments of each of chlorophyll a, b, and c as well as total chlorophyll and carotenoids in *Azolla* plants that were exposed to concentrations of 10 and 30 mg L^{-1} of phenanthrene and pyrin pollutants for 10 days, a significant decrease has shown According to Figure 3(a, b), the reduction of pigments in *Azolla* plants treated at a concentration of 30 mg L^{-1} for each of the pollutants phenanthrene and pyrene for chlorophyll a (20.5% and 14%), chlorophyll b (31% and 28%) and carotenoid (25.4% and 22.5%) compared to the control sample. A similar study has shown the adverse effect of PAH_S compounds on the content of photosynthetic pigments in *C. Vulgaris*. In this study, by increasing the concentration of phenanthrene from 2 to 50 mg L^{-1} and exposure time, the content of pigments (total chlorophyll) and protein content in *C. Vulgaris* decreased [27]. The reduction of photosynthetic pigment content in plants is considered as physiological indicator of the phytotoxicity of pollutants [28]. Therefore, it can be concluded that phenanthrene and pyrene reduce the photosynthetic capacity of *Azolla*, which may be a protective response to limit the production of reactive oxygen species (ROS) in chloroplasts.

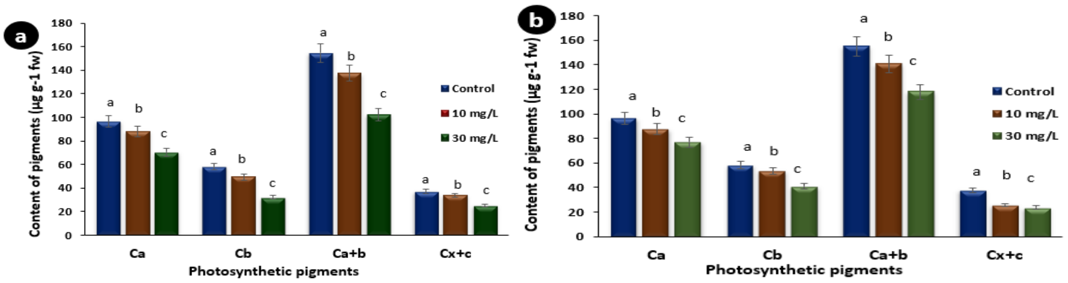

Fig. 3. The effect of different concentrations of phenanthrene (a) and pyrene (b) on photosynthetic pigments content of *Azolla* after 10 days of treatment. Different letters indicate significant differences (P < 0.05) according to Duncan Test (mean ± SD, n = 3).

Accumulation and Degradation of Phenanthrene and Pyrene by Azolla

The analysis of the samples extracted from the tissue of *Azolla* plants was done to measure the absorption and accumulation of phenanthrene and pyrene using high-performance liquid chromatography (HPLC). The absorption and accumulation of phenanthrene and pyrene in *Azolla* plants after 10 days of purification in each of the concentrations of 10 and 30 mg L^{-1} was 0.0075 and 0.0116 mg g^{-1} FW for featuring and 0.00965 and 0.0165 mg g^{-1} FW for pyrene respectively (Figure 4. a.b). The results obtained from the advanced analysis of the device in measuring the absorption concentration of analytes show that the absorption concentration of phenanthrene and pyrene increased significantly with the increase of treatment levels from 10 mg to 30 mg (P<0.05). The absorption concentration of pyrene was higher than that of phenanthrene. The calculation and analysis of absorption concentrations measured for each milligram of phenanthrene introduced into the growth medium of *Azolla* plants have shown that *Azolla* plants absorb more and almost twice as much at a low concentration (10 mg L^{-1}) than at a higher concentration (30 mg L^{-1}) in the environment where *Azolla* plants were treated with PAH_S. And this ratio for the absorption of pyrene at a concentration of 10 mg L^{-1} is 1.816 times higher than its absorption concentration at a concentration of 30 mg L^{-1}. The ability and efficiency of *Azolla* plant to absorb phenanthrene and pyrene from aqueous solutions with a concentration of 10 mg L^{-1} is higher compared to aqueous solutions with a concentration of 30 mg L^{-1}. And the highest absorption capacity by *Azolla* occurred during 10 days of treatment with a concentration of 10 mg L^{-1} of pyrene and at the rate of 0.00075 mg g^{-1} FW for each milligram of pyrene pollutant in the environment. In a study, the capacity of *Azolla filiculoides* for the bioremediation of PAHs in crude oil was investigated. Based on this, *Azolla filiculoides* plants were grown in culture medium containing 0.05, 0.1, 0.2, 0.3, 0.4 and 0.5% crude oil for 15 days. The results of this study showed that the ability of *Azolla filiculoides* to purify PAHs present in crude oil completely depends on the concentration of crude oil and its toxicity to plants. So that *Azolla filiculoides* will probably be more effective in low concentrations of oil for green purification of polluted waters [29]. In another study, the ability of *Azolla filiculoides* to remove fluoride in different concentrations (1, 5, 10, 20, 40, 80, 100) mg L^{-1} from aqueous solutions was investigated. According to the results of this research, the fluoride removal efficiency increases up to a concentration of 10 mg L^{-1}. So, for a concentration of 10 mg L^{-1}, the removal rate is equal to 98 %, and after that, the removal rate decreases with an increase in the initial concentration of fluoride [30]. Higher concentrations decrease the photosynthetic capacity of *Azolla* and create oxidative stress, which causes a decrease in growth and then a decrease in the concentration of analytes under investigation. Also, the results of the study show that both analytes (phenanthrene and pyrene) were probably partially metabolized by *Azolla* during 10 days. The results obtained are in agreement with the results of other studies that showed the absorption and accumulation of PAHs widely in different plants [14, 31-33]. The results of Hoshani and his colleagues' studies showed that phenanthrene can be metabolized in corn plant tissues, but Pyrene has a greater tendency to accumulate [31]. In a study conducted by Salehi Lisar et al. [32], similar results were reported regarding the accumulation of fluorene as PAH over time in sunflower, wheat, and alfalfa plants [33]. The properties of organic hydrocarbon compounds that determine their accumulation and degradability by plants include solubility in water, molecular weight, lipophilic properties, and structure of these compounds [34]. Aromatic organic hydrocarbons with higher molecular weight, Higher density, and lower solubility in water such as four-ring pyrene compared to PAHs with lower molecular weight, lower density, and higher solubility in water such as three-ring pyrene are more stable and more resistant to removal and degradation [35, 36]. This is probably the main reason for the higher bioaccumulation of pyrene compared to phenanthrene. The results of this study, confirming the absorption of PAHs in *Azolla* plants, show that *Azolla* plants have a high capacity for absorbing phenanthrene and pyrene. As it shows a significant increase in absorption compared to the blue lentil plant in another study [14], this capacity is 95% and 50% for pyrene and 75% and 40% for phenanthrene in concentrations of 10 and 30 mg L^{-1}, respectively.

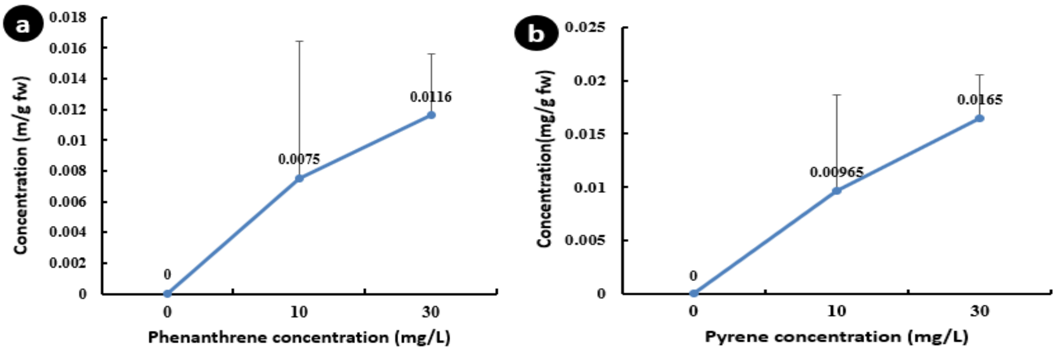

Fig. 4. Changes in the concentration of phenanthrene (a) and pyrene (b) (mg g^{-1} FW) of *Azolla* plant (C plant) after 10 days of the exposure time. The data are the means of three replications and error bars indicate SD and different letters indicate significant differences ($P < 0.05$)

Examining the samples taken from the aqueous environment with a concentration of 30 mg L^{-1} of phenanthrene and pyrene each separately, to which *Azolla* was exposed, using high-performance liquid chromatography (HPLC) has shown that none of them contain the concentration of analytes. It was not intended. One of the reasons for the absence of PAH_S in the aquatic environment for the growth of *Azolla* is their hydrophobic nature and high tendency to bind to particles that eventually lead to sediments. Probably a small part of the pollutants are absorbed in sediments. The *Azolla* macrophyte floats on the water surface and does not have roots in the sediment. In this study, due to the homogeneity of the *Azolla* growth environment and the short duration (10 days) of plant growth, no significant sediments were observed on the floor of the *Azolla* treatment and growth environment. According to the aim of the study to investigate the extent of *Azolla* phytoremediation in PAH_S absorption, its measurement in sediments has not been considered. Probably, other amounts of the remaining concentrations of PAH_S in the aquatic environment of *Azolla* and plant tissue are mainly destroyed or decomposed by *Azolla* and turned into by-products. Plants can transform, accumulate or transport PHAs [9].

Breakdown and degradation of phenanthrene and pyrene by Azolla

The samples extracted from the tissue of *Azolla* plants, which were treated with 30 mg L^{-1} of phenanthrene and pyrene for 10 days, were analyzed by GC-MS to investigate the by-products caused by the degradation of phenanthrene and pyrene by Azolla. The constituents were identified by matching their spectra with those recorded in the Mass library (Wiley7n and NIST08). Due to the hydrophobic nature of phenanthrene and pyrene, there is a possibility of degradation and decomposition of a part of PAH_S in the plant tissue and turning it into by-products, which was detected in the qualitative measurement of the by-products caused by decomposition and degradation by GC-MS. The effective compounds identified during the decomposition of pyrene and phenanthrene are shown in Figure 5(a, b). The number of detected side products (%) in the biodegradation of phenanthrene and pyrene was almost the same. In the analysis of the control sample (solution containing free PAHs), no peaks associated with the listed side compounds were detected using GC-MS. The oxygenase enzyme probably plays a role in the formation of these compounds.

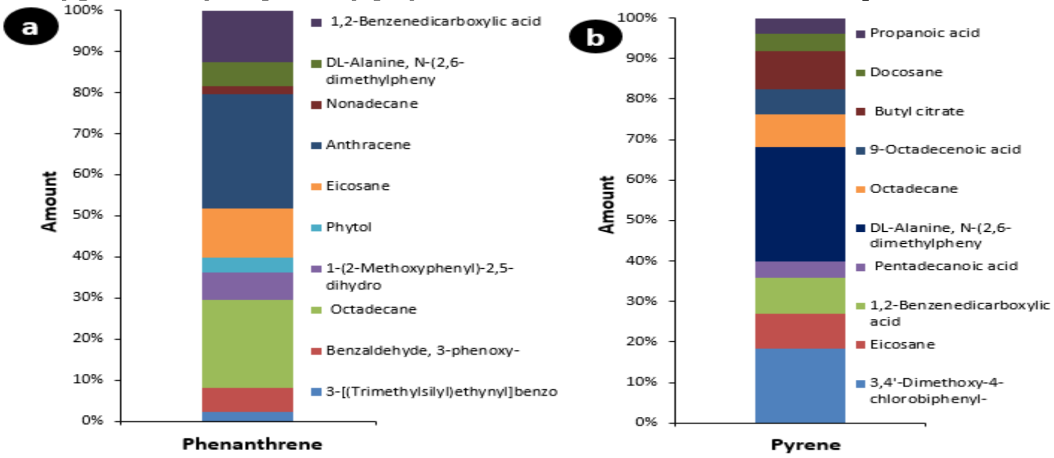

Fig. 5. Identified by-products during biodegradation of phenanthrene(a) and pyrene(b) by *Azolla*

Then, under further oxidation of the intermediate compounds and with the destruction of the benzene ring and the formation of surface structures, single-chain side products, and fatty acids are formed. According to the results obtained in this study, the oxidation of aromatic compounds by specific enzyme systems such as peroxidase and o-oxidase diphenol has already been reported in algae and plants [31, 37, 38]. In other studies, the degradation of PAHs by different plants has been reported, and these compounds were identified using GC-MS [14, 37]. In these studies, intermediate compounds were observed during the degradation of phenanthrene and pyrene, and the role of peroxidase, the degradation and decomposition of PAHs have been reported, which confirms the biological changes of aromatic organic hydrocarbons and the results stated in this study. Probably, with the increase in the retention time, the decomposition of organic hydrocarbons absorbed by the plant increases and turns into less harmful or harmless compounds. In phytoremediation, plants, as the first links of food chains, receive PAH_S compounds from polluted areas and convert them into less harmful or harmless compounds with low energy consumption [9].

CONCLUSION

Hydrocarbons of pyrene and phenanthrene reduce the growth factors (number of pigments, fresh weight, and dry weight) in *Azolla* plants. In the treatment of *Azolla* plants with pyrene and phenanthrene, significant absorption of both compounds has been detected in *Azolla* after ten days, which confirms the phytoremediation of these plants in removing relevant pollutants. *Azolla* plant can be used in the phytoremediation of environmental pollutants caused by organic hydrocarbons. The high capacity of PAH_S absorption by the *Azolla* plant makes it a suitable plant for phytoremediation of pyrene and phenanthrene pollutants, and introduces the *Azolla* plant as an environmentally friendly plant. Organic hydrocarbons are metabolized by *Azolla* and converted into side compounds. These compounds have been identified in plant tissue. The continuation of the growth process of plants and the fate of the side compounds created need more investigation and studies.

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ANALYSIS OF AIR POLLUTION WITH R LANGUAGE

Zoltan Kazi[1], Snežana Filip[1], Maria Kazi[2], Dragana Banović[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
[2]University of Novi Sad, Faculty of Sciences, Novi Sad, Serbia
e-mail: zoltan.kazi@tfzr.rs

Abstract: Basic aim of this paper is to present the usage of the R programming language in ecology and environmental protection areas. Main characteristics of R language are presented in order to better understand the language researchers who are not familiar to the information technology area. Data about air pollutants concentrations for analysis were collected from the internet site of Environmental Protection Agency from Ministry of Environmental Protection in Serbia. A novel R program was written and it was used for working with ecological data and creating statistical calculations of air pollutants. Several diagrams that illustrate possibilities of data visualization of R is created and drawn. This analysis compares the values of air pollutants for the cities of Novi Sad and Niš, which are located in Serbia.
Key words: R language, data, program, air pollution, analysis.

INTRODUCTION

Researchers and scientists who work in the field of ecology and environmental protection have many different software tools at their disposal for data analysis, but there are a small number of tools that allow reasoning and quality statistics based on programming possibilities [1]. Ecological and environmental protection knowledge and data have been increasing in recent years. Databases are already with extremely large and huge amounts of data and they are constantly growing. This huge amount of data is forcing researchers to develop or use new efficient ways of processing and analyzing both, data and knowledge [2]. Different tools and functions from the programming languages specialized for statistics and calculations, such as Python, MATLAB and R provide computational methods and techniques to help ecologists and other scientists to solve contemporary challenging world problems.
Air pollution is a growing problem that is extremely significant worldwide. This problem is complex and its solution can be facilitated by the use of modern software tools and programming languages. There is a need for accurate analysis and better air quality evaluations, modern and visualization. [3]
The rest of the paper is organized as follows: section 2 presents basic notes on that what air pollution is, section 3 describes main characteristics of the R programming language, section 4 is research methodology, section 5 introduces the R program for working with air pollution data, section 6 presents results of R program execution, diagrams and stats, and final section is conclusion.

AIR POLLUTION

According to [4] air pollutant is a substance in the air that can cause harm to humans and damage the health of people and could make environmental disturbance. Pollutants can be in the form of liquid droplets, solid particles, or gases. Air pollutants include ozone (O_3), oxides of nitrogen (NO, NO_2, NO_X), ammonia (NH_3), sulphur dioxide (SO_2), carbon monoxide (CO) and particulate matter (PM 10 and PM 2.5) etc. Sources of air pollution are:

- Anthropogenic - caused by human activities, especially in industrial processes, residential heating systems, transport and agricultural systems.
- Natural - volcanic eruptions, natural decomposition of organic matter or fires that occur naturally.

The anthropogenic air pollution is increasing because of global human population growth and continuous increase of energy demand. The anthropogenic air pollution doesn't have borders the pollutants are released in atmosphere will have a global impact. The consequences of high values of air pollutants has affected on health of people. Air pollution can also cause different impacts on nature and environment. Concentrations of air pollutants are higher in urban areas than in the rural regions.

So, the need to reduce air pollution is very significant. Exposure to pollutants, especially to PM and O3 are related with health concern, linked to a loss of life expectancy, acute and chronic respiratory and cardiovascular problems and diseases. [4]
Major air pollutants, according to [5] are: particulate matters (PM), including PM 2.5, PM 10, and air contaminants such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO).
Air pollution caused by burning fossil fuels has been affecting human health for centuries. Air pollution negatively affects the health of people around the world. New studies suggest that PM particles and several gaseous pollutants are associated with short-term variations in mortality, and effects estimates are higher than reported. A large part of the world's population lives in Asia with an associated large increase in energy production and consumption. Emissions of air pollution are high with negative impacts on air quality to a large extent distances from the main source area. A major challenge is to reduce the negative impact on the environment. [6]
Examples of the use of programming languages in the field of ecology and air pollution analysis are presented in [2]. Prolog program was written for reasoning with ecological data. Reasoning rules were designed for calculating average concentrations, for discovering greater concentrations than it is allowed, and some diagrams were drawn in spreadsheet program because Prolog language has weak capabilities for graphical representation of data.

PROGRAMMING LANGUAGE R

R is a programming language for statistical calculations, data analysis, data visualization, and for reporting. This language is increasingly used nowadays [7]. The first version of this language appeared in 1993. Authors were Robert Gentleman and Ross Ihaka from the University of Auckland in New Zealand. According to their names and the first letters of the surnames (Robert and Ross), this programming language was named R.
The R language is derived from the S and the Scheme programming languages. Scheme was developed in Bell Labs, the authors are: John Chambers, Rick Becker, and Allan Wilks. The first version of R appeared in 1995, while a stable and usable version has appeared in 2000. R is a part of the GNU Project, leaded by Richard Stallman, founder of the Free and Open Source Initiative institution. The source code is free and must be used under the terms of the GNU General License - GPL. R has a command-line interface in many graphical user environments. The R Development Core Team has been developing the R programming language since 1997. [8]
R is, according to [9], an open source and free programming language that is freely available for different operating systems. It is extremely flexible and convenient for using in statistics area. It is an object-oriented programming language that allows users to create methods, procedures and functions that perform customized procedures and high degree of automation of performed tasks. [10]

RESEARCH METODOLOGY

Our research began with gathering air pollution data collected from automatic stations installed in the Republic of Serbia. These stations are located at different places, especially in cities. This stations measure air pollution at urban city streets and in industrial zones. This measured data were downloaded from the internet site of Environmental Protection Agency in Republic of Serbia [11]. This site displays measured values of air pollutants through the national network of automatic stations for air quality monitoring. We choose to observe air pollution in the cities of Niš and Novi Sad, smaller from the capital Belgrade, but they are the second and third largest city in Serbia with the significant volume of traffic and industry that can affect on the level of air pollution. Measurement results of pollutants are expressed in mass per unit of the gas volume or particulate matter in the time unit.
The sample in our study included 1080 measurements in the year 2022 for the following components: particulate matter (PM 10, PM 2.5), nitrite oxides (NO, NO_2, NO_X), sulphur dioxide (SO_2), carbon monoxide (CO). The measurement units of air pollutant values are $\mu g/m^3$. Collected data also contain the atmospheric meteorological conditions: relative humidity (rh, percentage), air temperature (t,

Celsius), and atmospheric pressure (p, millibar). The observed period was January and February. It is the winter period when the air pollution is expected to be relative high.
This collected data are stored in worksheets of a workbook file format in a spreadsheet program. Then this data collection is exported to the tabbed delimited format textual file. Structure of data is: city, time, so2, pm10, no2, nox, co, no, pm25, p, t, rh. This file format was chosen for usage because it is suitable for processing in the R programming language with its possibility to make various statistical calculations, data analysis and graphics, and data visualization. Text file with air pollution raw data separated by a tab character ise saved in the working directory of the R language. Then it is loaded in the program written in R language. Data is processed with R functions and procedures, transformed into the programming structures like R vectors. Similar data processing is presented in [12] and done with the Prolog language and a program for air pollution analysis based on clauses that represent a different way of working and reasoning than this in the R language.

THE R PROGRAM FOR AIR POLLUTION ANALYSIS

The R program for air pollution analysis is listed below:

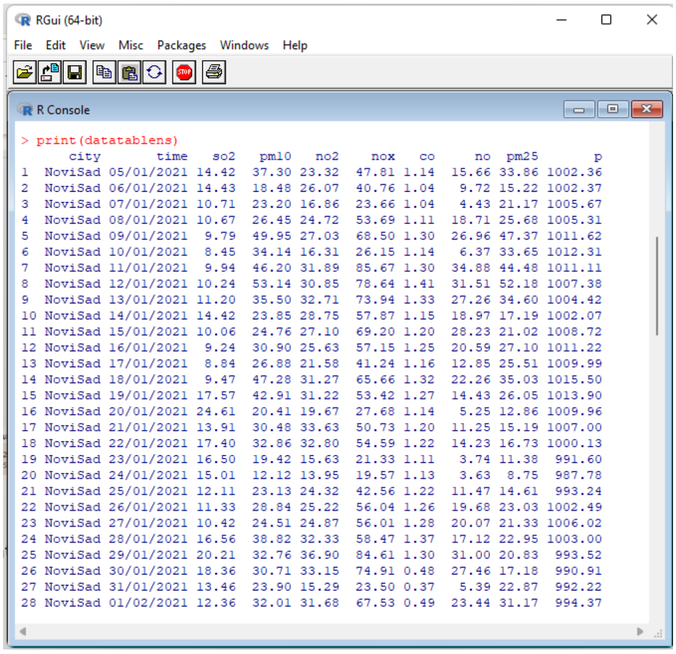
```
setwd("C:/Data/AirData")
datatablens <- read.table("azzsdatans.txt", header = TRUE, fill = TRUE)
datatableni <- read.table("azzsdatani.txt", header = TRUE, fill = TRUE)
vecnsso2 <- datatablens$so2
vecnspm10 <- datatablens$pm10
vecnsno2 <- datatablens$no2
vecnsnox <- datatablens$nox
vecnsco <- datatablens$co
vecnsno <- datatablens$no
vecnspm25 <- datatablens$pm25
vecnst <- datatablens$t
vecnsp <- datatablens$p
vecnsrh <- datatablens$rh
vecnscity <- datatablens$city
vecnstime <- datatablens$time
vecniso2 <- datatableni$so2
vecnipm10 <- datatableni$pm10
vecnino2 <- datatableni$no2
vecninox <- datatableni$nox
vecnico <- datatableni$co
vecnino <- datatableni$no
vecnipm25 <- datatableni$pm25
vecnit <- datatableni$t
vecnip <- datatableni$p
vecnirh <- datatableni$rh
vecnicity <- datatableni$city
vecnitime <- datatableni$time
summary(vectorniA)
summary(vectornsB)
print(datatablens)
print(datatableni)
png(file = "diagramAni.png")
plot(vecniso2,col = "black",main = "SO2 - Niš",ylab = "SO2 values - microgram/m3",xlab =
"Day",type = "p")
dev.off()
png(file = "diagramBns.png")
plot(vecniso2,col = "black",main = "SO2 – Novi Sad",ylab = "SO2 values - microgram/m3",xlab =
"Day",type = "p")
```

dev.off()

Where A, B are short names from following set of pollutants: {so2, pm10, pm25, no, no2, nox, co}.

First line in our program is for setting the working directory in R language with setwd(path) procedure. Second command is reading data from external tab delimited textual file that include the stored data about measured concentrations of air pollutants with read.table() function. Parameters are header for using the names of columns and fill for ignoring blank characters in data structure. This function creates a table data structure with title row that contains names for each column. Third step is creating various vector structures for measured pollutants values from previously created table with "<-" operator. A vector is a set of data of the same or different basic type. An R table is a list of vectors. In our program we created vectors for all pollutants and for measured temperature, pressure and relative humidity. Next R commands used in analysis are summary() and print(). Print outputs the selected data structure specified as a parameter. An example of executing this command is shown on Fig. 1 that illustrates data table with measured pollutant values imported into the R for the city of Novi Sad:

> print(datatablens)



	city	time	so2	pm10	no2	nox	co	no	pm25	p
1	NoviSad	05/01/2021	14.42	37.30	23.32	47.81	1.14	15.66	33.86	1002.36
2	NoviSad	06/01/2021	14.43	18.48	26.07	40.76	1.04	9.72	15.22	1002.37
3	NoviSad	07/01/2021	10.71	23.20	16.86	23.66	1.04	4.43	21.17	1005.67
4	NoviSad	08/01/2021	10.67	26.45	24.72	53.69	1.11	18.71	25.68	1005.31
5	NoviSad	09/01/2021	9.79	49.95	27.03	68.50	1.30	26.96	47.37	1011.62
6	NoviSad	10/01/2021	8.45	34.14	16.31	26.15	1.14	6.37	33.65	1012.31
7	NoviSad	11/01/2021	9.94	46.20	31.89	85.67	1.30	34.88	44.48	1011.11
8	NoviSad	12/01/2021	10.24	53.14	30.85	78.64	1.41	31.51	52.18	1007.38
9	NoviSad	13/01/2021	11.20	35.50	32.71	73.94	1.33	27.26	34.60	1004.42
10	NoviSad	14/01/2021	14.42	23.85	28.75	57.87	1.15	18.97	17.19	1002.07
11	NoviSad	15/01/2021	10.06	24.76	27.10	69.20	1.20	28.23	21.02	1008.72
12	NoviSad	16/01/2021	9.24	30.90	25.63	57.15	1.25	20.59	27.10	1011.22
13	NoviSad	17/01/2021	8.84	26.88	21.58	41.24	1.16	12.85	25.51	1009.99
14	NoviSad	18/01/2021	9.47	47.28	31.27	65.66	1.32	22.26	35.03	1015.50
15	NoviSad	19/01/2021	17.57	42.91	31.22	53.42	1.27	14.43	26.05	1013.90
16	NoviSad	20/01/2021	24.61	20.41	19.67	27.68	1.14	5.25	12.86	1009.96
17	NoviSad	21/01/2021	13.91	30.48	33.63	50.73	1.20	11.25	15.19	1007.00
18	NoviSad	22/01/2021	17.40	32.86	32.80	54.59	1.22	14.23	16.73	1000.13
19	NoviSad	23/01/2021	16.50	19.42	15.63	21.33	1.11	3.74	11.38	991.60
20	NoviSad	24/01/2021	15.01	12.12	13.95	19.57	1.13	3.63	8.75	987.78
21	NoviSad	25/01/2021	12.11	23.13	24.32	42.56	1.22	11.47	14.61	993.24
22	NoviSad	26/01/2021	11.33	28.84	25.22	56.04	1.26	19.68	23.03	1002.49
23	NoviSad	27/01/2021	10.42	24.51	24.87	56.01	1.28	20.07	21.33	1006.02
24	NoviSad	28/01/2021	16.56	38.82	32.33	58.47	1.37	17.12	22.95	1003.00
25	NoviSad	29/01/2021	20.21	32.76	36.90	84.61	1.30	31.00	20.83	993.52
26	NoviSad	30/01/2021	18.36	30.71	33.15	74.91	0.48	27.46	17.18	990.91
27	NoviSad	31/01/2021	13.46	23.90	15.29	23.50	0.37	5.39	22.87	992.22
28	NoviSad	01/02/2021	12.36	32.01	31.68	67.53	0.49	23.44	31.17	994.37

Fig. 1. Air pollution data loaded into the R GUI

Basic R procedure for calculating various elementary statistics is summary(). Parameter for this function is a data vector name through which statistics are calculated. An example of executing this command is shown on Fig. 2 that illustrates calculated stistics for SO_2 pollutant measured in the city of Niš.

> summary(vecniso2)

The summary function returned statistics such as: the minimum, the first quintile, the median, the mean, the 3rd quintiles, and the maximum value of input data i.e. vector with data. Quintiles are points in a distribution that relate to the rank order of values in that distribution. [13]

> summary(vecnspm25)

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
5.64	20.88	26.77	31.61	41.05	75.73

> summary(vecnipm25)

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
10.79	30.78	44.13	51.11	64.86	182.66

Creating diagrams for measured air pollutants values was done with a set of commands that are not all shown in this paper, because of limits on the maximum number of pages per paper. We will show how to draw a diagram on the following two examples:

> #SO2 Nis points type diagram

```
> png(file = "diagramso2ni.png")
> plot(vecniso2,col = "black",main = "SO2 - Niš",ylab = "SO2 values - microgram/m3",xlab =
"Day",type = "p")
> dev.off()
> #SO2 NS points type diagram
> png(file = "diagramso2ns.png")
> plot(vecnsso2,col = "black",main = "SO2 - Novi Sad",ylab = "SO2 values - microgram/m3",xlab =
"Day",type = "p")
> dev.off()
```

Png() procedure creates an image file, plot() creates a diagram over a data set, with a specific title, text on the x and y axes, there is also a diagram type. Finally dev.off() procedure saves the result of diagram creation physically to disk, within the working folder.

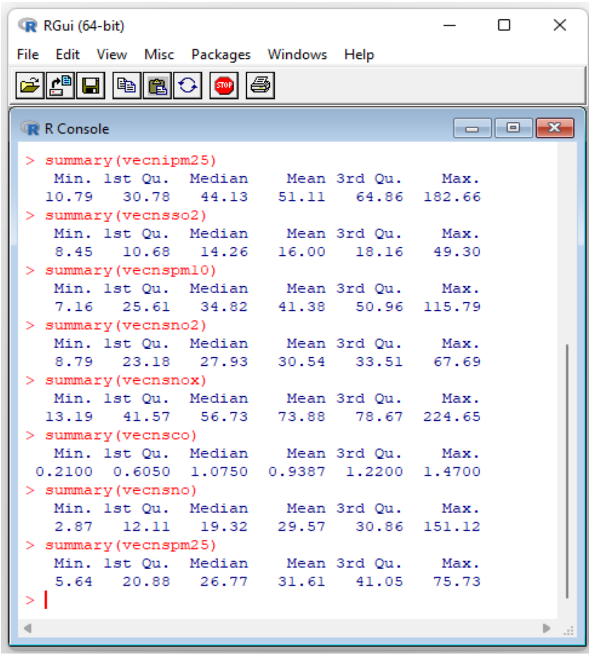


Fig. 2. Results of executing the R summary procedure

RESULTS AND DISCUSSION

Statistical results of multiple execution of summary() procedure is presented in Table 1. The minimum, the first quintile, the median, the mean, the 3rd quintiles, and the maximum values of all air pollutant for both cities is shown in the corresponding columns.

Table 1. Statistical results given from the R program

Air pollutant	City	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
SO_2	Niš	9.70	14.98	17.09	17.42	18.71	49.85
PM 10	Niš	14.29	32.90	50.03	59.05	78.14	189.68
NO_2	Niš	10.71	19.66	26.04	27.60	33.67	63.10
NO_X	Niš	14.97	31.66	40.99	52.41	58.59	231.80
CO	Niš	0.54	0.78	1.07	1.225	1.345	4.56
NO	Niš	2.41	6.45	8.93	16.18	17.12	109.79
PM 2.5	Niš	10.79	30.78	44.13	51.11	64.86	182.66
SO_2	Novi Sad	8.45	10.68	14.26	16.00	18.16	49.30
PM 10	Novi Sad	7.16	25.61	34.82	41.38	50.96	115.79
NO_2	Novi Sad	8.79	23.18	27.93	30.54	33.51	67.69
NO_X	Novi Sad	13.19	41.57	56.73	73.88	78.67	224.65

CO	Novi Sad	0.21	0.60	1.075	0.94	1.22	1.47
NO	Novi Sad	2.87	12.11	19.32	29.57	30.86	151.12
PM 2.5	Novi Sad	5.64	20.88	26.77	31.61	41.05	75.73

Diagarams that graphicaly illustrates measured pollutant values are shown on figures Fig. 3-Fig. 8. Left picture shows the pollutants in the city of Novi Sad, and the right picture in the city of Niš.

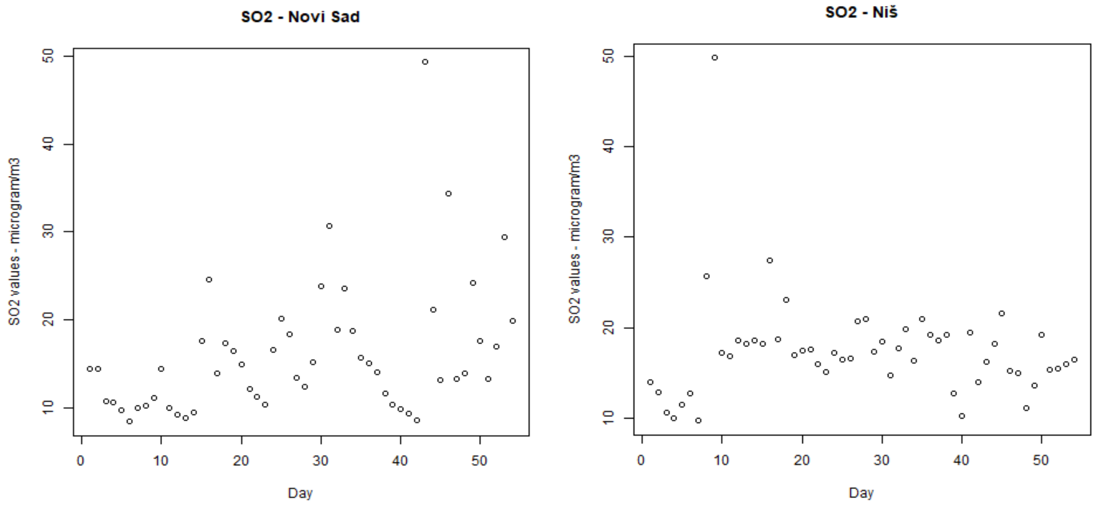


Fig. 3. SO_2 pollutant measured values diagram for Novi Sad and Niš

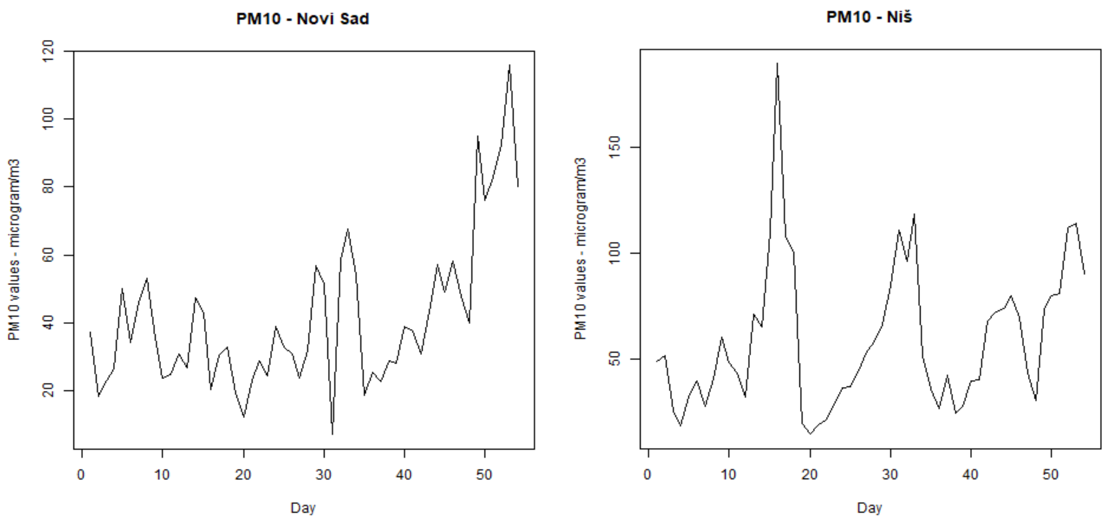


Fig. 4. PM 10 pollutant measured values diagram for Novi Sad and Niš

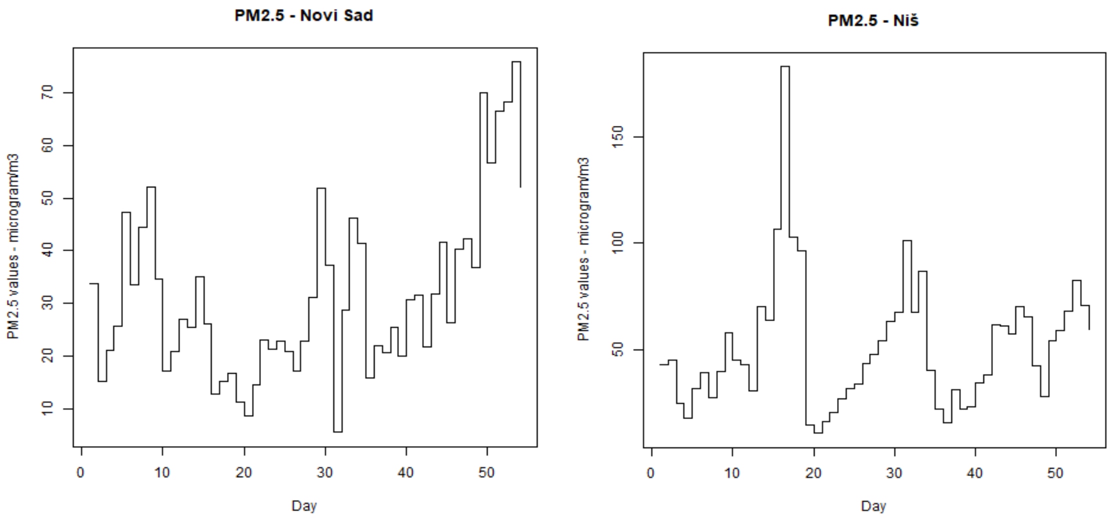


Fig. 5. PM 2.5 pollutant measured values diagram for Novi Sad and Niš

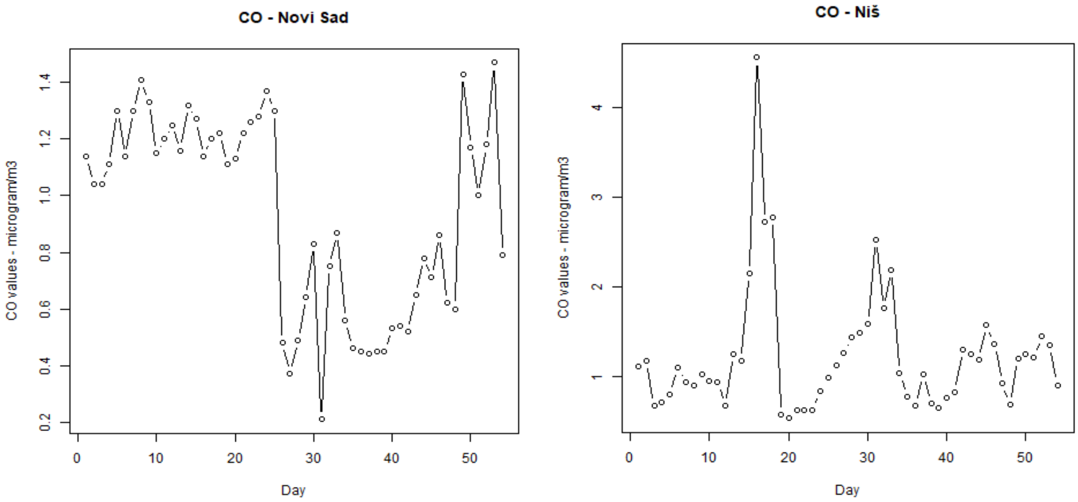


Fig. 6. CO pollutant measured values diagram for Novi Sad and Niš

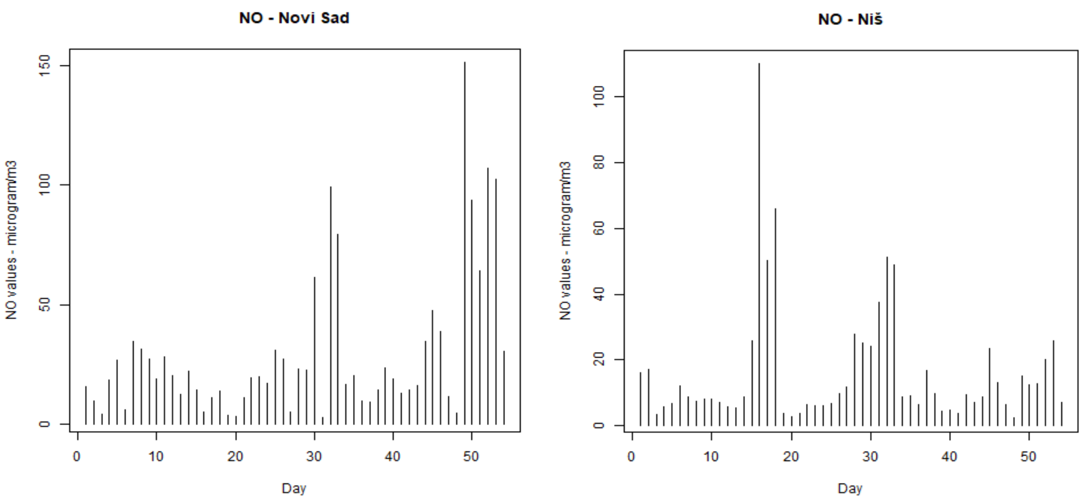


Fig. 7. NO pollutant measured values diagram for Novi Sad and Niš

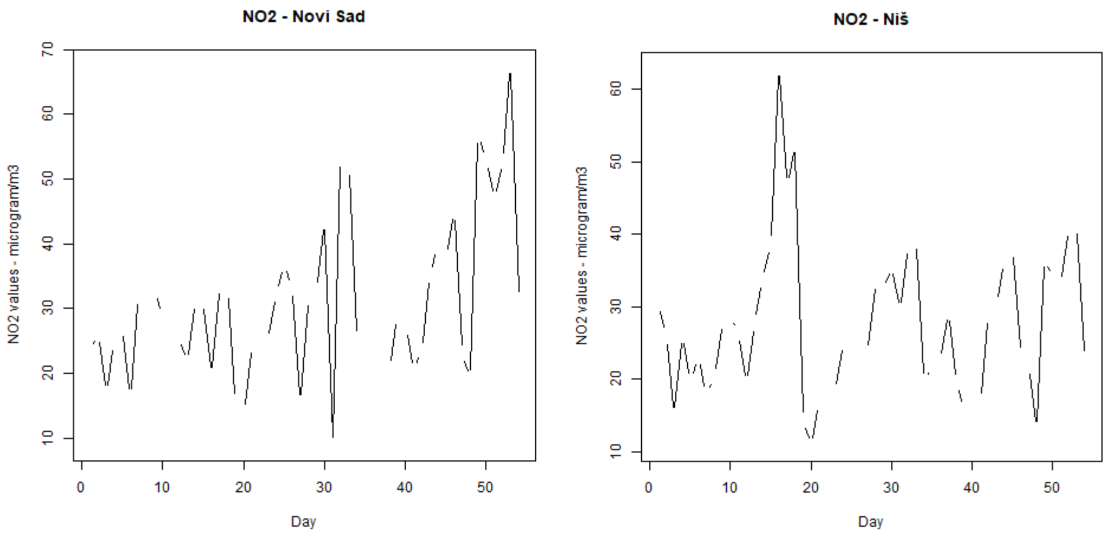


Fig. 8. NO_2 pollutant measured values diagram for Novi Sad and Niš

Monitoring air pollution during two winter months (January and February) in 2022, shows that pollutions in both cites was relatively high. The concentration of SO_2 was high, for both cites, as expected in that period of year, when consumption of fossil fuels for household heating is high (Fig. 3). The amount of PM 10 suspended matter, in the same period, had 20 days of overruns, above the daily average of 50 $\mu g/m^3$, in the Niš city. In the same time, Novi Sad had 12 days of overruns (Fig. 4). The same situation is for PM 2.5 matters, which was higher in both cities during two months, and under the limited values of 25 $\mu g/m^3$ (Fig. 5). Monitoring CO pollution, have been shown that the Novi Sad and Niš was significantly polluted in january, then in february, and that it did not exceed the daily limit value of 5 mg/m^3 (Fig. 6). In the winter months, the concentration of nitrogen oxides are high, as a consequence of the operation of thermal power plants and individual conbustion. There fore, the monitoring NO and NO_2 shows that NO_2 was in the tolerated value almost in both months, and both cites (Fig. 7 and 8). Therefore, we can conclude that during these two months, suspended particles were the dominant pollutant in the area of these two cities.

CONCLUSION

Our research presents the possibilities of applying the programming language R in the field of ecology. Pollutant data were collected and loaded into the R language, within a program we wrote. Basic statistical calculations were performed, the data was visualized, the obtained results were discussed and the level of pollution in the two large cities in Serbia was compared. The direction of further application of the R language can be making more complex statistical calculations with larger data sets and the usage of free R libraries with better visualization functions. The main goal of this research is to present R's opportunities to help scientists to contribute on the reduction of air pollution.

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LITHIUM ION BATTERY RECYCLING AND STATE IN THE REPUBLIC OF SERBIA

Snežana Filip[1], Branislav Leleš, Zoltan Kazi[1]
[1]University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia
e-mail: zana@tfzr.uns.ac.rs

Abstract: Today, the use of lithium (Li) ion batteries is rapidly increasing, which leads to the problem of their disposal, recycling and reuse. If they are not handled properly, it will certainly have a negative impact on the environment and resources. Therefore, the recycling of Li-ion batteries attracts the attention of many researchers. In this paper, the technologies for waste Li-ion battery recycling, the state of recycling in developing country and Serbia, will be presented and analyzed. Additionally, many problems and prospect of the current recycling processes are discussed. Also, our intention is to stimulate further interest in spent Li-ion battery recycling and in the appreciation of its benefits.
Key words: Li-ion batteries, recycling, sustainability

INTRODUCTION

From the first commercialization in 1991, Li-ion battery are extensively used in portable computing (laptops, tablets) and telecommunication (mobile phones) equipment, cameras, power tools, medical devices, e-bike and etc. Moreover, rapid development of electric vehicle (EV) and energy storage system (ESS) technologies, has increase the needs for lithium and their consumption has been more than doubled over the last decade [1]. For these reasons, lithium may become a very required and valued metal, so the significance for Li-ion battery recycling is vital, primary for environmental, and secondary for industry, energy and economy.
Lithium is widely used for his good ones phisico-chemical properties: a) it is lightest metal; b) it has the highest electrochemical potential of all metals, and c) it has the highest energy density among all metals. Regarding the use Li in battery (65%), it is also used in ceramics and glass (18%), and greases/castings (8%), polymers (3%) and others (6%) [1].
Lithium is exploits from two sources: ores and salt lakes. Chile, Bolivia and Argentina possess more than 70% of the global Li deposits. Australia produces the most lithium (43.5% of global production), followed by Chile (32.8%), while the biggest exporters are China and Argentina [1].
Today, rapid consumption of batteries leads to accelerated generation of them, which has a harmful effect on the state of the environment and the state of exploitation of other rare metals which are integral parts of them. Therefore, recycling provides a crucial solution to raw material supplier. The aim of this paper is to summarizes technologies for recycling Li-ion batteries, analyze the state of recycling in the developed countries of the world and the state in our country, as well as points out the problems that arise in the use of available recycling technologies.

STRUCTURE OF LI-ION BATTERY

Generally, lithium ion battery are consists of: anode, cathode, current collectors, a separator, liquid electrolyte, container and sealing parts [2]. The anode is usually a copper foil coated with a mixture of graphite, conductor, polyvinylidene fluoride (PVDF) binder and the electrolyte. The electrolyte provides the movement of electrons between the electrodes, and is normally lithium hexafluorophosphate (LiPF6) dissolved in an organic solvent (usually ethylene carbonate (EC), diethyl carbonate (DEC), dimethyl carbonate (DMC) or mixture thereof). The cathode is aluminum foil coated with cathode materials, PVDF binder, conductor, and fluoride salt. Separator is between the anode and cathode as a barrier, and is made of polypropylene (PP) or polyethylene (PE) [2]. In the Figure 1 is presented the components of various forms of Li-ion batteries. The cathode materials may be: lithium cobalt oxide (LCO, $LiCoO_2$), lithium manganese oxide (LMO, $LiMn_2O_4$), lithium nickel manganese cobalt oxide (NMC, $LiNiMnCoO_2$), lithium iron phosphate (LFP, $LiFePO_4$), lithium nickel cobalt aluminum Oxide (NCA, $LiNiCoAlO_2$). The use and application of different types of Li-ion batteries depends on the used cathode materials. In the Table 1 are given the types of Li-ion batteries and their applications.

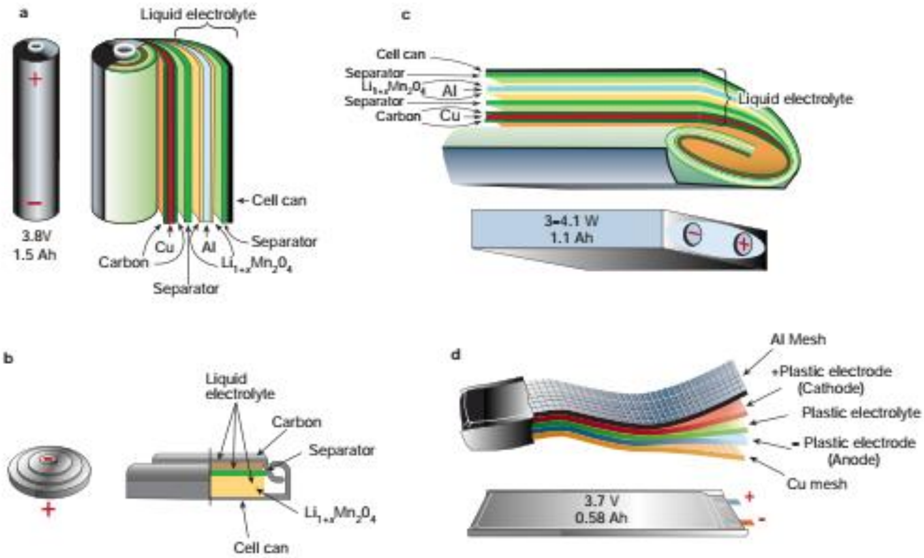

Fig. 1. Shematic representation of the components of various forms of Li-ion battery, a) cylindrical, b) flat, c) prismatic, and d) thin and flat [4]

Table 1. Types of Li-ion batteries and their main application [5]

Cathode type	Properties	Applications
LCO	Voltages: 3.60 V nominal; specific energy: 150–200 Wh/kg	Mobile phones, tablets, laptops, cameras
LMO	Voltages: 3.70 V nominal; specific energy: 100–150 Wh/kg	Power tools, medical devices, electric powertrains
NMC	Voltages: 3.70 V nominal; specific energy: 150–220 Wh/kg	E-bikes, medical devices, EVs, industrial
LFP	Voltages: 3.20 V nominal; specific energy: 90–120 Wh/kg	Portable and stationary needing high load currents and endurance
NCA	Voltages: 3.60 V nominal; specific energy: 200–260 Wh/kg	Medical devices, industrial, electric powertrain (Tesla)

Due to their low cost, high safety and long life cycle LFP and NMC batteries are mainly used in electric vehicles and electrical storage systems, and are dominating to the market.
Li-ion battery life is from three to five years, for small and large electronic devices. Regard to their progressive usage and life cycle, Li-ion battery disposal was estimated to be 10 700 tons in 2012, while in 2020 this disposal is estimated to be 250 000 tons [6]. This value will grow every year, and it is estimated that in 2025 it will reach a value of 464 000 tons [1]. The huge amount of spent Li-ion battery, already now, and in the future will soon become a huge problem that overload the environment. Therefore, the recycling process of used battery has appreciable prospect and is environmentally friendly, and much more, can generate an economic benefits of 22 000 $/t by extracting rare metals such as Co, Al, Ni, Cu and Li [7].

AVAILABLE TECHNOLOGIES FOR RECYCLING LI-ION BATTERIES

Various technologies are used in Li-ion battery recycling process. Most methods focus on the extraction of Co, Ni, or Mn; whereby new technology is based on Li extraction and colection. Battery structure further complicates recycling efforts. Li-ion batteries are complex and compact devices that come in a variety of sizes and shapes, and are not designed to be disassembled. Recycling for Li-ion batteries includes both physical and chemical process [7].

Physical processes usually involve pretreatment and direct recovery of electrode materials. These processes usually include screening, magnetic separation, disassembly, washing, crushing, heating treatment, etc. Chemical processes can be divided into pyrometallurgical and hydrometallurgical processes, which usually involve separation, leaching, extraction and chemical/electrochemical precipitation. Before these different technological methods, it is necessary to get pre-treatment process, which includes full discharging battery. The often used method is to submerge the battery in a conductive solution, such as a NaCl solution. After that, comes physically grinding the discharged Li-ion batteries, and solvent pre-treatment which implies removing the additive binder material that strengthens the foil contact with the active materials, thereby separating the active materials. After separating the plastic, metal case, electrode plate, and separator, the cathode is cut into small pieces.
In the next secondary step, which is the main process for the separation of materials from the battery charger and the process of decomposition, pyrometallurgy or hydrometallurgy process is employed. Pyrometallurgy uses high temperatures to remove organic material via evaporation and causes reactions in the cathode and anode to make lithium soluble in water [1].
Hydrometallurgy usually involves leaching and reduction. It is usually parted into acid leaching and biological leaching according to the leaching method. Additionally, lithium compounds can be created using acids or bases for leaching, followed by precipitation, solvent extraction, or selective adsorption [8].
Aditionally, every of these recycling technologies have advantages and disadvantages. Pyrometallurgy could cause the high energy consumption, low recovery efficiency, and the production of toxic gases (dioxins, furans, etc.), the development of high recovery rate, low energy consumption and low environmental hazard. This process has been commercialized because of its simplicity and efficiency in recovering Co, the most valuable metal in the spent Li-ion batteries. On the other hand, hydrometallurgical process is low power consumption, with low waste, high purity, and high emissions rate. The great disadvantages are complex measures, excessive use of reagents, pollution of contaminated water and etc. Although these techniques are generally accepted in the world, new technological solutions are sought in order to reduce harmful gases, reduce the use of chemicals and be economically more profitable.

STATE OF RECYCLING LI-BATTERIES IN THE WORLD AND IN THE SERBIA

Analyzing the amount of production and the amount of spent Li-ion battery it is obvious, that in the future we can expected increasing in spent Li-ion batteries. Most of those batteries may ending in landfills although Li-ion batteries can be recycled. Industry analysts predict that 11 million of metric tons of Li-ion batteries expected to reach the end of their service lives between now and 2030 [9]. In the Figure 2 is display the representation of different types of Li-batteries recycling worldwide.

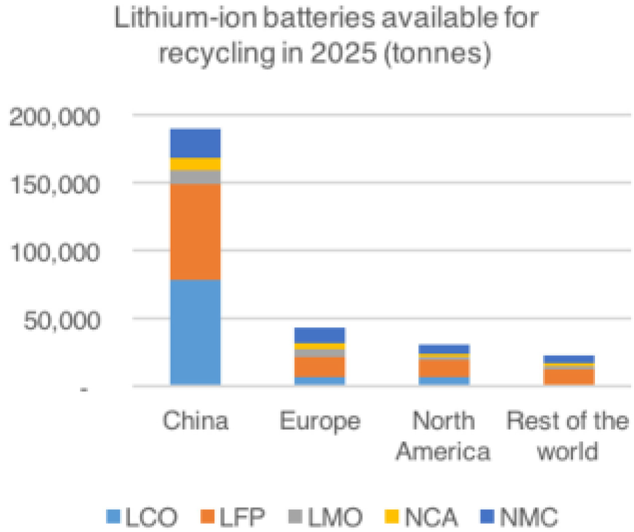

Fig. 2. Li-ion batteries for recycling in 2025 [10]

Based on this information, the governments are realizing the importance of setting up a comprehensive collection system and laws relevant to the collection and disposal of spent batteries. Li-ion spent battery recycling is carried out in Asia, North America and Europe. At European level, the collection of waste batteries is organized through three main directives: the Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators [11], the Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) [12], and the Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end of life vehicles [13]. The Battery Directive regulates the waste management of any type of battery at its end of life. The WEEE Directive regulates electrical and electronic equipment (EEE), including batteries used in these products: when EEE become a waste and are dismantled for further treatment, batteries are collected for separate recycling, reuse or repurpose [2]. The Battery Directive therefore applies to portable batteries, automotive batteries as well as industrial batteries.
The batteries are valuable and recyclable, but because of technical, economic, and other factors, less than 5% are recycled today. In Australia, only 2-3% battery are collected and recycled. The recycling rates in the European Union and the USA is less than 5%, and less than 1% of lithium is recycled [9]. The mean reason for such low collection and recycling rate is the lack of consumer awareness. Even more, it may vary by country, because of a lack of legal and physical infrastructure for widespread collection and efficient, safe, and economical transportation of the disposed Li-ion batteries.
Fortunately, this situation is changing. In the last decade has seen global arise in interest of Li -ion recycling. Thus the researchers, environmentalists and buttery specialists, invest enormous efforts in finding recycling technologies and implementing legal regulations in this area. In addition to potential economic benefits, recycling also reduce the quantity of matals and other materials going into landfills. In many types of Li-ion batteries, concentration of metals, such as Ni, Co, Mn, Al, along with those of Li, exceed the concentrations in natural ores. The demand for rare metals can increase their exploitation, where the world reserves of Li and Ni are adequate to sustain rapid growth of battery production. But battery manufacturing could decrease global Co reserves by more than 10%. The second and very important fact, is that metals and electrolytes found in batteries can readily leak from the casing of buried batteries and contaminate soil and groundwater, threatening ecosystems and human health.
The companies worldwide, such as Umicore, Sumitomo-sony, DK recycling und Roheisen GmbH, and SNAM, recycle batteries using the pyrometallurgy and hydrometallurgy methods for recycling. These companies have focused on recycling Co and Ni, rather than Li [1]. For exzample, Apple's Liam robot disassembles the iPhone to recover metals such as cobalt and gold.
The research carried out by IDTechEx forecasts, by 2040 global Li-ion battery recycling market will be worth 31 billion dollars annually [14]. According to IDTechEx, analysis of each markets – China, Europe and North America will be provided with insights on their market size and value. China is the largest market for Li-ion battery recycling: by 2040 over 50%, or 4.3 million tonnes of the world's spent Li-ion batteries will be recycled in China. And although in the early 2020s, most Li-ion battery available for recycling come from electronic equipment, from 2025 onwards, the electric vehicle sector will dominate and significantly increase the share of Li-ion battery recycling (Fig. 3)[14].

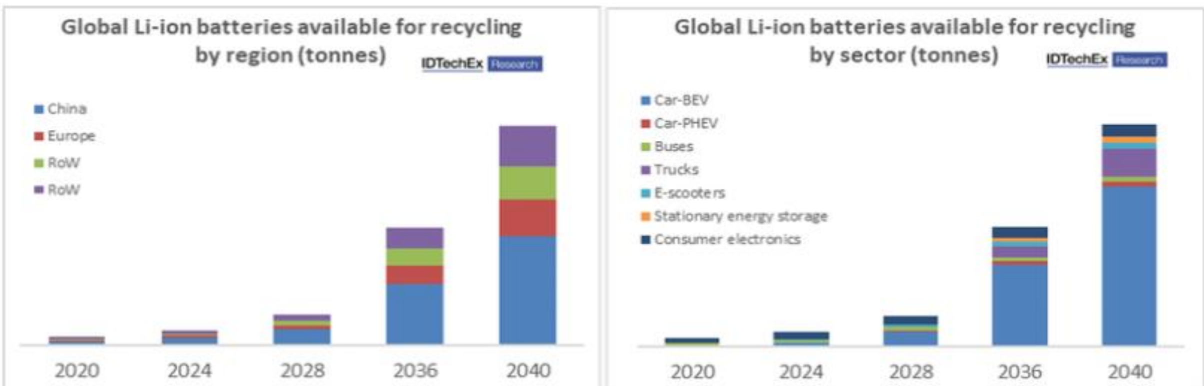

Fig. 3. Forecast of global Li-ion batteries recycling [14]

The situation in the Republic of Serbia is detable on this isssue. According to the data of the Environmental Protection Agency, in Serbia, an average of 1 900 tons of spent batteries and accumulators ends up as waste every year, where the largest part is lead batteries. These data do not include households, so there are only unofficial estimates that each citizen of Serbia uses about a kilogram of batteries per year, which after use end up in municipal waste or in illegal landfills. From there, batteries are "returned" through the food chain, with toxic substances such as iron and cadmium ending up in soil and groundwater. The main reasons for the low percentage of recycling of this type of waste are the lack of larger facilities for these purposes, a poorly developed collection network. There is no factory for recycling this type of batteries in Serbia. There is only one company in Serbia that deals with the export of used portable batteries, "Jugoimpex" from Niš, and its daughter company "E-reciklaža". According to the company's data, in 2020, 17 173 kilograms of unsorted waste batteries were exported to recycling in Germany.

CONCLUSION

In theory, recycling is the least sustainable measure in circular economy and should be the last step when the batteries couldn’t be exploited anymore. Also, recycling should be used wherever possible, both for environmental protection and for economic, production and other benefits. In the recycling chain must be the valorization of the whole waste; not only cathode material, but also anode material (basically of graphite presence) and electrolyte according to the principle of sustainability.
In the conclusion, for better battery recycling, it is necessary to organize a better collection network and develop sophisticated technologies, with battery classification based on the type of electrode. Also, the cooperation of state and governments on the recovery of spent Li-ion battery and relevant legislative, woud link this process around the world.

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MACROPHYTES AS INDICATORS OF ECOLOGICAL STATE OF SURFACE WATER

Ivana Krtolica[1], Snežana Radulović[2] , Dušanka Cvijanović[2]
[1]The Institute for Artificial Intelligence Research and Development of Serbia, Novi Sad, Serbia
[2] University of Novi Sad, Faculty of Sciences, Department of Biology and Ecology, Serbia

e-mail: ivana.krtolica@ivi.ac.rs

Abstract: This work represents an advantage of using macrophytes as indicators for ecological state class prediction based on orthophosphate anions concentrations instead of calculating water quality index, Serbian Water Quality Index (SWQI) concretely. Calculating of SWQI requires standard laboratory methods of water sampling that include sampling chemical parameters such as pH, temperature, orthophosphate anions, ammonium ions, total organic nitrogen concentrations, temperature, conductivity, values of biological oxygen demand, oxygen saturation in percents and amount of suspended solids. Macrophytes, as an official biological parameters for prediction of ecological state of rivers, are recognized as good predictors of ecological state classes based on concentrations of orthophosphate anions. *Phragmites australis L.* is an indicator species for river sections that belong to IV class of ecological state based on orthophosphate anions concentrations. For all river sections where presence of this macrophyte was detected during Joint Danube Survey 3 (JDS 3) scientific research expedition was calculated Serbian Water Quality Index (SWQI). Values of SWQI predicted good ecological state even for sampling points where among concentrations of orthophosphate anions river section belong to IV class of ecological state. This fact lead us to conclude that *in situ* prediction of ecological state of river according to orthophosphate anions concentrations is more specifically by presence of macrophyte *Phragmites australis L.* then by calculating quality index that requires expensive chemical analysis.
Key words: macrophytes, orthophosphates, SWQI

INTRODUCTION

Assessing and prediction quality of surface water is an extremely complex task for which there is no established general algorithm. Developing a low cost model for ecological assessment of large rivers is a challenging task. According to Water Frame Directive 2000/60/EC (WFD) parameters for ecological state prediction are divided into biological, chemical, physico – chemical and hydromorphological groups of parameters [1]. Macrophyte presence belong to biological group of parameters for ecological state prediction, and orthophosphate anions concentration values are official chemical indicators of ecological state [2]. Serbian Environmental Protection Agency (SEPA) developed Serbian Water Quality Index (SWQI) for predicting surface water quality according to selected chemical parameters. Calculation of SWQI is based on pH values, temperature, conductivity, amount of suspended solids and concentrations of ammonium, orthophosphate anions, total organic nitrogen and oxygen saturation values. Each of selected parameters used for calculating of SWQI value has it's own weight (wi) and quality index (qi). Online calculator of SWQI is available on official site of Serbian Environmental Protection Agency (SEPA) [3].

Danube River basin, as the second longest river in Europe that flow through 19 countries makes Danube the world's most international river [4]. For purpose of Joint Danube Survey 3 (JDS 3) scientific expedition organized by *International Commission for the Protection of the Danube River* (ICPDR) Danube River basin was divided on 68 sampling sites for sampling all official parameters for ecological state prediction proposed by Water Frame Directive 2000/60/EC (WFD) [2,4]. Both, left and right river sides, were included in this investigation. The total number of sampling sites was 123, because some of sampling sites were inaccessible. In paper Krtolica et al. (2021) is described developed model of Feed Forward Neural Networks (FFNN), based on dataset collected during this scientific research activity, where macrophyte presence determined by Kohler's five grade scale among Danube River basin were used as input variables, and classes of ecological state based on

orthophosphate anions concentrations were outputs [5]. In that modelling is confirmed significant impact of *Phragmites australis L.* as indicator species for river sections that against to orthophosphate anions concentration belong to IV class of ecological state. According to concentration of orthophosphate anions 96 from 123 JDS sampling sites belong to IV class of ecological state (0.1 – 0.19 mg/L) **(Table 1)**. Macrophyte species *Phragmites australis L. w*as detected on all of these sampling points [6]. Macrophytes are large enough plants suitable to the naked eye determination, so they are "easy-to-detect" parameters for ecological state prediction. In accordance with that fact prediction of ecological state based on orthophosphate anions, using *Phragmites australis L.* presence as indicator, is advantageable method in field of ecology and environmental engineering.
For purpose of this paper for all JDS sampling points where *Phragmites australis L*. was detected on river sections that according to orthophosphate anions concentrations belong to IV class of ecological state was calculated value of Serbian Water Quality Index (SWQI)[3]. For calculation of SWQI values of oxygen saturation and biological oxygen demand were excluded. Values of SWQI predicted good ecological state even for sampling points where river section according to orthophosphate anions concentration belong to IV class of ecological state. In keeping with that fact prognosing of ecological state of river section based on orthophosphate anions concentrations is more specifically by presence of macrophyte *Phragmites australis L.* as compared with prediction based on SWQI index.

MATERIAL AND METHODS

Study area

Danube is 2850 km long river, so after the Volga, is the second longest river in Europe and the longest river in European Union. Danube flows through much of Central and Southeastern Europe, from it's source in Germany to river mouth in Romania. Danube basin size is 801.463 km^2. Sampling points among Danube river determined in the frame with Joint Danube Survey 3 expedition, where macrophytes and chemical parameters were sampled, are presented in **Fig.1**.

Figure 1. Macrophytes and orthophosphate anions concentration sampling points along Danube River basin
https://www.researchgate.net/figure/Overview-of-the-Joint-Danube-Survey-3-JDS3-sampling-points-along-the-river-Danube-The_fig1_277348358

Aquatic macrophytes

Macrophytes are official biological parameters for ecological state prediction proposed by Water Frame Directive (WFD).

Aquatic macrophytes are aquatic photosynthetic organisms, large enough to see with the naked eye, that actively grow permanently or periodically submerged below, floating on, or growing up through the water surface [7].
Submersed macrophytes has significant role in nitrogen and phosphorus cycling processes, which both depends on dissolved oxygen concentrations in water [8].
Macrophyte type *Phragmites sp.* is one of the most widely distributed wetland plant genera worldwide. *Phragmites australis L.* is an emergent macrophyte species, sensitive to the increase of nutrients concentrations in water. *Phragmites australis L.* is a good indicator of eutrophication in water ecosystems and shows increase of biomass in eutrophic habitats [9].

Orthophosphates in surface water

In river ecosystems phosphorus is a key limiting factor for controlling primary production and also stimulate processes of eutrophication [10]. Orthophosphate anions concentration values in water above 0.8 mg/L extensively accelerate process of eutrophication [6]. Orthophosphoric acid, as triprotic acid, by electrolytic dissociation in aquatic environment gives 3 types of orthophosphate anions (PO_4^{3-}, HPO_4^{2-} and $H_2PO_4^{-}$). Orthophosphate anions in water occur due to intensive urbanization and agricultural production, so as due to discharging of sanitary installations. In Serbian part of Danube River basin amounts of phosphorus emission that originate from agricultural activities is above 75 kg/km^2 per year, and that is the highest amount of phosphorus emission along all Danube River basin [11]. Eutrophication caused by high amounts of orthophosphate anions has negative impact on dissolved oxygen concentration level in surface water [10,11].

Dataset

Presence of macrophyte species *Phragmites australis L.*, and values of orthophosphates anions concentrations among Danube River basin were gathered from dataset collected during Joint Danube Survey 3 scientific expedition [4]. For all sampling points among Danube River basin dataset included values of selected parameters for both sides of river. For river classification based on orthophosphate anion concentrations was used scheme that include 7 classes of ecological state [5,6].

Table 1. Classification of Danube river sections according to orthophosphate anions concentrations [PO_4^{3-}]

Ecological state class	**[PO_4^{3-}]**
I	0 – 0.019
II	0.02 – 0.039
III	0.04 – 0.09
IV	0.1 – 0.019
V	0.2 – 0.49
VI	0.5 – 0.8
VII	> 0.8

Serbian Water Quality Index (SWQI)

Serbian Water Quality Index is a descriptive indicator based on the Water Quality Index methodology which uses ten chosen quality parameters (Oxygen Saturation, Biological Oxygen Demand (BOD5), Ammonium ion concentration, pH, Total Oxidized Nitrogen and Orthophosphate anions concentrations, Suspended solids, Temperature, Conductivity and *E.Coli* /MPN) as an input in form of ten values (qi) representing surface water quality that are summarized as one index on a 0-100 scale. Each parameter doesn't have the same influence on the final, indexed overall water quality, thus each parameter has an appropriate weight (wi) where the sum of all weights equals to 1. SWQI score in the range of 72-78 corresponds to good ecological state (II class) [12].

RESULTS AND DISCUSSION

Analysing dataset collected in Joint Danube Survey 3 scientific expedition across all Danube River basin where according to orthophosphate anions concentration river section belong to IV class of ecological state, and *Phragmites australis L.* was occured in all sampling points. In JDS 3 dataset in all of selected sampling points beside orthophosphate anions concentration were measured values of pH, total organic nitrogen, suspended solids, temperature and conductivity. All of those parameters were used for calculating Serbian Water Quality Index (SWQI). Values of SWQI determined good ecological state even for sampling points where among concentration of orthophosphate anions river section belongs to IV class of ecological state. According to that fact prediction of ecological state of rivers based on orthophosphate anions concentration is more precisely using presence of macrophytes, and that is also low – cost and eco - friendly method for ecological class prediction.

Table 2. List of SWQI scores for Joint Danube Survey (JDS) sampling points with *Phragmites australis L.* presence where orthophosphate anions concentrations indicate IV class of ecological state

JDS sampling point with *Phragmites australis L.*	Orthophosphate anion concentration (mg/L)	SWQI value
JDS 1 (L)	0.11	75
JDS 1 (R)	0.11	75
JDS 2 (R)	0.12	75
JDS 7 (R)	0.11	75
JDS 13 (L)	0.12	73
JDS 13 (R)	0.12	73
JDS 15 (L)	0.1	76
JDS 15 (R)	0.1	76
JDS 17 (L)	0.14	73
JDS 18 (L)	0.17	73
JDS 18 (R)	0.17	73
JDS 19 (R)	0.1	75
JDS 20 (R)	0.13	76
JDS 25 (L)	0.17	73
JDS 25 (R)	0.17	73
JDS 42 (L)	0.14	75
JDS 43 (L)	0.18	75
JDS 45 (L)	0.14	76
JDS 46 (L)	0.13	78
JDS 46 (D)	0.13	78
JDS 52 (L)	0.17	76
JDS 66 (L)	0.15	73
JDS 66 (D)	0.15	73

* L- left river side
**R – right river side

CONCLUSION

Values of Serbian Water Quality Index (SWQI) based on official chemical parameters for ecological state class prediction proposed by Water Frame Directive (WFD) for all the sampling points where river section site belong to IV class of ecological state according to orthophosphate anions concentration prognoses good ecological state.

According to that fact we can conclude that on SWQI value of orthophosphate anion concentration doesn't have the most significant impact. *In situ* prediction method for ecological state class based on orthophosphate anion concentrations is noticing macrophyte species *Phragmites australis L.* Presence of *Phragmites australis L.* in river basin section indicate that orthophosphate anion concentrations on that river section are in range of 0.1 – 0.19 mg/L or higher. River sections with high levels of orthophosphates indicate purification treatment and control of pollutants sources. Even if value of Serbian Water Quality Index signify good ecological state levels of orthophosphates in water may indicate IV class of ecological state.

Prediction of high levels of orthophosphates in surface waters using presence of macrophytes is low – cost and eco – friendly method that should have more attention by scientific researchers.

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AGRICULTURE AND THE IMPACT OF AN INVISIBLE THREAT

Timotei Bogdan Bacoş[1], Adrian Eugen Cioablă[1], Francisc Popescu[1]
[1]University Politehnica Timisoara, Faculty of Mechanical Engineering, Timisoara, Romania
e-mail: adria.n.cioabla@upt.ro

Abstract: The traditional definition of noise is "unwanted or disturbing sound". Noise becomes unwelcome when it interferes with normal activities (such as sleeping or talking) or disrupts or impairs quality of life. The fact that you can't see, taste or smell it probably explains why it hasn't received the same attention as other types of pollution like air or water pollution. The air around us is constantly filled with noise, but most of us probably wouldn't say we're surrounded by noise. For some, however, the constant and escalating source of noise tends to be annoying. This "annoyance" can have serious consequences, especially for overall health.
Manufacturing agriculture produces high levels of noise. The following study shows a series of measurements on various agricultural machinery in different situations and the data received from the laptop connected to Sound Level Meter and Arduino Nano receiver with sound sensor attached [1].
Key words: noise pollution, cabin sound propagation, sound

INTRODUCTION

In agriculture noise is the most frequent exposure, but up to recent years it was rarely recognized. It affects the hearing organ of farmers [2]. Because of a great variety of machines used on farms and a changing magnitude of exposure to noise, noise has to be studied extensively. The aim of our study was to recognize and evaluate annual exposure to noise among private farmers engaged in plant production.
The middle ear is made up of three tiny bones or ossicles that transmit noise vibration to the inner ear. Noise will not affect the middle ear unless the sound impact or pressure is so great as to cause the bones to dislodge or fracture. The inner ear is highly susceptible to damage from overall exposure to loud noise. It is composed of hair-like structures that transmit noise messages to the brain by changing mechanical energy to electrical energy. With repeated noise exposure, hair cells are destroyed, causing substantial hearing loss [3].
A recent study performed in New Zeeland showed that noise in farm activities lay in a range between 84.8 to 86.8 dB(A) and hearing losses were consistent with this level of exposure. Age, driving tractors without cabs, and working with metal were important risk factors. The same study showed that majority of farmers involved in the study have a moderate risk of hearing loss, but a significant minority is at high risk [4].
In an Asian study, performed on 335 Thai farmers, found that a very high prevalence of clinical (> 25 dB HL threshold) hearing loss was observed in this study (50–55%) in the high-frequency band (3–6 kHz) [5].
Therefore, the goal of this study was to determine the level of exposure to noise of the operator of a modern tractor and combine, both used at large scale in Romania.

MATERIAL AND METHODS

Sound pressure analysis was conducted in the cabins of a tractor and a combine with DT-8852 sound meter, in various load scenarios. Sound level meters are frequently used in noise pollution studies to determine almost any type of noise, but especially for the industrial fields, environmental protection and airport noise [3]. The SPL (Sound Pressure Level) measurement application uses the built-in microphone to measure the volume of noise in decibels (dB), displaying a reference.

Fig. 1. Massey Ferguson tractor 8S.265 & Massey Ferguson Ideal 9T combine.

The tractor (Fig.1 left) is manufactures in 2021, 6 cylinders/7.4 liter and combine used (Fig.1 right) is 15.2 liters/8 cylinders, 647 HP engine, equiped with a 12.2 meters cutting blade. The combine hopper has a capacity of 17 tons and can be unloaded in 82 seconds. The gearbox is attached directly to the engine, driving all the main components of the combine: the processor, the cleaning system, the hydraulic pumps and the header comprising the chopping heads for different grains [6, 7].

RESULTS AND DISCUSSION

The measurements will be performed at different times and in different places. The first series will be carried out in the cab, at the level of the driver's head, when the machinery is idling and in working process. The second set of measurements will be performed outside the machine, as close as possible to the engine compartment, while it will perform the related work.

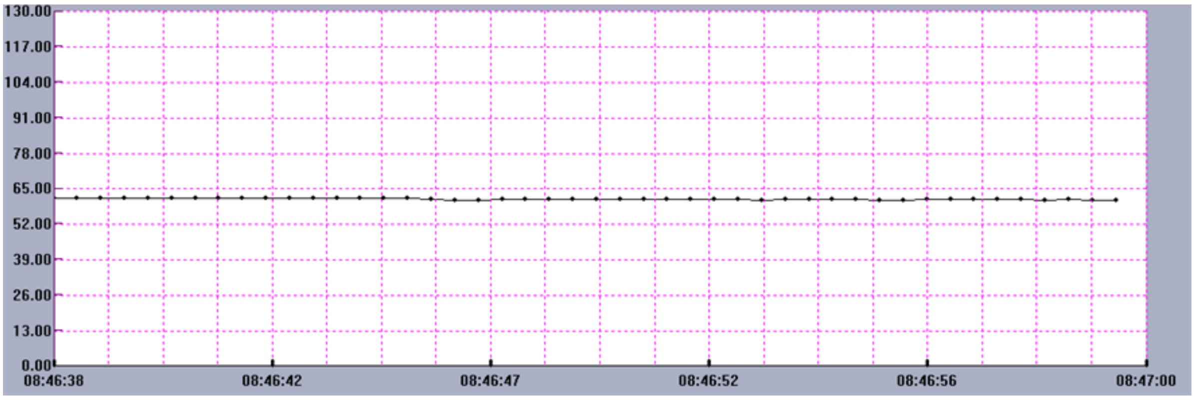

Fig. 2. Sound level inside MF 8S.265 tractor cabin at 800 rpm.

In figure 2 are presented the sound levels recorded inside the MF 8S.265 tractor, running at idle at 800 rpm. Values are reached with an average of 53.7dB. The sound intensity level is at the high comfort level. The sound perceived by the driver is at the normal conversation stage. It is observed from the beginning the efficiency of the new materials and technologies implemented regarding the comfort in the cabin.

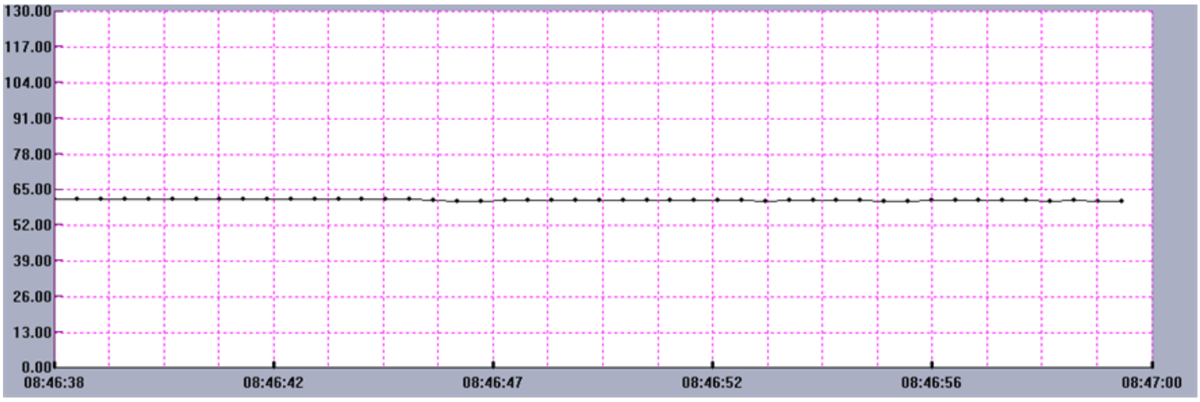

Fig. 3. Sound level inside MF 8S.265 tractor cabin at 1460 rpm.

In figure 3 are presented the sound levels recorded inside the MF 8S.265 tractor, running at 1460 rpm. With the positioning of the machine at a load speed of 1460 rpm, an increase of up to 60.5dB is observed, with over 7dB compared to the idle position. The machine tows a trailer to assist the combine. The suspension systems are active and controlled by the tractor computer, absorbing most of the sounds and shocks.

In figure 4 are presented the sound levels recorded inside the MF Ideal 9T combine, running at idle at 1000 rpm. Values are reached with an average of 61.4 dB. The value is about 20dB below the discomfort threshold. The soundproofing elements in the cab construction keep away from the operator the noise emitted by the entire engine-working group.

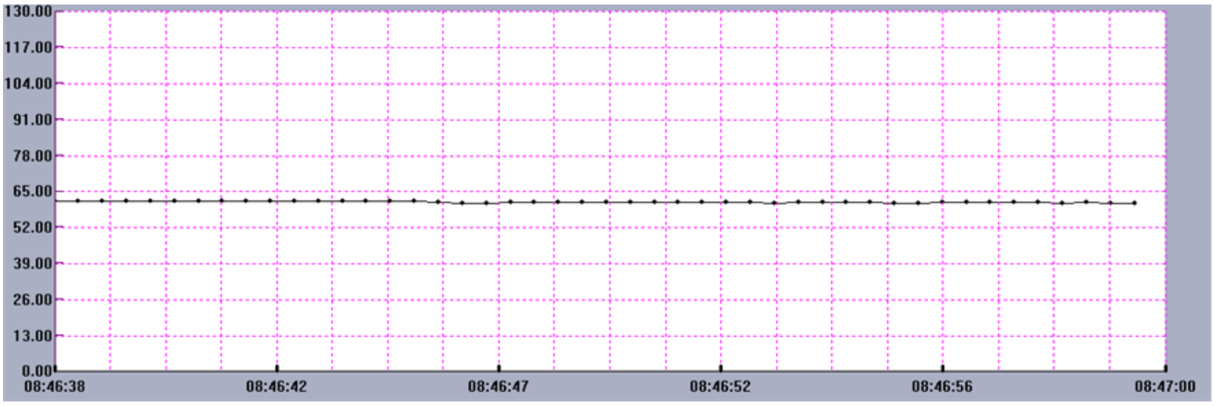

Fig. 4. Sound level inside MF Ideal 9T combine cabin at 1000 rpm.

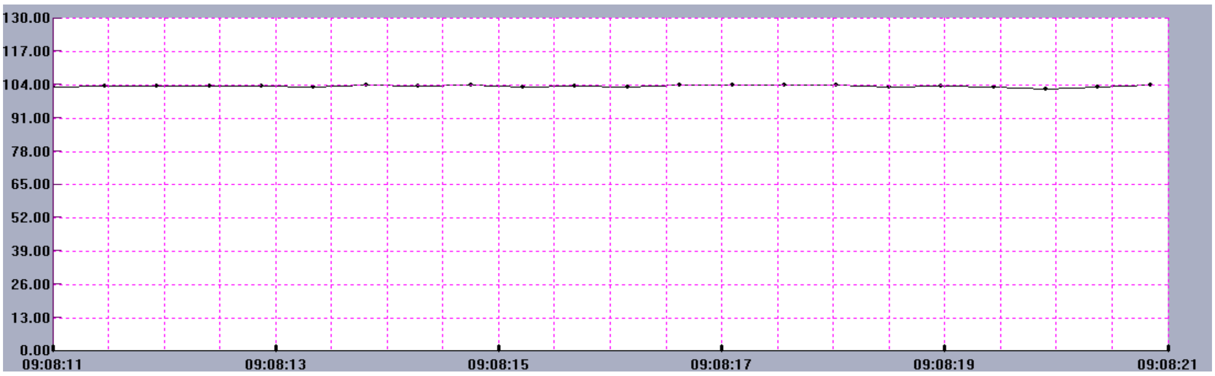

Fig. 5. Sound level inside MF Ideal 9T combine cabin at 1931 rpm.

Increasing the speed by over 900 rotations / minute leads to an increase in sound intensity of only 5dB, reaching a constant of 66.7dB. The additional elements of the engine compartment, but also the construction part of the cabin lead to a high absorption of the noises emitted during the load. Thus, during the mapping operation, simultaneously with the test part of the working organs, a high level of comfort is observed in the cabin. It is observed the efficiency of the automatic working speed control system, but also the use of the data initially entered by the manufacturers.

CONCLUSION

The equipment of the machines drastically influences the propagation of the sound inside them.
The tractor cab insulates by more than 20dB in the case of operation and by more than 21dB in the idle position. The combine cab insulates with over 38dB in the operating situation and with over 32dB in the idle position.
Inside the cab of the combine, the speed difference of 931rpm is felt by only 7dB. The equipment of the machines leads to a uniform, constant and protected way of working. The fluctuations are due to uncontrollable external auxiliary factors, such as weather conditions, the shape and quality of the tread.

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BIOGAS APPLICATIONS AT SMALL LABORATORY SCALE: COMPARATIVE TESTING FOR DIFFERENT MATERIAL SOLUTIONS

Bacoș Timotei Bogdan[1], Vujic Bogdana[2]
[1]Politehnica University Timisoara, Mechanical Engineering Faculty, Mihai Viteazu Blv, 1, 300222, Timisoara, Timis
[1]University of Novi Sad, Technical Faculty “Mihajlo Pupin”, 23000 Zrenjanin, Serbia
e-mail: bacost@yahoo.com

Abstract: Biogas currently represents an important energy carrier, because of its multiple sources and applications. Regarding those aspects, there are demands and research made, and correlated with the increase energy demand and pricing, to obtain biogas from multiple alternative sources and through different technologies for increasing the existing production in order to try and achieve at regional level an increased level of energetic autonomy. The present study involves the comparative testing of biogas at small laboratory scale in order to determine the potential for production of laboratory scale reactors created from different materials (inox and 3D printed PLA), by using as substrate waste waters from municipal treatment plant.

Key words: Anaerobic digestion, biogas, waste waters

INTRODUCTION

Biogas represents a combustible energy carrier which can be used to replace partially the existent fuel gas (methane) used for house holdings or industrial applications. The simplest applications of biogas are the generation of heat and/or electricity using boilers, generators or with Combined Heat and Power (CHP) units [1]. Anaerobic digestion consists of four stages; hydrolysis, acidogenesis, acetogenesis and methanogenesis [2,3]. Co-digestion increases methane yield because of the positive interactions in the assimilation medium [4,5]. Using waste water and sludge represents a high source for anaerobic digestion processes. Sludge that appear at waste water treatment plant (WWTP) is one of the most efficient resource for biogas production. One cubic meter of waste water may contain 3 to 6 MJ of potential heat energy according to biological oxygen demand (BOD) and chemical oxygen demand (COD) concentrations. At the same time, there is only 1.2-2.4 MJ needed to carry out treatment processes of this water (aeration, pumping of sewage and sludge, dewatering of sludge, and heating of digesters). That means that waste water contains more energy than its treatment needs [6,7].
3D printing is an existent applications which can be found in many fields of research and expertise. Currently, components and subassemblies created using 3D printing technology have great applications with increased potential to improve the used materials and quality of the process in order to obtain components with high level of quality in terms of endurance, tensile strength and other specific elements of material resistance.
The present material represents an initial comparative study of 5L batch reactors created conventionally for laboratory anaerobic digestion processes, using inox and 3D printed materials in order to determine if 3D printing can be a solution for using components with long lasting properties and if the designed reactor can sustain good quality anaerobic digestion with biogas production in different material combinations

MATERIAL AND METHODS

As previously presented, the two models of reactors used for experiments are presented below.

Figure 1 – PLA 3D printed reactor

The first reactor is developed using PLA printed filament. It is a batch type reactor with a total volume of 6L and batch volume of 5L. The lid was developed with orifices in which the sampling probe was inserted, for pH correction purposes, together with the temperature measurement thermocouple and biogas collecting dedicated bag.

In order to have a relatively constant temperature inside it, the reactor was inserted into a thermally controlled bath which in its turn was maintained at a temperature of 36-38 °C for a determined period of time.

Figure 2 – Standard inox reactor

The second type of reactor was developed using inox based material, also using a batch type reactor, the lid was developed in a similar manner, with the possibility of sampling for pH correction, temperature measurement and heating control, as well as the possibility of material agitation for homogenization purposes. The speed of agitator and temperature control is made by separate control unit, put in front of the reactor. This type does not need insertion into a thermal bath. The chosen temperature regime was again 36-38 °C.

The used materials for the present study were inserted into a recipe containing waste water from a treatment plant in Timis County, an inoculum from a biogas factory, containing cow and chicken manure (liquid part) together with degraded corn grains.

The experiments took place until no biogas was produced during the testing period. The produced biogas was analyzed with a gas analyzer model Geotech Biogas 5000 for methane, carbon dioxide and hydrogen sulphide

RESULTS AND DISCUSSION

The first experiment was conducted using the inox reactors – there were used 2 reactors for parallel measurement in order to observe the temperature and pH variation in time.

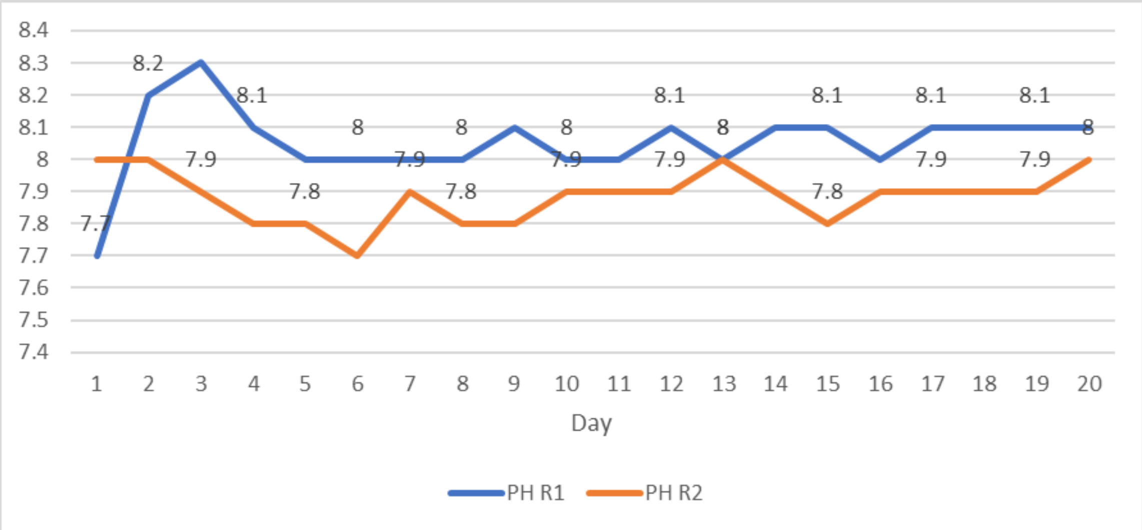

Figure 3 – pH time variation for the two reactors

From figure 3 it can be observed that the cow and chicken based liquid manure fraction are a solid buffer suspension for stable pH, the starting values being at mesophilic temperatures (36 – 38 °C) around an alkaline value of 8 for both reactors.

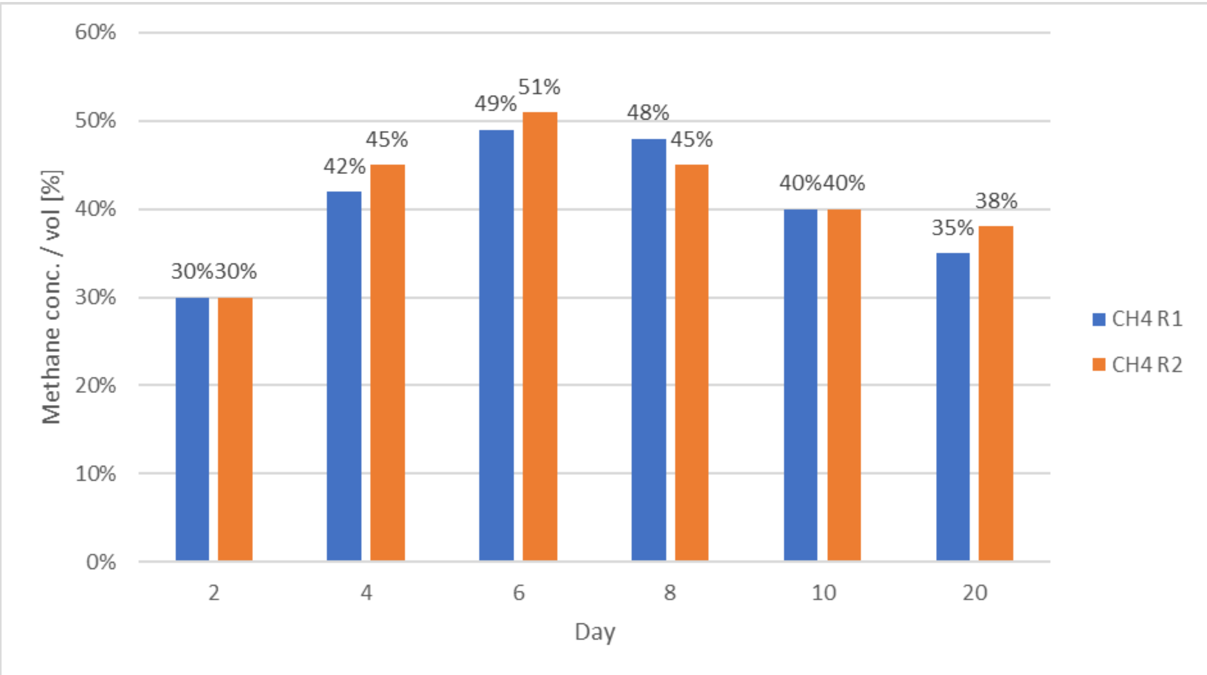

Figure 4 – Methane concentration during experiment

From figure 4 it can be determined the maximum methane concentration during the testing period which is around 50% by volume. This indicates a relatively low calorific potential for the produced biogas in terms of firing applications.
In the exact manner, the CO_2 concentration by volume is around 50%, while H_2S concentration is around 1100 ppm (parts per million) by volume. This value can have a negative impact on the metal components of any firing chamber in time.
The biogas quantities produced during the experiment were 14 liters for the first reactor and 8 for the second one.
The second experiment was made using the 3D printed reactor. Because it was an initial approach, for the experiment it was used just one reactor and the testing conditions were conducted in the same manner, using the same configuration of materials for substrate and the same temperature imposed conditions.

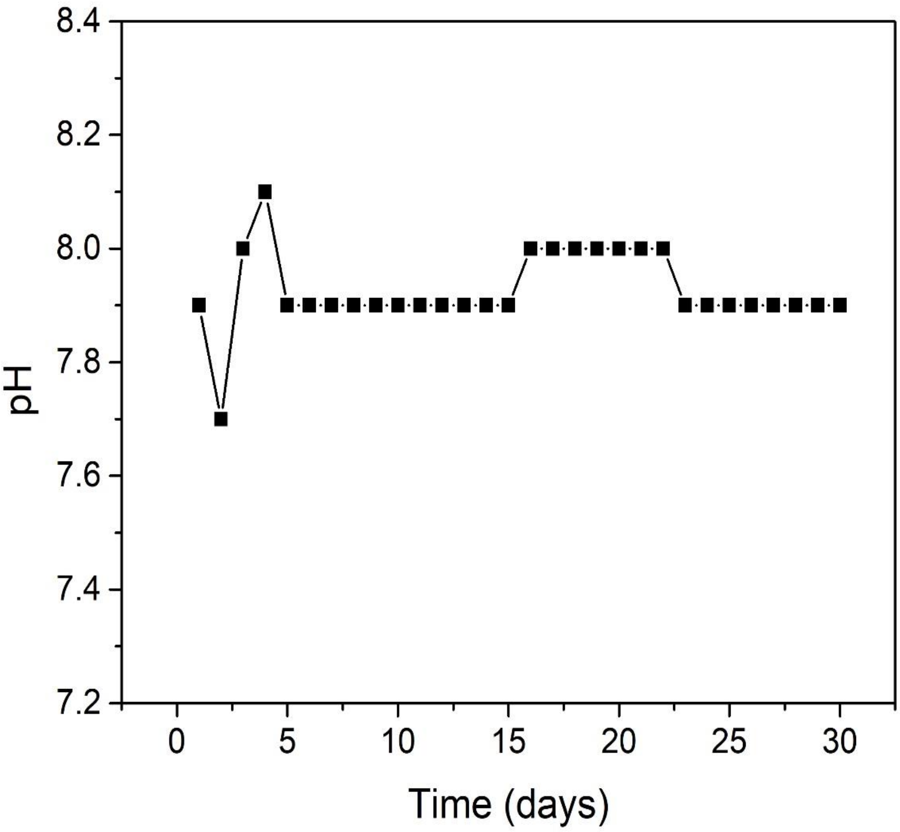

Figure 5 – pH time variation

From figure 5 it can be observed the initial value of 7.7 for pH and the average value of 8 – 8.1 for the entire period of testing. In this case the testing period was longer because of the fact that biogas was produced during a longer period of time.
The temperature regime involved, as per previous experiments was 36 – 38 °C.
In this context the total volune of obtained biogas was around 17 liters, wit a maximum value for methane (by volume) of 51%, carbon dioxide vas in the range of 49% and H_2S was around 500 ppm by volume.

CONCLUSION

The present paper was intended to be an initial study on the similitudes and influences of parameters in case of biogas production by using different types of materials for the reactor construction.
Two different solutions were chosen, inox and 3D printed PLA filament, while respecting the same date n regards to used substrates and temperature regime.
During the experiments it was concluded that both reactors are suitable for biogas production and both solutions are a possibility, but the quality of produced biogas is of low value by current standards in order to be further used in firing processes with high efficiency.
Further studies are needed to be done in regards to temperature regime, residence time and used combinations of materials for co-substrates in order to optimize the existent process at laboratory scale, for possible applications at larger scale.

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ENVIRONMENTAL RISK ASSESSMENT OF PHTHALATES IN SURFACE AND WASTEWATER

Maja Sremački[1], Nevena Živančev[1], Mirjana Vojinović Miloradov[1], Ivan Španik[2]
[1] University of Novi Sad, Faculty of Technical Sciences, Department for Environmental Engineering and Occupational Safety, Serbia
[2] Slovak University of Technology in Bratislava, Institute of Analytical Chemistry, Faculty of Chemical and Food Technology, Bratislava, Slovak Republic
e-mail: *majasremacki@uns.ac.rs*

Abstract: The urban wastewater in Serbia is predominantly untreated, and as such is discharged into the natural recipient, posing the great risk for aquatic environment and organisms. In this paper, the gas chromatography coupled with mass spectrometry (GC-MS) was used for analysis of phthalates in collected water samples in order to determine concentration levels and calculate risk quotient for detected phthalatic compounds, indicating potential ecotoxicological risk. Priority, hazardous priority and emerging substances are on these lists with a purpose, as these substances are showing one or more characteristics of hazardness or are suspected to have hazardous or (eco)toxic characteristics. GC-MS method is used for identification of the presence of priority, hazardous and emerging substances in surface and wastewater samples. The most abundantly detected substances in obtained samples were phthalatic compounds which have the most significant concentration levels. Two phthalatic compounds, di-n-butyl phthalate (DBP) and di-n-octyl phthalate (DnOP), were detected in significant concentrations in every sample of surface and waste water in range from 0.12 to 4.26 µg/L. The predicted no-effect concentration (PNEC) values of 10 µg/L and 1.3 µg/L, respectively, were obtained from literature sources. The risk quotients (RQ) for DBP in surface water was calculated in range of 0.18 to 1.84, and in wastewater form 0.92 to 3.28. For DnOP RQ in surface water was calculated in range of 0.09 to 2.02, and in wastewater 0.12 to 1.67.
Key words: wastewater; surface water; phthalates; priority, priority hazardous and emerging substances

INTRODUCTION

In Serbia one of the most potent sources of environmental pollution is wastewater from urban areas. This wastewater is very specific stream of pollutants, as it is the mixture of untreated industrial, domestic and agricultural wastewater, and run-off form urban areas. The urban wastewater is a significant source of organic pollution in natural water bodies, especially priority, hazardous priority and emerging substances, that are and objective of this research.
Priority substances are defined in the Water Frame Directive as the substances that pose a certain significant risk for the aquatic environment. The list of priority substances is determined by a special regulation, including the "priority hazardous substances" that have been identified as priority substances and selected by causing increased risk to human health or the environment.
Emerging substances (EmS) are identified as chemical species that can be found in widespread use around the world in industry, agriculture, as well as the daily activities of the human population, and some of those substances can be found on list of priority and priority hazardous substances [1]. Most of the emerging substances have either been suspected of having hazardous characteristics or are in such abundance that the sheer concentration represents the hazard to the environment. Such substances are di-n-butyl phthalate (DBP) and di-n-octyl phthalate (DnOP) are both included in the NORMAN list of emerging substances [2].
Phthalates are known endocrine disruptors that have been linked to lower fecundity, pregnancy loss, and negative obstetrical outcomes, although the underlying processes are unknown. By changing epigenetic marks, environmental influences can influence gene expression and cell function, affecting

both the developing embryo and future generations of offspring [3]. The effect of phthalates on the methylation and expression of placental genes is mainly unclear.

The use of DBP (Figure 1) in cosmetics is banned in the EU under Directive 76/768/EEC from 1976, in children's toys since 1999. To eliminate a potential risk to plants in the vicinity of DBP processing and manufacturing sites and workers through inhalation, measures should be taken within the framework of the IPPC Directive (96/61/EC) and the Occupational Exposure Directive (98/24/EC). DBP is an important endocrine disruptor known for reproductive toxicity [4, 5].

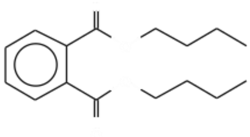

Fig 1. Di-n-buthyl phthalate (NIST Chemistry WebBook) [6]

DnOP (Figure 2) is a substance that is incorporated in the list of priority and hazardous priority substance list in Annex II of EU Directive 2008/105/EC. DnOP and DBP have shown antiandrogenic activity.

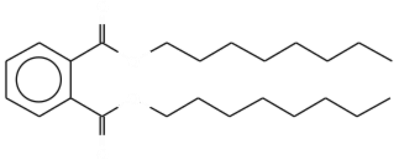

Fig 2. Di-n-octyl phthalate (NIST Chemistry WebBook) [6]

Among phthalates only six analytes are regularly monitored. Phthalates in general show high potential for estrogen-like behaviour, which is why in recent years these substances are of the most interest and human exposure to them [7].

The both identified phthalatic compounds are on the list of the restricted substances of Annex II Directive 2011/65/EU of the European Parliament and Council and NORMAN list of emerging pollutants.

Phthalates and plasticizers are endocrine disruptive chemicals (EDCs) that are commonly used as plasticizers, oils, defoaming agents, and repellents. Because xenobiotics can interact with many hormone pathways or hormone receptors, they are active at extremely low concentrations, and new epidemiological studies demonstrate that environmental exposure to these substances is linked to human illnesses [7].

MATERIALS AND METHODS

The wastewater and surface water were collected from the wastewater collectors and 100 m downstream of the discharge of wastewater. Samples were transported in portable refrigerated systems in sterile environment on 4 °C.

Liquid-liquid extraction method is used for the preparation of samples for chromatographic techniques; this method has been shown to be the most effective for extraction of low concentration pollutants. The solvent used for extraction was dichloromethane (DCM).

Analysis was performed on a gas chromatogram (GC) paired with a mass selective detector (MSD) (Shimadzu QP 2010 Ultra).

The GC injector was set to splitless operating mode, which is suitable for large-volume samples and highly polluted samples. The prepared extract, 1 μL volume was injected into the system by gas chromatography. The capillary column 30 x 25 mm ID, 0.25 mm df HP-5MS was used during the analysis.
The MSD was used during the analysis in scan mode (m/z 45-600) for all samples. Oven temperature gradient programme was set to hold time of 10 minutes on 40 °C, then increase of 1 °C per minute to 240 °C, and end of programme. Helium was used as carrier gas [8, 9].
Phenanthrene-D10 was used as internal standard (SupraSolv® MS, Merck Millipor Chemicals, USA). Other chemicals used: sodium sulphate, wax, acetonitrile, acetone, and methanol (SupraSolv® MS, Merck Millipor Chemicals, USA).
Environmental risk assessment was performed via EU approved methods, using MEC (Measured Environmental Concentration) and PNEC (Predicted No-Effect Concentration) values to calculate the risk quotient (RQ). When calculated if the value of risk quotient (RQ) of a substance is higher than 1, the substance is of the significant risk to the environment. If the RQ is lower than 1, the observed substance doesn't represent the risk on observed location.

RESULTS AND DISCUSSION

In this research 6 samples of surface water before and after the discharge points of wastewater and 4 samples of wastewater generated in urban area were analysed. Wastewater samples analysed in this research was generated in an urban area populated with approximately 300 000 inhabitants.
In Table 1 the detected concentration levels and calculated RQs for DBP and DnOP for wastewater (WW) and surface water (SW) samples.

Table 1. Concentration levels of phthalates in water samples with calculated risk quotient

Sample type	**RQ_{DBP}**	**RQ_{DnOP}**
SW1	0.22	*1.03*
SW2	*1.25*	*2.02*
SW3	*1.04*	0.51
SW4	*1.84*	*1.29*
SW5	*1.01*	0.09
SW6	0.18	*1.03*
WW1	0.92	0.12
WW2	*3.28*	*1.67*
WW3	*1.22*	0.17
WW4	*1.16*	0.21

In the Table 1 the risk quotient for all samples and obtained concentration levels of DBP and DnOP have been presented. It is shown that the significant risk can be attributed to the DBP in wastewater on almost all locations (WW2, WW3 and WW4), which cannot be stated for DnOP (only WW2). The sample WW2 (mixed urban and industrial wastewater), can be seen as the location of the highest risk as it is followed by results of SW3 sample which also has the significant risk for DBP. The risk factor for both substances in surface water can be attributed as high, as it is above threshold in 4 samples, for DBP samples SW2, SW3, SW4, SW5, and for DnOP in SW1, SW2, SW4 and SW6.
Urban wastewater in the research area is directly discharged into the Danube River which on the location has a high dilution factor for all pollutants. This said, it is highly concerning that even with

this high dilution factor DBP and DnOP are detected in the surface water, and concentration levels are so high that the calculated RQ is over 1 (high).
In the Figure 1. Whisker plot of concentration levels of the detected di-n-butyl phthalate and di-n-octyl phthalate are shown.

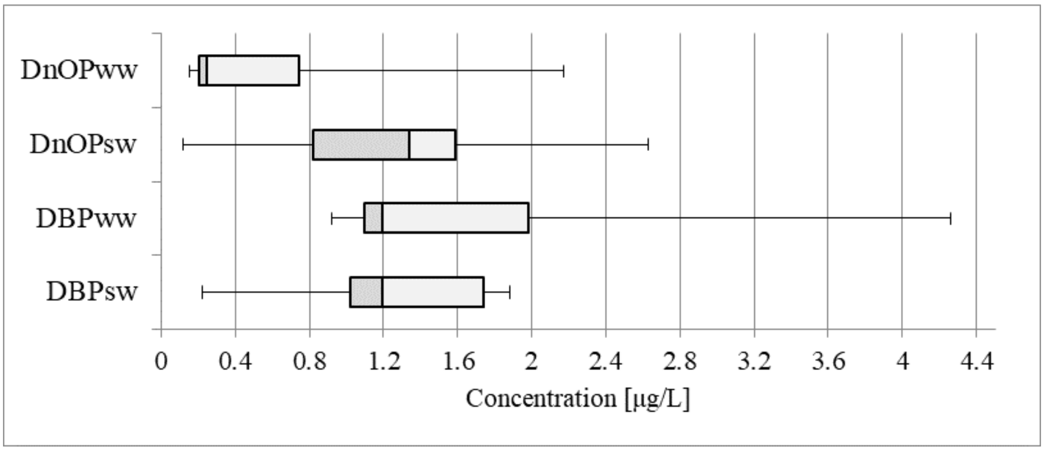

Fig 1. Whisker plot of concentration levels for detected DBP and DnOP in surface and wastewater samples

In the Figure 2. Whisker plot of calculated risk quotients of the detected di-n-butyl phthalate (DBP) and di-n-octyl phthalate (DnOP) are shown.

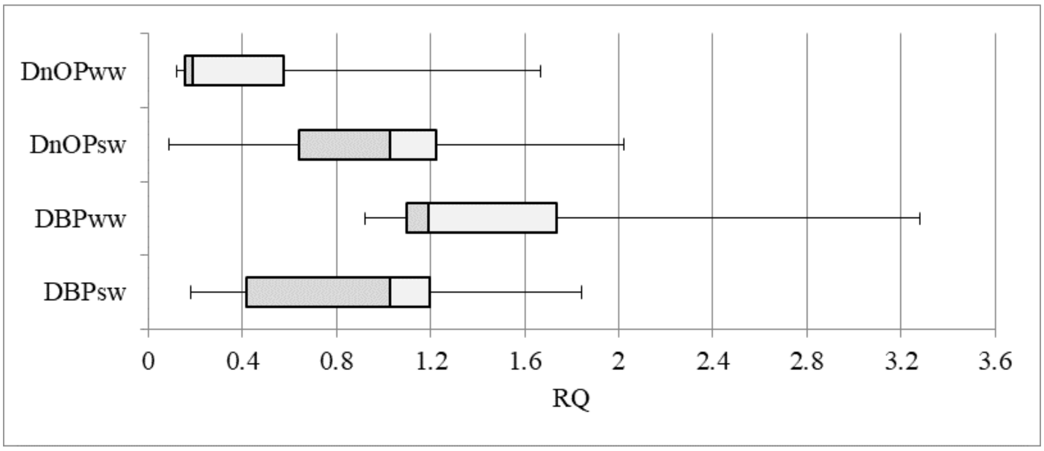

Fig 2. Whisker plot of calculated Risk quotient (RQ) for detected DBP and DnOP in surface and wastewater samples

CONCLUSIONS

The identified phthalatic compounds are on the list of the restricted substances of Annex II Directive 2011/65/EU and NORMAN list of emerging pollutants. The presence of DnOP and DBP in all samples, without the concentration levels and risk quotients data, is by itself a cause for concern. These are xenobiotic compounds that have a significant impact on aquatic environment and human health. However, once these substances reach the environment and infiltrate the food chain it is exceptionally hard to neutralise and remove them. The risk assessment shows the concentrations of DBP are higher than predicted no-effect concentrations in surface and wastewater, and DnOP mostly in surface water. In the research area untreated urban wastewater is directly discharged into the Danube River, and even with such a high dilution factor as Danubs', DBP and DnOP are found in surface water, and concentration levels are so high that the predicted RQ is greater than one (high). As a result of the findings, a conclusion may be drawn that DBP and DnOP are already present in the food chain, based on their frequency of use in various anthropogenic activities.

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IMPACT OF LANDFILL FIRES ON AIR QUALITY IN SERBIA

Igor Jezdimirović[1], Zoran Čepić[1], Nemanja Stanisavljević[1], Xiaoming Wang[2], Višnja Mihajlović[3]
[1] Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
[2] Key Laboratory of Three Gorges Reservoir Region's Eco-Environment, Ministry of Education, Chongqing University, Chongqing, 400045, China
[3] Technical Faculty "Mihajlo Pupin", University of Novi Sad, Zrenjanin, Serbia
e-mail: igor_jezda@yahoo.co.uk

Abstract: Wild landfills and unsanitary landfills - dumps represent places with an increased risk of surface and deep-seated fires due to landfill gas and the properties of the dumped waste. Air pollution caused by emissions from landfill fires is a serious problem and according to the data only during 2021 in Serbia, 1,715 fires were recorded at landfills that affected an area of 42.220,376 acres. The main objective of this study was to analyze the air quality monitoring data related to the Belgrade unsanitary landfill and the landfill fires in August 2021. The study used data from official documents from three locations in the National network and sixteen stations in the Local network were taken into consideration. During the fire at the Vinča landfill there were short-term episodes with high concentrations of pollutants, so data on mean concentrations collected through cooperation with the National Environmental Association were used in the data analysis. In the context of monitoring suspended particles (national and "civic"), several periods of increased concentrations of PM particles have been recorded. It seems that the number of fires in wild and unsanitary landfills is increasing by the year and the existing network of national measuring stations in Belgrade is not adequate to perceive the real air pollution during a fire at the unsanitary landfill Vinča as well as that the network of city measuring stations shows significant air pollution as a result of the fire at the unsanitary landfill Vinča. It is necessary to improve the system of informing citizens about the ways to act in the event of air pollution that occurs as a result of fires in landfills.
Key words: landfill fire, air quality, environment

INTRODUCTION

Inadequate management of municipal waste leads to severe consequences for the population's health and quality of life. Although there are various advanced waste treatment techniques, in low and middle-income countries, landfills dominate as a way of dumping waste due to their low cost [1]. Wild landfills and unsanitary landfills - dumps represent places with an increased risk of surface and deep-seated fires due to landfill gas and the properties of the dumped waste. During a fire, a significant part of landfill waste has the role of fuel with medium or high energy value, so the higher the amount of landfill waste, the higher the amount of landfill gas contained in it, and thus the risk of fire. Despite numerous studies that testify to the consequences of waste accumulation in unsanitary landfills - dumps and wild landfills [2,3], this type of waste disposal is still the main way of waste management in Serbia. Pollutants that reach the environment from waste, through the air, water, soil, food, and living organisms, have long-term consequences [4,5]. Most unsanitary landfills do not have a system for controlled disposal of landfill gas, which can lead to fires or explosions. According to the data of the Ministry of Interior of the Republic of Serbia - Sector for Emergency Management [6], only during 2021, 1,715 fires were recorded at landfills that affected an area of 42.220,376 acres. This represents the largest number of fires in recent years (2016 - 584 fires; 2017 - 1,296 fires; 2018 - 950 fires; 2019 - 1,244 fires; 2020 - 1,205 fires). Fires are the primary source of air pollution in landfills. The lack of a landfill gas management system and the absence of adequate cover layers, combined with climate change and the slow improvement of the waste management system in Serbia, could lead to an increase in landfill fires and their size. In places of fire, a decline in environmental quality can be assessed. One of the most significant indirect impacts on the environment is the change in air quality due to the emission of various air pollutants during a fire [7]. Air pollution caused by emissions from landfill fires is a serious problem [8-11]. However, it seems more difficult to explain to authority and to evaluate indirect than direct environmental impacts caused by these fires over wider temporal and spatial scales [12,13]. The results of such and similar research can give decision-makers a deeper insight into providing effective intervention strategies to minimize the risk of large landfill fires. The main objective of this study was to analyze the air quality monitoring data related to the Belgrade unsanitary landfill and the landfill fires in August 2021.

MATERIAL AND METHODS

The study used data from official documents: "Annual report on air quality control at measuring points in Belgrade in the National network for 2021" and "Annual report on the results of measuring air quality in Belgrade in the Local network of measuring stations and/or measuring points for 2021". Data from three locations in the National network and sixteen stations in the Local network during 2021 were taken into consideration. Given that these reports gave aggregate daily averages, and during the fire at the Vinča landfill there were short-term episodes with high concentrations of pollutants, data on mean concentrations collected through cooperation with the National Environmental Association were used in the data analysis.
The data was verified by comparison with the average daily data provided in the above-mentioned official reports. The maximum daily and mean daily concentrations of $PM_{2.5}$, PM_{10}, SO_2, and NO_2 at automatic stations from national monitoring, "civic" monitoring, as well as mean hourly concentrations of $PM_{2.5}$ and PM_{10} pollutants for the period 1st August – 10th September 2021 were analyzed. An overview of the stations and their locations with the pollutants inspected in the analysis is given in Table 1.

Table 1. Overview of measuring stations and pollutants considered in the analysis for the period 1.8.-10.9.2021.

Automatic Monitoring Network	Measuring station	pollutants
	Belgrade – Vračar	$PM_{2.5}$, PM_{10}, SO_2, NO_2
	Belgrade – Zeleno brdo	
	Belgrade – Stari grad	
	Belgrade – Novi Beograd	
	Belgrade – Mostar	
National – Institute of Public Health of Belgrade	Belgrade – Despota Stefana	National – Environmental Protection Agency
	Belgrade – Omladinskih brigada	
	Belgrade – Ovča	
	Belgrade – Zemun TB	
	Belgrade – Vinča	
	Belgrade – Lazarevac	
	Belgrade – Obrenovac	
National – City of Pančevo	Pančevo – Starčevo	
	Pančevo – Firehouse	
	Pančevo – Vojlovica	
„Civic“ – Sensor Community	Zoran Đinđić Boulevard Belgrade	$PM_{2.5}$, PM_{10}
	Gospodara Vučića Belgrade	
	Koče Kapetana Belgrade	
	Sazonova Belgrade	
	Milovana Marinkovića Belgrade	
	Obalskih radnika Grad Belgrade	
	Gostivarska Belgrade	
	Borča-Greda Belgrade	
	Mileve Marić Ajnštajn Belgrade	
	Garsije Lorke Belgrade	
	Vojvode Hrvoja Belgrade	
	Vlajkovićeva Belgrade	

	Mažuranićeva Belgrade	
	Vitezova Karađorđeve zvezde Belgrade	
	Stojana Novakovića South Banat District	
	Mitropolita Petra Belgrade	
	Darinke Radović Belgrade	
	Bolečka mehana Boleč	
	Moše Pijade Vojvodina	
	Filipa Hristića The city of Belgrade	
	Timočke divizije Belgrade	

RESULTS AND DISCUSSION

Based on the report of the Institute of Public Health of Belgrade, the section “Indicative measurements of pollutants to establish fixed measurements" and according to available average daily data from three measuring points where the possible impact of landfill gases is being monitored: AMS Vinca, Reservoir BVK Stojcino brdo (Mirijevo) and Milena Pavlović Barili Primary School (Višnjička Banja) the following conclusions have been reached in terms of exceeding the limit values:

- On August 9, 11, and 17, at the AMS Vinča station, the concentrations of PM_{10} suspended particles exceeded the average daily limit values defined by the regulation for PM_{10} (50 µg / m^3) with the maximum mean daily value of 113 µg / m^3 recorded on August 9, 2021. On August 10, 12, 13, 15, and 23, concentrations 10% lower than the limit value (> 45 µg / m^3) were recorded.
- At the Reservoir BVK Stojčino brdo (Mirijevo) and Milena Pavlović Barili Primary School (Višnjička banja) stations, there was no exceedance of the daily limit values of measured pollutants: soot, SO_2, NO_2. At the first station, additional analyses of heavy metals (arsenic, cadmium, nickel, and lead) and benzo[a]pyrene were performed 4 times during August, while at the second location the concentration of benzene was also analyzed 4 times. There are no hourly or daily limit values for these pollutants, and in the context of annual concentration, a possible increase during a particular period of time would not be adequately represented by the annual mean value.
- As there are no limit values for other pollutants in the legislation (Regulation on monitoring conditions and air quality requirements), except for the average annual limit values, it is impossible to give a qualitative assessment based on average daily concentrations of heavy metals, benzene and benzo[a]pyrene (AMS Vinča and Reservoir BVK Stojčino brdo) or only benzene (Milena Pavlović Barili Primary School).

In the context of monitoring suspended particles (national and "civic"), several periods of increased concentrations of PM particles have been recorded as follows:

- August 8 in the morning (Palilula, Stari Grad), and then in the evening (Karaburma)
- August 9 in the evening at Vinča National Station
- August 11 in the early morning hours (Konjarnik and Šumice)
- August 12 and 13 during the night and morning (Karaburma and Konjarnik)
- August 14 in the morning (Karaburma and Mirijevo

At national stations, the maximum hourly concentrations of PM particles ranged up to 177 µg/m^3 for PM_{10} and 151 µg/m^3 for $PM_{2.5}$ at Despota Stefana station in the city center (on August 8, 2021, at noon) while the absolute maximum was recorded at the Vinča station, namely PM_{10} - 505 µg/m3 or $PM_{2.5}$ - 442 µg / m3 on August 9, 2021. at 9 p.m., this episode at the Vinča station lasted for 3 hours with slightly lower concentrations.
According to the CAQI Air Quality Index applied by the Institute of Public Health of Belgrade [14], the air is considered to be "polluted" and "heavily polluted" for average hourly concentrations above 55 i.e. 110 µg/m3 ($PM_{2.5}$) and 90 i.e. 180 µg/m3 (PM_{10}) respectively. Applying this criterion leads to

very similar episodes of pollution. Therefore, the air was "polluted" or "heavily polluted" on several occasions (Table 2).

Table 2. Overview of air pollution in different time periods

Period/Episode	Station	Polluted	Heavily polluted
8.8.2021. 12:00 -19:00	Despota Stefana	PM_{10}	$PM_{2.5}$
	Stari Grad	PM_{10}	$PM_{2.5}$
	Novi Beograd	$PM_{2.5}$	
	Omladinskih brigada	$PM_{2.5}$	
9.8.2021. 20:00-24:00	Vinča		$PM_{2.5}$, PM_{10}
11.8.2021. 00:00-08:00	Vinča	$PM_{2.5}$, PM_{10}	
11.8.2021. 20:00-23:00	Vinča	PM_{10}	$PM_{2.5}$
15.8.2021. 20:00-23:00	Zemun TB	PM_{10}	
16.8.2021. 09:00	Zemun TB		PM_{10}
17.8.2021. 11:00-16:00	Zemun TB	PM_{10}	

At "civic" stations, both due to a greater number of stations and better coverage of city parts that are directly affected by possible transport of smoke caused by landfill fire (Karaburma, Mirijevo, Konjarnik, etc.), a greater number of episodes of high pollution of PM particles with concentrations above 180 µg/m3 (the limit for qualification "heavily polluted" according to the CAQI index) have been recorded on the above dates.
In the context of the Regulation on monitoring conditions and air quality requirements, the Official Gazette of RS, No. 11/10, 75/10, and 63/13, [15] of the bylaw defining the limit values of pollutants according to aggregation and duration, can be concluded that there was a small number of exceedances (several at the station in Vinča and Despota Stefana) of 24-hour average limit values for PM_{10} particles (50 µg/m3), for which no hourly mean limit values were defined, noting that for $PM_{2.5}$ no daily or hourly limit values have been defined apart from average annual values. There was no exceedance of the limit values for sulfur dioxide and nitrogen dioxide at all, except for one exceedance of the hourly mean limit value of NO_2 at the Vračar station, which cannot be attributed to the fire in Vinča. A similar number of exceedances can be noted if we applied the Regulation to civic monitoring stations for the PM_{10} daily limit values, the only relevant ones concerning pollutants monitored at these stations ($PM_{2.5}$ and PM_{10}).
However, the wind roses from Nikola Tesla Airport, Belgrade, for the two selected dates (August 8 and August 10-11) [16] show a definite link between increased concentrations of PM particles and the fire at the Vinča landfill.
Regarding other pollutants measured in the national system, the rise in the concentration of SO_2 and NO_2 was noticed by the national stations on August 15. However, this phenomenon does not have a clear connection with the fire at the landfill.
The main question is what additional pollutants made an integral part of the PM particles at high concentrations during the short time period when large areas of densely populated parts of eastern Belgrade were exposed. There is no additional information on this issue.
In the context of access to data and informing the citizens, on the portal of the Institute of Public Health of Belgrade in case of fire at the unsanitary city landfill in Vinča, information can be found that the Mobile Ecotoxicological Unit of the City Institute visited the field several times and performed measurements of pollutants. Furthermore, it is stated that the network of measuring points for continuous air quality monitoring conducted by the Institute analyzed concentrations and possible exceedances for the 24-hour monitoring period for carbon monoxide, nitrogen dioxide, sulfur dioxide

and suspended particles below 10 microns. It is explicitly stated that field measurements did not show exceedances of specific parameters such as polycyclic aromatic hydrocarbons, while the results of these additional analyses are not even shown in descriptive form.

The portal of Belgrade City Administration, on a special page of the Secretariat for Environmental Protection [17] shows daily reports on the state of air quality which contain reviews of concentrations of basic pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2) at 6 measuring points managed by the Belgrade City Institute for Public Health, namely: Ovča, Zemun, Despota Stefana Bulevard, Novi Beograd, Dragiša Mišović and Vinča. The measurement results of polycyclic aromatic hydrocarbons are not available on this page. Also, automatic stations managed by the Environmental Protection Agency (Zeleno Brdo, Vračar, Stari Grad, Mostar, Omladinskih Brigada, etc.), as well as by Pančevo City Administration (Vojlovica, Starčevo, etc.) are not included in monitoring the situation, namely in providing post-accident reports, although data from these stations would be more than relevant for reviewing the overall state of air quality during a landfill fire.

CONCLUSION

The lack of a landfill gas management system and the absence of adequate cover layers, combined with climate change and the slow improvement of the waste management system in Serbia, could lead to an increase in landfill fires and their size.

- The number of fires in wild and unsanitary landfills is increasing by the year
- The existing network of national measuring stations in Belgrade is not adequate to perceive the real air pollution during a fire at the unsanitary landfill Vinča
- Network of civic measuring stations shows significant air pollution as a result of a fire at the unsanitary landfill Vinča
- It is essential to improve the system of informing citizens about the ways to act in the event of air pollution that occurs as a result of landfill fires.

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IMMOBILIZATION OF Pb AND Cd IN CONTAMINATED SOIL - EVALUATION OF DIFFERENT PHOSPHATE TREATMENTS

Višnja Mihajlović[1], Marina Naodović[1], Una Marčeta[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: visnjamihajlovic@uns.ac.rs

Abstract: With increased anthropogenic activities, many places worldwide have become abundantly contaminated with heavy metals and metalloids. Accumulation of these metals in soil can produce adverse effects on soil fertility, microbial activity, and overall biodiversity. It is therefore of utmost importance to establish effective remediation technologies to reclaim contaminated soils. In situ chemical immobilization is one the most efficient remediation techniques, and phosphate compounds are still the most cost-effective amendments often used for that purposes. In this paper, several commonly used inorganic phosphates for chemical immobilization of Pb and Cd have been evaluated based on the TCLP extractability and sequential extraction analysis data.
Key words: extraction, heavy metals, soil pollution

1. INTRODUCTION

Heavy metal contamination is undoubtedly one of the most critical issues in modern agriculture and environmental sciences. These heavy metals can adversely impact water resources, soil ecology, and agricultural products quality, while simultaneously causing many damaging effects on human health. With the growing public concern of the impact of contaminated soils on human health and environment, there has been increased interest within scientific community in the transformation and fate of metals in soils, and the development of strategies to remediate and reclaim contaminated sites. Unlike organic compounds, most metals are inert to microbial or chemical transformation, and the concentration of these metals in soil persists for significant time periods after their introduction [1].

Generally, metal concentrations present in soils, available for plant uptake and leaching to ground water, can be significantly minimized by reducing the bioavailability of metals through chemical and biological immobilization. Within a broad spectrum of efficient remediation methods [2-7], *in situ* chemical immobilization is a promising remediation strategy that reduces the extractable potential of heavy metals. In the recent years, there has been renewed interest in the immobilization of metals using diverse inorganic compounds, such as lime, phosphate (P) compounds (e.g. apatite rocks), and alkaline waste materials; and organic compounds with exceptional quality (bio-solids) [8-10]. Traditionally, scientific research was focused on the potential value of hydroxyapatite for the immobilization of heavy metals. However, presently there is a growing interest in evaluating other P compounds on metal transformations in soils. Because these phosphate compounds are applied to soils as a nutrient source, most of them are considered and register as phosphate (P) fertilizers.

Phosphate fertilizers are commonly regarded as very general and cost-effective amendments for immobilization. The addition of P amendments can cause a reaction between metals ions in soils and phosphate [11-13]. They can change soil characteristics, i.e. pH value, available phosphate concentrations, and surface charge, or can directly react with metal ions in soil [8]. Consequently, phosphate treatment can cause a shift in the mobile forms of heavy metals towards more stable forms/species. The goal of immobilization is then usually defined as the reduction in the bioavailable fraction of metals, either through increased metal sorption or precipitation, or through the formation of specific mineral forms [14-16].

Although P amendments have mainly been applied to remediate Pb-contaminated soil, they are also applicable to other metals such as Zn, Cu, and Cd. Phosphates effectively remove Zn and Cd from aqueous solutions, but the removal mechanism is different from that of Pb. In this work, we investigate several different most commonly used phosphate compounds, and compare their effectiveness in reducing the extraction potential of Pb and Cd.

2. METHODOLOGY AND MATERIALS

The efficiency of immobilization was evaluated on the basis of two criteria: (i) the reduction of extractable Cd and Pb concentrations below the TCLP regulatory level, and (ii) Pb and Cd content changes associated with specific soil fractions using sequential extraction analysis.

Soil sample preparation: the soil sample, from vegetable plot, was excavated from the surface layer (0-0.2 m), transferred to plastic bags, and carried to the laboratory. Air-dried samples were mixed and passed through sieve. The soil was prepared by adding cadmium nitrate or lead nitrate to yield a concentration of approximately 100mg/kg. Prepared soil was then left at 25˚C for seven days, and after a week air-dried samples were stored in plastic containers for further immobilization test.

Three phosphates $Ca_3(PO_4)_2$, KH_2PO_4, $(NH_4)_2$ HPO_4 were evaluated in immobilization test. The phosphate dose was calculated on the basis of the molar ratio of PO_4^{3-} to the total concentration of Cd/Pb in the soil samples. Each immobilization test included 50g of soil, a pre-calculated weight ratio of phosphate added to air-dried soil sample, and the amount of deionized water sufficient to reach homogenous and saturated mixture. Samples prepared in this manner were kept in plastic container until laboratory tests were performed.

Standard EPA toxicity characteristic leaching procedure is a chemical analysis method used to verify the presence of hazardous compounds in waste and environmental samples. The test is based on simulation of leaching process through a landfill, and indicates whether present hazardous materials are dangerous for the environment. In the present case, modification of the original method described by USEPA (1986) was applied. This modified TCLP method is based on predetermined soil pH value to differentiate two distinct extraction procedures. In cases where pH < 5, extraction solution contained 5,7 ml of glacial acetic acid and 64.4 ml of 5 M sodium hydroxide, and diluted to 1.0 L with deionized water. Extraction solution, for samples where pH>5, contained 5.7 ml of glacial acetic acid diluted to 1.0 L with deionized water. 20 ml of extraction solution was added to 1.000 g of sample prepared as described previously.

Sequential Extraction Analysis, developed by Tessier *et al.* [17], sequential extraction analysis is used to evaluate the availability and specific chemical form of heavy metals in the analyzed samples. Extraction procedure differentiates metals associated with five soil fractions: (i) soluble-exchangeable (SE), (ii) weakly absorbed to carbonates (WSA), (iii) bound to Fe-Mn oxides (OX), (iv) bound to organic matter (OM), and (v) residual (RES). Extractions are carried out using 1.000 g of test soil using specific extraction solutions as detailed in Table 1.

Table 1**. Sequential Extraction Analysis. (Adapted from Tessier et al. [17].)**

Step	**Fraction**	**Extraction procedure**
1	Soluble-exchangeable (SE)	1M $MgCl_2$, pH7, rt
2	Bound to carbonates (WSA)	0.04 M NH_2OH•HCl, pH2, 96˚C
3	Bound to Fe-Mn oxides (OX)	0.02 M HNO_3, H_2O_2, 3.2 M CH_4COONH_4
4	Bound to organic matter (OM)	
5	Residual (Res)	HF-$HClO_4$, digestion

3. RESULTS AND DISCUSSION

TCLP Extractability After Treatment With Different Phosphates

The results of TCLP extractability of Pb and Cd after treatment with three different phosphates, after 25 days of immobilization, are shown in the Figure 1.

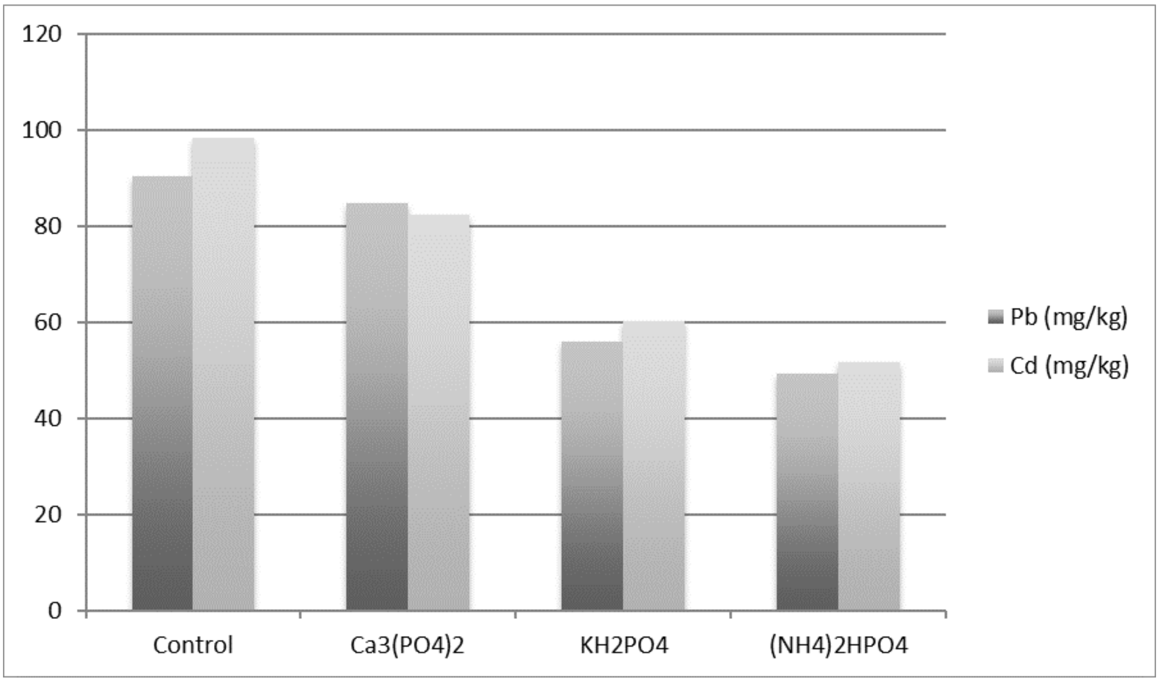

Figure 1. TCLP Extractability of Pb and Cd with Different Phosphates

Among the four phosphates screened, the application of $(NH_4)_2\ HPO_4$ affords the most significant decrease in TCLP leachability of both Pb and Cd chemical species. Roughly, the efficiency of phosphates to reduce TCLP concentration of Pb and Cd follows the order: $(NH_4)_2\ HPO_4$ > KH_2PO_4 > $Ca_3(PO_4)_2$. The reason might be partially attributed to the fact that $(NH_4)_2\ HPO_4$ is highly water soluble and can therefore afford the most effective P forms. In contrast, $Ca_3(PO_4)_2$ is a water insoluble phosphate and cannot provide sufficient amounts of available phosphate for significant decrease in TCLP Pb and Cd concentration. Additionally, the effect of calcium ion can also be observed. Such increase in stability of heavy metal species in the presence of Ca^{2+} has been well documented by other authors [18,19]. It can also be speculated that introduction of N-moiety, present in $(NH_4)_2\ HPO_4$, can further decrease Cd/Pb bioavailability, most likely due to formation of discrete low-solubility and low-mobility mineral forms.

It should also be noted that the addition of phosphates amendments alters the pH value of soil which inevitably leads to the shift in metal solubility and extractability. Namely, pH value is a parameter which affect metal precipitation [20], occlusion [21], and movement and sorption [20]. Thus, difference in effectiveness levels of phosphates to affect extractability of specific metal can be traced to the nature of the phosphate, as well as the treatment effect it produces.

Sequential Extraction Analysis

Sequential extraction procedure is often applied for studying the relative availability of soil-sorbed metals by revealing the operationally defined speciation of metal in solid phase [23]. The trace metals detectable in water-soluble and exchangeable fractions (SE) are considered more mobile and bio-toxic than those found in other fractions [8]. The following data, Figure 2. and Figure 3. (adapted from [24] and [25]), shows the distribution of Pb and Cd in four different fractions of the same soil sample.

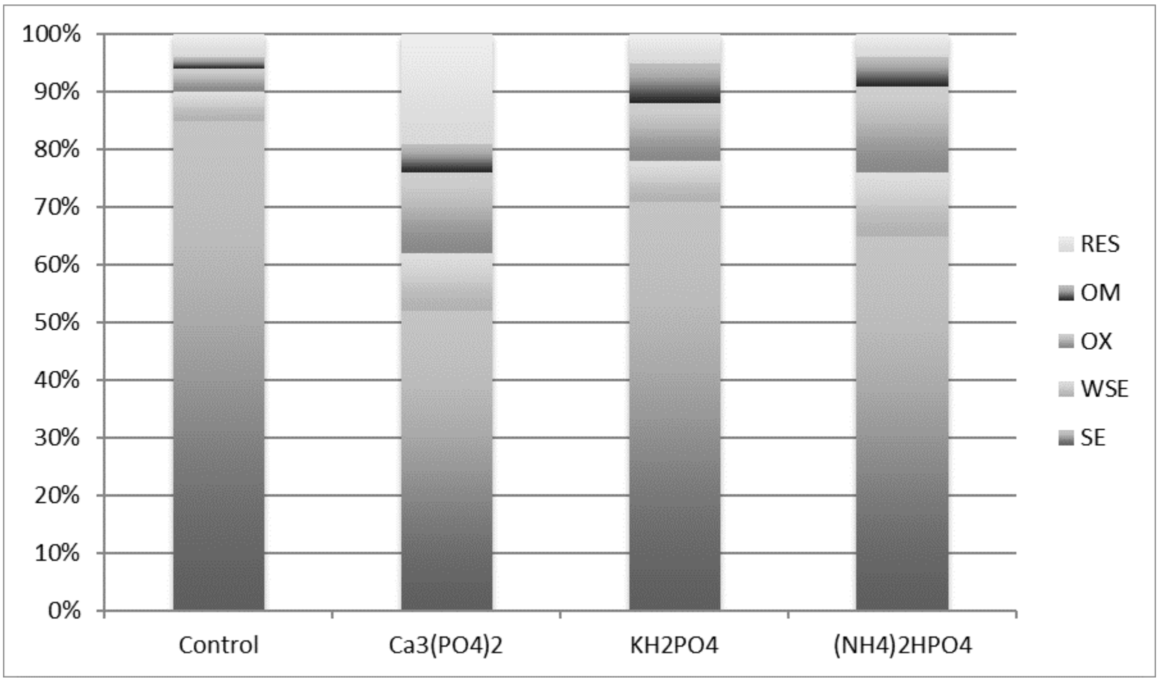

Fig. 2. Cd Percentage in Individual Fractions After Sequential Extraction Procedure.

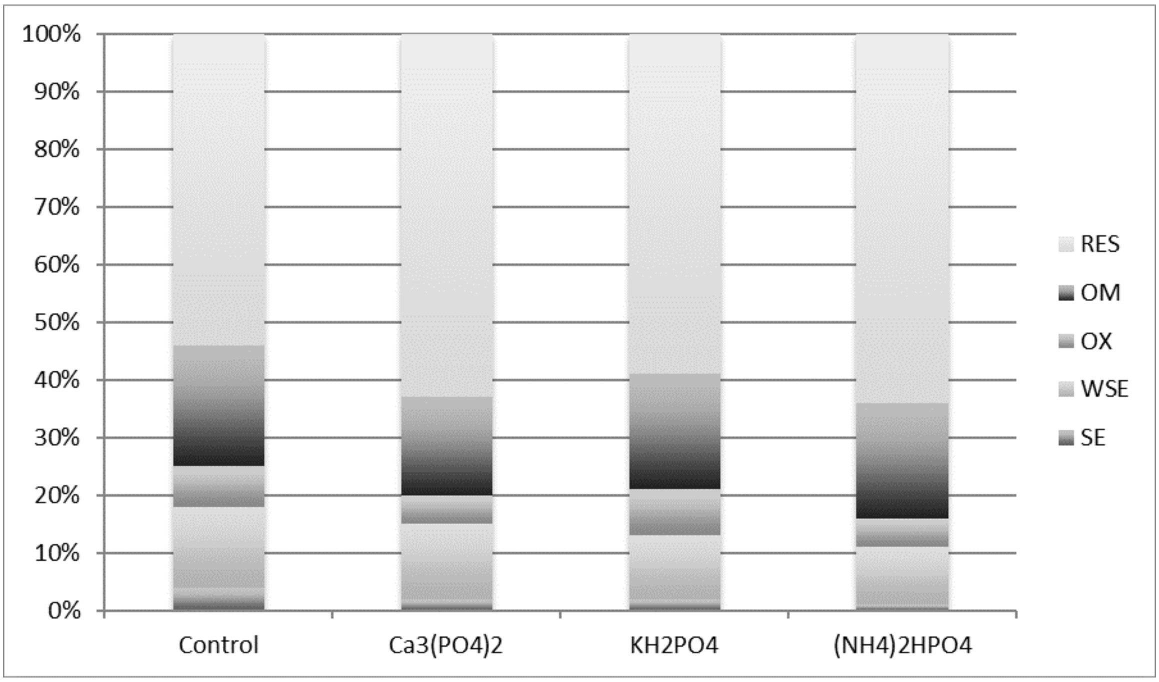

Fig. 3 Percentage Pb in Individual Fractions

The reduction of SE fraction of Pb after phosphate application can be attributed to the transformation of soluble Pb to insoluble Pb-phosphate species. Similar to SE fraction, the OM and OX fractions of Pb in the soil decreased after the phosphate treatment. However, the RES fraction increased. One plausible explanation for such significant shift from extractable Pb to the residual Pb is due to the formation of pyromorphite [22].

It is speculated that water-soluble fraction of Pb might be converted to more stable fractions (WSA and RES form) by the phosphate amendments. Both Cd and Pb exhibit similar chemical behavior and can react with phosphates to form derivatives with very low solubility. Both surface complexation and co-precipitation have been suggested as most likely chemical mechanism which occurs in these processes [9].

3. CONCLUSION

The results shown here indicate that extractable concentration of heavy metals, specifically Pb and Cd, in contaminated soil can be significantly decreased after phosphate treatment. These observations are supported by both reduced TCLP extractable concentrations of Pb and Cd, as well as sequential extraction data. Among phosphate amendments screened, $(NH_4)_2$ HPO_4 provides most promising results, most likely due to increased solubility which, in turn, influences immobilization efficiency. In contrast, $Ca_3(PO_4)_2$ would not be the first choice of amendment, eventhough it can affect the immobilization of heavy meal. The primary reason for such low efficiency observed with $Ca_3(PO_4)_2$ can be attributed to negative Ca^{2+} affect.

It would be advantageous to focus future studies on the combination of amendments to formulate immobilization strategy for sites contaminated with multiple metallic species.

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KINETIC AND THERMODYNAMIC APROACH OF STRONTIUM ADSORPTION ONTO ELECTRIC ARC FURNACE SLAG

Milena Tadić[1], Irena Nikolić[1], Dijana Đurović[2], Nevena Cupara[2], Ivana Milašević[2]
[1]University of Montenegro, Faculty of metallurgy and Technology, Podgorica, Montenegro
[2]Institute of Public Health of Montenegro, Podgorica, Montenegro
e-mail: ncupara@ymail.com

Abstract: Adsorption of strontium ions from aqueous solution at three different temperatures (20 °C, 30 °C and 45°C) onto electric arc furnace slag (EAFS) was investigated in this study. The results show that the rise of temperature favors the adsorption process. Kinetic of Sr^{2+} adsorption onto EAFS was evaluated using pseudo-first and pseudo-second order models and results have shown that experimental data better fit the pseudo-second order model. Thermodynamic investigation indicated that adsorption of Sr^{2+} onto EAFS is endothermic in nature and spontaneous.
Key words: electric arc furnace slag, strontium, kinetic, thermodynamic

INTRODUCTION

Disposal of radioactive wastewaters presents the one of huge problems in the field of environmental protection due to their adverse effect on human health and environment at all. Since, strontium is a persistent radionuclide in the environment which is characterized by high solubility, biotoxicity and long shelf life [1] its removal from wastewaters is of great importance. Different methods (precipitation and flocculation, membrane processes, ion exchange and adsorption) have been proposed for this purpose. Currently adsorption is regard as the most promising method for radioactive wastewaters treatment due to low cost of process and variety of adsorbents. Natural and synthetic zeolites [2], natural clinoptilolite [3], binary mineral mixtures of montmorillonite and kaolinite [4], multiwall carbon nanotube/iron oxide magnetic composites [5], composite magnetic particles derived from Fe_3O_4 and bis (trimethoxysilylpropyl) amine [6], activated carbon [7].
This paper investigated possibility of use of electric arc furnace slag (EAFS) as a sorbent for strontium removal from synthetic solutions. EAFS is non-hazardous waste material which is generated during the steel production in electric arc furnaces. Possibility of usage of EAFS as an adsorbent for heavy metals removal from wastewater was investigated previously [8]. However, to the best of our knowledge there is no data regards the EAFS usage for removal of radionuclides from wastewaters. Thus, the aim of this research was to investigate removal of strontium ions from chloride solutions by means of kinetics and thermodynamic analysis of Sr^{2+} adsorption process.
Different methods have been used to describe the adsorprion kinetics: pseudo-first order (PFO) and pseudo-second order (PSO) models, Elovich, Avrami, Crank, Vermeulen, Weber-Morris, Bangham, linear film, mixed surface reaction and diffusion, and multi-exponential models. However, majority of studies over the last two decades used the PFO and PSO models for a kinetic analysis and these two models have been applied to a wide variety of adsorption systems from biomass to nanomaterials as adsorbent and from heavy metals to pharmaceuticals as adsorbate or contaminant [9].

MATERIAL AND METHODS

Batch adsorption experiments

EAFS supplied from the Steel Mill in Montenegro which chemical composition is given in Table 1. was used as an adsorbent for adsorption tests. Adsorption experiments were carried out in a batch conditions for 35 min at adsorbent dosage of 1.5 $g \cdot L^{-1}$, at initial concentration of 150 ppm and three temperatures 20 °C, 30 °C and 45°C and pH value 5. Solutions containing Sr^{2+} ions were prepared from analytical grade chemicals, $SrCl_2$ in deionized water. During the adsorption experiments, an aliquot of the suspension was taken at certain intervals of time, filtered and tested for the

concentrations of metal ions using inductively coupled plasma optical emission spectrometry (ICP-OES).
Removal efficiency of Sr^{2+}ions (RE) and adsorption capacity (q_t) at any given time were calculated according Eq 1. and 2.

$$RE = \frac{C_0 - C_t}{C_0} \cdot 100\ \% \quad (1)$$
$$q_t = \frac{C_0 - C_t}{m} \cdot V \quad (2)$$

where C_0 and C_t are the initial and final concentrations of Sr^{2+} ions in solution, V is the volume of Sr^{2+} ions solution and m is the dry mass of adsorbent.

Table 1. Chemical composition of EAFS

Component	%
CaO	46.5
FeO	23.5
SiO_2	12.2
Al_2O_3	7.2
MgO	6.5
MnO	1.3
TiO_2	1.06
Fe_2O_3	0.9
Cr_2O_3	0.8
LOI*	4.2

*Loss on ignition

Adsorption kinetic

Adsorption kinetic was evaluated using the pseudo-first-order (PFO) and pseudo-second-order (PSO) kinetics model which integrated forms are expressed by Eq. (3) and (4), respectively:

$$log(q_e - q_t) = log\, q_e - \left(\frac{k_1}{2.303}\right)t \quad (3)$$
$$\frac{t}{q_t} = \frac{t}{q_e} + \frac{1}{k_2 q_e^2} \quad (4)$$

where q_e (mg g^{-1}), denotes adsorption capacity in equilibrium, k_1, (min^{-1}) and k_2, (g mg^{-1} min^{-1}) are rate constants of the pseudo first-order sorption and pseudo second-order sorption, respectively. When PFO model was applied, values of k_1 and q_e were calculated from the slope and intercept of straight line plots log (q_e- q_t) versus t. In case of PSO model, k_2 and qe were calculated from the intercept of and slope of the plot of t/q_t versus time.

Adsorption thermodynamic

Thermodynamic of Sr^{2+} adsorption onto EAFS was evaluated using following equations:

$$\Delta G^o = \Delta H^o - T\Delta S^o \quad (5)$$

$$\Delta G^o = -RT\, ln\, K \quad (6)$$

$$ln\, K_d = \frac{\Delta S^o}{R} - \frac{\Delta H^o}{RT} \quad (7)$$

$$K_d = \frac{(C_o - C_e) \cdot V}{C_e \cdot m} \tag{8}$$

Where, $\Delta G°$, $\Delta H°$, $\Delta S°$ and K_d present standard free energy, enthalpy, entropy and equilibrium distribution coefficient, respectively. The straight-line plots $ln\ K_d$ *vs* 1000/T enables determination the values of $\Delta H°$ and $\Delta S°$ from the slope ($\Delta H°/R$) and intercept ($\Delta S°/R$), respectively.

RESULTS AND DISCUSSION

The results of adsorption tests are given in Fig 1. The achieved removal efficiency of Sr^{2+} using EAFS at the temperature of 20 °C was 68.8%. The majority of Sr^{2+} ions were removed in a first 15 min. Increase of temperature of adsorption lead to the increase of efficiency removal of Sr^{2+} onto EAFS which indicated endothermic character adsorption process. The increase of temperature increases the removal efficiency of Sr^{2+} onto EAFS to 75.9% at 35 °C and 88.4% at 45 °C.

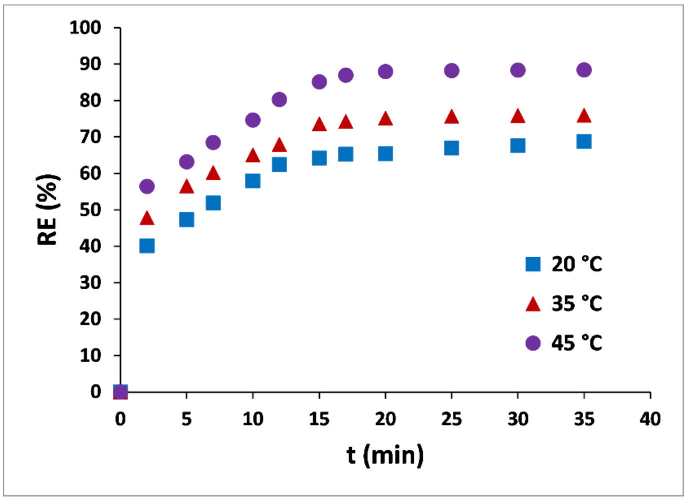

Fig. 1. Removal efficiency of Sr^{2+}ions by EAFS

The results of investigation of adsorption kinetic of Sr^{2+} ions onto EAF slag are presented in Fig. 2. and Table 2. Analysis of adsorption kinetic has shown that PSO kinetic model better fit with experimental data since high regression coefficients (R^2) were obtained and calculated values of q_e were in good agreement with the experimental values for q_e (table 2). The PSO model supposes the formation of chemisorptive bonds between the adsorbate and the adsorbent i.e. a chemical reaction is a rate controlling process [10]

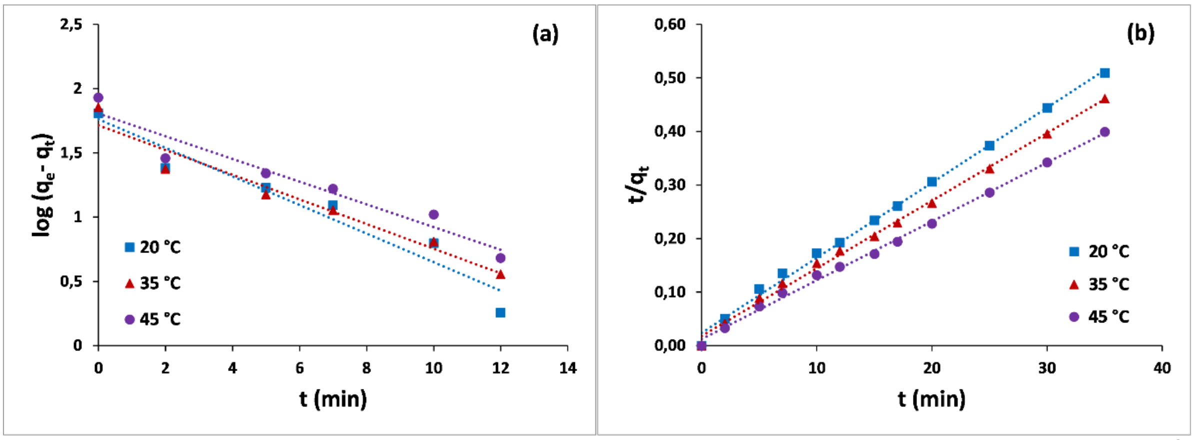

Fig. 2. The pseudo first-order (a) and pseudo second-order (b) kinetics plots for the adsorption of Sr^{2+} onto EAFS at different temperature

Table 2. Kinetics parameters for Sr^{2+} adsorption onto EAFS

Pseudo-first-order kinetic model				
Temperature (°C)	**q_e, experimental**	**q_e, calculated**	**k_1**	**R^2**
20	64.2	57.7	0.26	0.9357
35	75.3	51.7	0.22	0.9531
45	87.7	63.80	0.20	0.9322
Pseudo-second-order kinetic model				
Temperature (°C)	**q_e, experimental**	**q_e, calculated**	**$k_2 \times 10^{-3}$**	**R^2**
20	64.2	71.4	10.2	0.9963
35	75.3	79.3	10.3	0.9969
45	87.7	90.9	10.8	0.9972

The results of thermodynamic analysis are given in the Fig.3 and Table 3. The results obtained indicated that adsorption of Sr^{2+} onto EAFS is endothermic in nature since positive value of enthalpy (44.9 KJ mol^{-1}). Moreover, this value falls in the range 40–200 kJ mol^{-1} which means that the Sr^{2+} adsorption onto EAF slag involves chemisorption [11]. Negative values of free energy ($\Delta G°$) obtained at all investigated temperatures indicate that Sr^{2+} adsorption onto EAFS occurs spontaneously. The rise of temperature lead to the decrease of ΔG which indicates that the adsorption process is more favorable at higher temperatures.

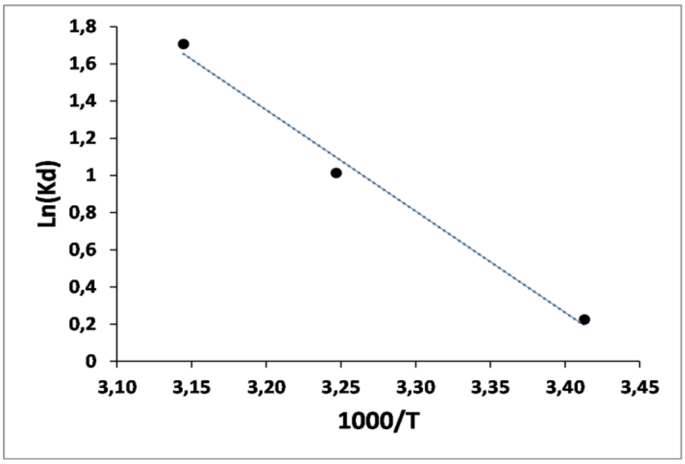

Fig. 3. Plot ln K_d vs. 1000/T for the adsorption of Sr^{2+} onto EAFS.

Table 3. Thermodynamic parameters of Sr^{2+} adsorption onto EAFS.

Temperature (°C)	**K_d**	**$-\Delta G°$, (KJ mol^{-1})**	**$\Delta H°$, (KJ mol^{-1})**	**$\Delta S°$, (J mol^{-1}K^{-1})**
20	1.3	0.6	44.9	156.3
35	2.8	2.6		
45	5.5	4.5		

CONCLUSION

The results of investigation have shown that EAF slag is an effective adsorbent for Sr^{2+} removal from aquatic solution. A high removal efficiency of Sr^{2+} (68.8 %) was obtained after 15 min at temperature of 20 °C. Increase of temperature to 45 °C lead to the increase of removal efficiency of 88.4%. The results of kinetic analysis suggested that adsorption of Sr^{2+} onto EAFS proceeds according to the pseudo second-order kinetic model. Thermodynamic investigations have indicated endothermic character of Sr^{2+} adsorption onto EAFS. Moreover, adsorption process is spontaneous since negative values of $\Delta G°$ were obtained. These values become more negative with an increase of temperature suggesting more favorable adsorption process at higher temperatures.

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HEAVY METALS CONTENT IN SOIL AND VEGETABLES IN THE VICINITY OF MINE OF LEAD AND ZINC (MONTENEGRO): CONTAMINATION OF SOIL AND HEALTH RISK ASSESSMENT

Nevena Cupara [1,2], Irena Nikolić[3], Dijana Đurović[1,4], Ivana Milašević[1], Sladjana Krivokapić[2]
[1]Institute of Public Health of Montenegro, Podgorica, Montenegro
[2] University of Montenegro, Faculty of Science and Mathematics, Podgorica, Montenegro
[3]University of Montenegro, Faculty of Metallurgy and Technology, Podgorica, Montenegro
[4]University Donja Gorica, Faculty for Food Technology, Food Safety and Ecology, Podgorica, Montenegro
e-mail: ncupara@ymail.com

Abstract: Contamination of agricultural soil and vegetables grown at respective soil by heavy metals (As, Hg, Cd, Pb, Cu, Zn, Cr) in the vicinity of mine of lead and zinc in Montenegro was evaluated in this study. The results obtained indicated polluted agricultural soil in study area. It was found that main concentration of Pb, Cd and Zn exceeded maximally allowed concentrations of these metals in soil according Montenegrin legislation. Moreover, health risk assessment for inhabitants in investigated area due to the vegetable consummation was also evaluated. As for vegetables, only Cu and Zn were detected in all examined vegetables. Non-cancerogenic health risk of edible vegetable consumption was found for children while there was no health risk for adults.
Key words: heavy metals, pollution, agricultural soil, health risk

INTRODUCTION

Contamination of agricultural soils by heavy metals has attracted special attention due to their well-known adverse effect on soil function in food production. Different industrial activities lead to the continual loading of agricultural soils with heavy metals which inevitably leads to soil contamination, dysfunction and decline in crop productivity but also affect human health through the food chain [1].
Mining activities represent one of the most important anthropogenic sources of heavy metal pollution. Spilt ore tailings, emissions of dust containing heavy metals into the atmosphere and the generation of a large number of acidic mine wastewaters that contain heavy metals are the main pathways for soil contamination by heavy metals caused by mining activities [2]. Production of a large amount of mining waste all over the world which is deposited at the land surface may lead to the continual transforming fertile soil into wasteland. Thus, special attention should be paid to the soil contamination by different mining activities.
The municipality of Pljevlja is located in the north of Montenegro. The soil quality in this municipality is greatly influenced by the industrial activities associated with mining activities of mine of lead and zinc located in this town. To the best of our knowledge, there is no study conducted to assess agricultural soil pollution in the municipality of Pljevlja in Montenegro. Thus, this study aimed to assess the potential heavy metals (As, Hg, Cd, Pb, Cu, Zn and Cr) content in agricultural soils and vegetables (potato, beet, onion and carrot) in the vicinity of mine of lead and zinc in the municipality of Pljevlja. Rrisk index (RI) and pollution load index (PLI) were used to estimate heavy metals soil pollution. Moreover, health risk for children and adults were assessed through vegetable consumption. Daily intake (EDI), target hazard quotient (HQi), total hazard quotient (THQ) and hazard index (HI) was used to evaluate health risk for inhabitants in study area.

MATERIALs AND METHODS

Assessment of soil contamination by heavy metals

Soil contamination by heavy metals due to the anthropogenic activities was assessed by the evaluation of ecological risk index (RI) and pollution load index (PLI). The potential ecological risk (RI) is determined as proposed by Hakanson and used to quantify the level of ecological risk degree of heavy metals in agricultural soils [3]. RI is calculated as follows:

$$RI = \sum E_r \quad (1)$$

$$E_r = T_i \cdot C_f \quad (2)$$

$$C_f = \frac{C_i}{C_{ri}} \quad (3)$$

where E_r, C_f and T_i are ecological risk factor, contamination factor and toxic response factor of the element i; respectively. C_i and C_{ri} are the concentrations of the element i in the soil sample and the geochemical reference or background value of the element i in the earth's crust, respectively. The values of toxic response factor for As, Hg, Pb, Cd, Cu, Zn and Cr are 40,10,5,30,5,1 and 2 [3] and geochemical background concentrations 13, 0.4, 20, 0.3, 45, 95 and 90, respectively [4]. The degree of ecological risk can be categorized as follow: RI < 150: low risk, 150 ≤ RI < 300: moderate risk and RI ≥ 600: high contamination.
The pollution index (PLI), calculated using Eq.4, provides the information on the overall level of heavy metal pollution.

$$PLI = (C_{f1} \cdot C_{f2} \cdot C_{f3} \cdot \ldots\ldots C_{fn})^{1/n} \quad (4)$$

For PLI > 1, the soils are considered polluted by heavy metals, while for PLI < 1 the soils are categorized as unpolluted.

Assessment of health risk

To assess the health risk due to the root vegetable consumption, estimated daily intake (EDI), target hazard quotient (HQi), total hazard quotient (THQ) and hazard index (HI) were calculated according the following equations [3]:

$$EDI = \frac{I_{Intake} \cdot Ef \cdot ED \cdot C_p}{BW \cdot AT} \cdot 10^{-3} \quad (5)$$

$$THQ = \frac{EDI}{RfD} \quad (6)$$

$$TTHQ_{(individualplant)} = THQ_{(metal1)} + THQ_{(metal2)} + \ldots + THQ_{metaln)} \quad (7)$$

$$HI_{plant} = \sum TTHQ = TTHQ_{plant1} + TTHQ_{plant2} + \ldots + TTHQ_{plantn} \quad (8)$$

I_{intake} is a plant daily intake rate; C_p is the concentration of the contaminant in a specific plant, *EF* is an exposure frequency; *ED* is an exposure duration; *BW* is an average body weight; *A*T is an averaging time; RfD is reference dose which presents the maximum daily dose of each individual metal from ingestion pathway, for both adults and children, that is believed not to lead to an appreciable risk of deleterious effects to sensitive individuals during a lifetime; CRi is a cancer risk of each individual heavy metal, SF is a slope factor for carcinogenic exposure and TCR is a total cancer risk. Factors used in the risk assessment equations are given in Table 1 and reference dose values of some parameters for health risk assessment of heavy metals in soils are given in Table 2. If the THQ >1 there is a potential health risk and if THQ <1 there is no obvious risk from the substance over a lifetime of exposure. Also, if HI >1 there is a potential health risk and if HI <1 there is no health risk of vegetable consumption.

Table 1. Factors used in the risk assessment equations.

Factor	Value		Reference
	Children	Adults	
I_{intake} (g·day-1)	366	223	[5]
EF (days·year-1)	350	350	[6]
ED (years)	6	24	[6]
BW (kg)	24.5	59.4	[6]
AT (days) (Non-carcinogens)	EF·ED	EF·ED	[6]
AT (days) (Carcinogens)	EF·70	EF·70	[6]

Table 2. RfD values (mg·kg-^{1}·day^{-1}) [7].

Metal	RfD
As	3.00E-04
Hg	3.00E-03
Pb	3.50E-03
Cd	1.00E-03
Cu	4.00E-02
Zn	3.00E-01
Cr	3.00E-03

RESULTS AND DISCUSSION

Heavy metal content in agricultural soil and ecological risk assessment

Descriptive statistics of heavy metals concentration in agricultural soil is given in Table 3. As can be seen Zn is the metal with the highest concentration in all soil samples. The mean concentration of heavy metals varies in the range: Zn (119.89-661.72 mg·kg^{-1}), Pb (33.77-660.60 mg·kg^{-1}), Cu (47.69-113.31 mg·kg^{-1}), Cr (23.53-36.87 mg·kg^{-1}), As (9.18-18.19 mg·kg^{-1}), Cd (1.48-2.64 mg·kg^{-1}) and Hg (0.078-0.35 mg·kg^{-1}). The highest concentrations of heavy metals were observed in the soil collected near the MLZ area ranked in descending order as Zn > Pb> Cu> Cr> As> Cd> Hg. The mean concentrations of Zn (661.72 mg·kg^{-1}), Pb (660.60 mg·kg^{-1}), Cu (113.31 mg·kg^{-1}), As (18.19 mg·kg^{-1}) and Cd (2.49 mg·kg^{-1}), exceed their background values in the Earth's crust and Zn, Pb and Cd exceed the maximum allowed concentrations (MAC) in soil according to Montenegrin legislation [8] indicating considerable pollution in this study area. On the other hand, concentrations of Cr and Hg were below the prescribed limits.

Table 3. Descriptive statistics of heavy metal content presented as mean ± standard error (mg·kg^{-1}) in agricultural soil in the vicinity study area (Values of that exceed MAC are bolded).

Parameter	Metal						
	As	Hg	Pb	Cd	Cu	Zn	Cr
MAC*	20.00	2.00	20.00	2.00	200.00	300.00	50.00
Mean	18.19	0.35	**660.60**	**2.49**	113.31	**661.72**	23.53
Min	8.24	0.05	104.40	0.52	48.88	140.31	15.70
Max	57.71	0.93	901.00	4.36	168.70	1150.29	29.10
Median	12.91	0.27	780.70	2.94	128.31	815.27	25.39

* Maximal allowed concentration [36]

The values of ecological risk index (RI) and pollution load index (PLI) in the agricultural soils in the vicinity of mine of lead and zinc is given in Fig. 1. The values of RI for soil varied from 118.34 to 700.55 with an average value of 482.6. This result is in the range of $300 \leq RI < 600$, indicating that the integrated potential ecological risk of heavy metals is at considerable risk. Obtained value of PLI in investigated area was 2.59 which indicated the contaminated study area.

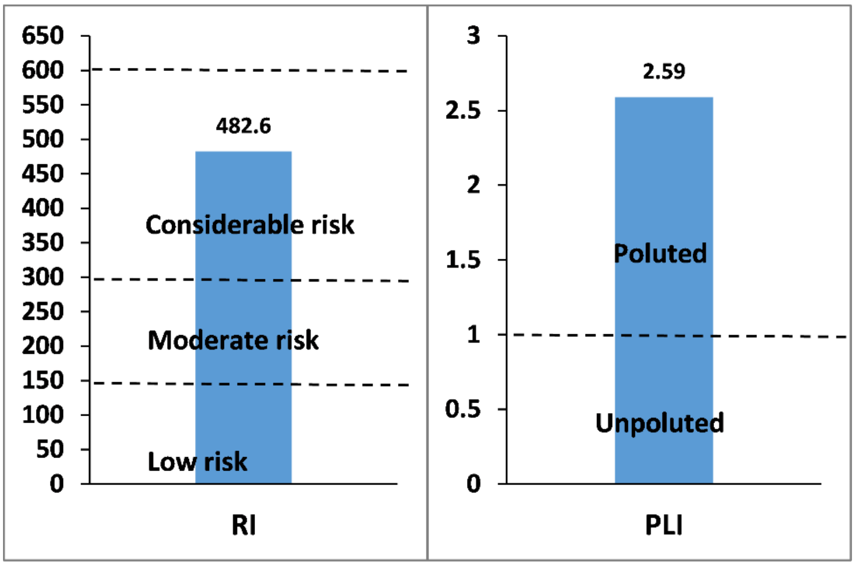

Figure. 1. Values of the potential ecological risk index (RI) and pollution load index (PLI) for heavy metals in the agricultural soils collected in study area.

Heavy metal contents in vegetables and health risk assessment

The results of descriptive statistics for metal content in a vegetable are given in Table 4. With exception of Cu and Zn, chemical analysis of vegetables indicated concentrations of majority of heavy metals (As, Hg, Pb, Cd and Cr) below the limits of detection. Thus, only content of Cu and Zn in vegetable samples were discussed. Proposed maximum allowable concentration for Zn in vegetable has not proposed while for Cu this limit is 40 mg·kg^{-1} of fresh vegetable [9]. The mean concentrations of Cu in all kinds of vegetables is far way below these limits. The highest mean value of Cu concentration was observed in potato samples (1.27 mg·kg^{-1}) followed by Cu content of 1.12 mg·kg^{-1}, 0.64 mg·kg^{-1} and 0.49 mg·kg^{-1} in beet, carrot and onion samples, respectively. The mean concentrations of Zn concentrations in vegetables show more variance beet (5.47 mg·kg^{-1}) > onion (3.40 mg·kg^{-1}) > carrot (2.76 mg·kg^{-1}) > potato (2.61 mg·kg^{-1}).

Table 4. Descriptive statistics of different heavy metals (mg·kg-^{1}) in vegetables collected in a study area.

Metal		Potato	Beet	Onion	Carrot
Cu	Mean	1.27	1.12	0.49	0.64
	Max	1.88	1.22	0.62	0.9
	Min	0.94	0.94	0.37	0.43
	Median	1.12	1.17	0.49	0.61
Zn	Mean	2.61	5.47	3.40	2.76
	Max	3.31	7.62	4.38	3.93
	Min	2.24	3.13	2.47	1.21
	Median	2.44	5.58	3.39	2.94
	Mean	2.61	5.47	3.40	2.76

Health risk assessment due to the vegetable consumption was evaluated through daily intake (EDI), hazard quotient (THQ), total hazard quotient (TTHQ) and hazard index (HI) were calculated and results are given in table 5. Only non-carcinogenic health risk was considered since these metals may promote only non-carcinogenic effect on human health. It is evident that higher EDI values were observed for Zn in comparison to Cu and these values were generally higher for children in comparison to adults. Moreover, the highest heavy metals intakes were observed as consumption of potato and beet. However, estimated EDI of Cu and Zn were below the tolerable RfD limits (Table 2.) The THQ values of both metals were lower than one for all kinds of vegetable for both populations. This indicate that inhabitants around mine of lead and zinc are not faced with health risk by intake of single metal Cu and Zn through vegetable consumption. There is also no health risk for inhabitants by the combined effect of Cu and Zn since TTHQ values for all kind of vegetables were less than one. Furthermore, results of HI values indicate that no potential health risk for adults (HI=0.78) while children are under the potential health risk by the consumption of vegetables cultivated in these areas (HI=1.65).

Table 5. The EDI, HQ, THQ and HI values for heavy metals caused by consumption of vegetables

Metal		Children				Adults			
		Potato	Beet	Onion	Carrot	Potato	Beet	Onion	Carrot
Cu	EDI	0.010	0.009	0.004	0.005	0.007	0.006	0.003	0.004
	THQ	0.261	0.228	0.107	0.136	0.177	0.154	0.072	0.092
Zn	EDI	0.022	0.053	0.030	0.026	0.015	0.036	0.020	0.018
	THQ	0.073	0.175	0.099	0.086	0.049	0.119	0.067	0.059
	TTHQ	0.334	0.403	0.206	0.222	0.226	0.273	0.139	0.151
HI		1.65				0.78			

CONCLUSION

Heavy metals content in agricultural soil and samples of vegetables collected from the respective soil samples was evaluated in this study. Moreover, contamination of soil by heavy metals and health risk for inhabitants living in study area due to the vegetable consumption was also evaluated. The results obtained indicated that main concentration of Pb, Cd and Zn in agricultural soil in the vicinity mine of lead and zinc exceeded maximal allowed concentration. The ecological assessment performed by RI showed a considerable risk of soil contamination by heavy metals in study area while PLI value indicated polluted agricultural soil. Presence of Cu and Zn was detected in the collected vegetable samples. Health risk assessed by estimated daily intake (EDI) of these metals through consumption of vegetables and hazard quotient (THQ) indicated no health risk for inhabitants in the vicinity of investigated study area. However, overall hazard index (HI) indicated possible adverse health effects from vegetable consumption for children while for adults there is no health risk.

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RECYCLED PLASTIC CONSTRUCTION BLOCKS AND BRICKS

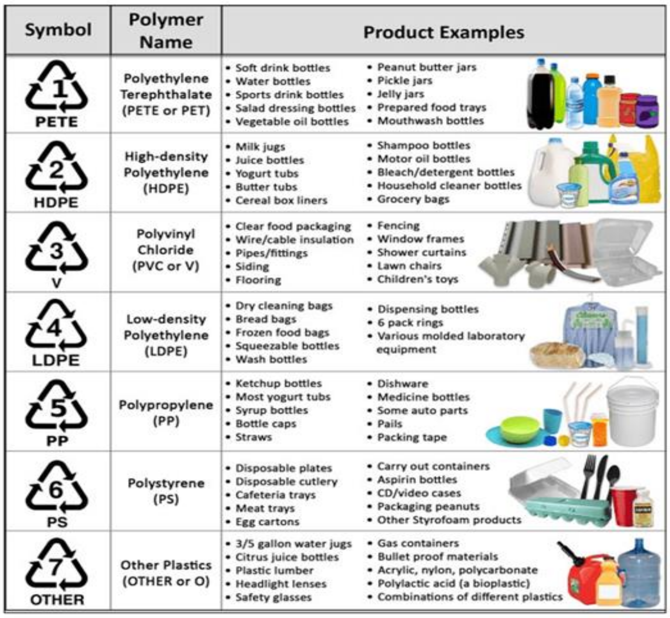
Jasmina Radosavljević[1], Ana Vukadinović[1], Amelija Đorđević[1]
[1]University of Nis, Faculty of Occupational Safety in Niš, Niš, Serbia
e-mail: jasmina.radosavljevic@znrfak.ni. ac.rs

Abstract: Plastic waste was initially landfilled along with every other type of waste. This has proved not to be an acceptable long-term solution considering the time it takes plastics to decompose, which ranges from 100 to 600 years. The ideas about reusing plastics emerged as early as the 1970s. Any kind of production is inevitably accompanied by waste, which is generated both in the production facilities and as a result of worldwide product use. This points to a logical conclusion that, owing to the plastic production growth, the amount of waste generated over time increases on a daily basis. This paper discusses the possibility of using recycled plastics to produce construction blocks and bricks.
Key words: plastic, recycling, building blocks, bricks

INTRODUCTION

Plastics are organic polymers composed of groups of monomers containing carbon and hydrogen. Natural polymers have been used since the dawn of humanity, whereas synthetic polymers are considerably more recent. Over the previous several decades, plastics gained popularity because of their ability to retain their mechanical properties after modeling, crushing, fabrication of threads, and post-use recycling. Plastic masses are processed using rolling into foils, injection molding, extrusion under pressure, etc. Owing to their mechanical and chemical properties, plastic masses have outperformed numerous other materials. Among other things, the use of plastics has been increasing owing to the low cost of the raw materials, small mass, and processing versatility.
Large amounts of plastic waste are deposited at landfills and often outside landfills. Waste disposal at landfills is unsuitable, because of its large volume and its weathering non-degradability.
Recycle plastic is used to obtain synthetic materials that are then used to produce clothing, foils, packaging (e.g., bottles, bins, barrels), and other products. It is only in recent years that recycled plastic has been used to produce construction blocks and bricks.
European plastics industry has opted to maximize the use of plastic waste as a resource and to minimize plastic waste disposal at sanitary landfills. This involves the utilization of plastics through mechanical or chemical recycling or as an energy-generating raw material, which is a path toward integrated waste management. Such a policy is in keeping with the EU Directive on packaging and packaging waste, which set a goal to utilize a minimum of 45% of packaging waste, 15% of which has to be recycled [2].
Of all packaging materials, plastic has enjoyed the highest growth rate over the previous decade. The first European strategy for plastics was adopted in Strasbourg in January 2018. Three years prior, the EU enacted the Circular Economy Action Plan, and the European strategy for plastics is the extension of this policy, which is supposed to regulate plastic production, use, and disposal flows and to incentivize a transition to circular economy.
The goal is to ensure the reuse and recycling of all plastic packaging on the EU market by 2030. To ensure a higher demand for recycled plastics, the EU Commission also launched a campaign aimed at taking on the obligation of putting ten million tonnes of recycled plastics into new products across the EU by 2025.
The EU generates over 28 million tonnes of plastic waste annually. Less than 30% of that amount gets recycled, while the remainder is either incinerated or landfilled. Analyses have shown that such a high degree of landfill disposal and incineration incurs losses of 70 to 105 billion euros due to a short utilization cycle of the raw materials.
In everyday life, plastics are used for a wide variety of purposes, from clothing, footwear, and tableware to cosmetics and car parts. Plastic is a light material that is easy to produce and mold. It is highly resilient, which means that every piece of plastic ever produced still exists on earth in one form

or another. These properties of plastic and irresponsible management of plastic flows have caused one of the crucial environmental issues affecting the planet – it is overrun by plastics.
In 2020, Serbia generated 356,021 tonnes of plastic waste, of which only 45,219 tonnes were recycled. [3,4].
In order to standardize and globalize recycling, special labels were globally adopted to inform customers about the material of which the product is made and to facilitate collection and subsequent sorting before recycling. The law mandates that every item has to contain a label informing the user about the material used to produce it. Figure 1 shows the universal symbols for labeling plastic materials (each type of plastic has only one symbol). Recycled plastics are classified according to their basic chemical composition.



Symbol	Polymer Name	Product Examples	
1 PETE	Polyethylene Terephthalate (PETE or PET)	• Soft drink bottles • Water bottles • Sports drink bottles • Salad dressing bottles • Vegetable oil bottles	• Peanut butter jars • Pickle jars • Jelly jars • Prepared food trays • Mouthwash bottles
2 HDPE	High-density Polyethylene (HDPE)	• Milk jugs • Juice bottles • Yogurt tubs • Butter tubs • Cereal box liners	• Shampoo bottles • Motor oil bottles • Bleach/detergent bottles • Household cleaner bottles • Grocery bags
3 V	Polyvinyl Chloride (PVC or V)	• Clear food packaging • Wire/cable insulation • Pipes/fittings • Siding • Flooring	• Fencing • Window frames • Shower curtains • Lawn chairs • Children's toys
4 LDPE	Low-density Polyethylene (LDPE)	• Dry cleaning bags • Bread bags • Frozen food bags • Squeezable bottles • Wash bottles	• Dispensing bottles • 6 pack rings • Various molded laboratory equipment
5 PP	Polypropylene (PP)	• Ketchup bottles • Most yogurt tubs • Syrup bottles • Bottle caps • Straws	• Dishware • Medicine bottles • Some auto parts • Pails • Packing tape
6 PS	Polystyrene (PS)	• Disposable plates • Disposable cutlery • Cafeteria trays • Meat trays • Egg cartons	• Carry out containers • Aspirin bottles • CD/video cases • Packaging peanuts • Other Styrofoam products
7 OTHER	Other Plastics (OTHER or O)	• 3/5 gallon water jugs • Citrus juice bottles • Plastic lumber • Headlight lenses • Safety glasses	• Gas containers • Bullet proof materials • Acrylic, nylon, polycarbonate • Polylactic acid (a bioplastic) • Combinations of different plastics

Fig.1. Plastic labeling symbols

Regarding the recycling process itself, it should be emphasized that there are four types of recycling: ***primary, secondary, tertiary, and quaternary***. The classification was established based on product lifecycle, which then dictates its later use after recycling.

- **Primary recycling:** Re-extrusion, or return of the plastics with the same properties into the production process. If the molding of plastic products generates waste (e.g., a material left over after trimming the product edges, a material that goes through a machine first during processing and is then discarded, a product that does not meet the shape requirements, etc.) that remains within the production facility, it is considered uncontaminated and may be returned to the polymer processing procedure.
- **Secondary recycling:** Mechanical recycling, developed to recycle different plastics using physical procedures. When a material leaves the production facility and is collected after its shelf life, cleaned of all traces of other materials, washed, and dried, it can be reshaped through processing, pure or combined with a pure polymer and other materials. Mechanical recycling is the only one of the four recycling types that maximizes the utilization of plastic waste while minimizing the negative environmental impact. When using mechanical recycling, it is important to select a suitable method of sorting and different processing stages. Despite the rapid technological progress, manual sorting of plastics is still the most common method, as it is a simple process requiring little technological support. It is a labor-intensive, cost ineffective, and inefficient method for sorting any material, especially plastic. Consequently, a labeling system was introduced with codes for the six most used types of plastic.
- **Tertiary recycling:** Chemical recycling is used to produce raw materials for the chemical industry. It is a process decomposing plastic materials into polymers with lower molecular

mass (usually liquids or gases), which are then used as raw materials for new petrochemical products or plastics [1]. The term *chemical* is used because the process changes the chemical structure of the polymers.

- **Quaternary recycling:** Its purpose is energy generation, or complete or partial oxidation of plastic waste to produce heat and/or gaseous fuels and oils and/or disposable materials (e.g., ash). Parts of the waste, most often specific types of polymers that cannot be processed using any of the previous three procedures, may be used for energy generation or as fuels, both on their own and combined with other wastes and fuel to generate heat due to the breaking of chemical bonds.

RECYCLED PLASTIC CONSTRUCTION BLOCKS

ByFusion Global Inc., a US company, plans to recycle 100 million tons of plastics and convert them into construction blocks by 2030. ByFusion Global created a new alternative construction material. ByFusion's Blocker system converts 100% of plastic waste into ByBlock® – an advanced and affordable construction material. ByBlock® is a multi-colored construction block made of recycled plastic. Its dimensions are 40x20x20cm and it weighs 10kg. It is the first construction material made entirely out of recycled (and often un-recyclable) plastic waste. The blocks are designed to be placed without any glue or adhesive, the same as regular concrete blocks. However, as opposed to concrete blocks, ByBlocks® do not crack or crumble.

The manufacturer claims that the production of these blocks generates zero waste. One ton of plastic yields one ton of ByBlocks®. These multi-colored construction blocks are visually appealing and functional. They can be used for the construction of retaining walls, sound walls, sheds, terracing, and even furniture. They can replace cement blocks in building foundations or indoor walls and are no different than concrete blocks.

The manufacturer also stresses that the production process has zero carbon emissions and does not require any additional chemicals. The plastic is not melted during recycling and standard construction materials such as plaster walls and tiles may be added later. Greenhouse gas emissions of ByBlock® production are 41% lower than emissions during concrete block production [5].

Fig. 2. Recycled plastic blocks – ByBlock

CONSTRUCTION BLOCKS MADE OF RECYCLED PLASTIC AND SILICATE WASTE

Indian company Rhino Machines invented a new design technology for plastic construction blocks. The blocks are called silica plastic blocks (SPBs) and are strong enough to be used for building a house. *Rhino Machines* conducted experiments to determine the sustainability of these blocks made from plastic waste and silicate foundry dust. The experiments were conducted by the company*'s* R&D division to prove that SPBs can be used in construction instead of traditional blocks. The general goal was to attempt to find a permanent solution for the growing issue of plastic waste in India.
According to the Indian Central Pollution Control Board data from 2012, India produced over 23,500 tonnes of plastics daily, of which 10,000 tonnes were deposited with other waste without being sorted. This waste is non-biodegradable and reaches the natural environment, polluting rivers, agricultural land, and the entire environment.

Fig. 2. Figure caption

Initially, the aim of creating SPBs was to achieve zero discharge from the foundry reclamation process. In the early stages of the experiments, tests were conducted using foundry dust mixed with cement to produce bricks. The experiment yielded the following results: 7-10% of recycled waste went into concrete bricks and 15% into clay bricks. The experiments indicated that other resources, such as cement, earth, and water, were also required, which was not justified by the recycled waste. Further research resulted in the mixing of foundry dust with plastic waste, which was used as a bonding agent, thus eliminating the need for water and cement during mixing.
SPBs require a mixture of approximately 80% foundry dust and 20% plastic, which means that neither water nor cement are necessary. Such blocks are less dependent on natural resources, while also reducing inorganic waste. According to *Technology Times*, SPBs are 2.5 times stronger than standard red clay bricks and their production costs are lower owing to the use of waste [8].
Even though some countries banned the use of single-use plastic products, the problem with plastic waste gives serious cause for concern. Therefore, technologies such as SPBs could significantly help reduce the amount of plastic waste. In addition to contributing to the solution of the plastic waste problem, such technologies should also help alleviate another global problem, which is the growing demand for residential space in urban environments. According to UN data, 55% of the world population reside in urban environments, where the problem of plastic waste is logically more pressing. It is estimated that about 68% of the world population will live in urban areas by 2050.

RECYCLED PLASTIC BRICKS

The House in Colombia shown in Figure 6 was built from recycled plastic by Fernando Llanos. Together with the architect Óscar Méndez, he founded the company Conceptos Plásticos, which patented the innovative system of construction using recycled plastic bricks, which allowed the cheap and fast construction of houses at difficult-to-reach locations. The construction of a plastic house with the total surface area of approximately 40 m^2 cost 6,000 euros and took only five days. The plastic bricks were joined together similar to LEGO® blocks.

Plastic bricks have good insulation properties, they are not flammable, and they comply with the local seismic building codes. Since 2011, the company has employed 15 persons to build plastic brick houses in areas affected by natural disasters [7].

Fig. 4. A house made of recycled plastic bricks

Located in Alta Gracia, province of Córdoba, Argentina, the non-profit organization Ecoinclusión works to reduce plastic waste, specifically PET bottle waste, by producing recycled plastic bricks. These bricks are also intended for housing construction in vulnerable areas. The bricks received the technical certification by the *UN – Habitat Secretariat*, after being developed by *Ceve-Conicet*. The production of one plastic brick requires twenty recycled bottles. The brick's properties are similar to a standard clay brick's but with better thermal insulation characteristics [9].

Fig. 5. A recycled plastic brick

The Kenyan startup Gjenge Makers, located in Nairobi, founded by 29-year-old Nzambi Matee, developed a cheap recycled plastic paving brick, which is harder than concrete bricks. Nzambi Matee was declared the Young Champion of the Earth 2020 for Africa by the UN Environment Programme (UNEP). The plastic waste paving bricks are now used to pave households, schools, and streets.

She conceived and developed a prototype of a machine that converts plastic materials into pavers for paths and sidewalks. The machine’s output capacity is 1,500 plastic pavers a day. The production is cost-effective because waste is used and their superior hardness makes them ideal for the paving of areas that require harder materials.

Fig. 6. Recycled plastic pavers in different colors

The company’s innovations in the civil engineering sector offer both economic and environmental benefits, because they involve a transition from linear to circular economy, in which products remain in the system as long as possible. Thus far, more than 20 tonnes of plastic waste have been recycled to produce paving bricks and tiles in a variety of colors (red, blue, brown, and green). Testing showed that they are two times stronger than regular concrete bricks [10].

CONCLUSION

The entire world is facing the problem of plastic waste today. Modern life is almost unimaginable without polymers, as everyday items, clothing and footwear, vehicles, construction materials and products, and information and communication devices are made of different types of polymers. Waste generation accompanies any kind of production, whether in production facilities themselves or as a result of product use throughout the world. Consequently, the increased production of plastics generates increasing amounts of plastic waste on a daily basis. Initially, plastic waste was landfilled with other waste, but it soon became clear that this could not be a long-term solution, because of the long period of plastic degradation.

Many plastic materials can be reused to create new items that are used in every sphere of life. The obtained plastic regranulate is used directly in the production of plastic items. This paper discussed how the plastic regranulate may be used to produce recycled plastic construction blocks and bricks. These new construction materials are then used for the construction of residences and for outdoor paving.

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AIR QUALITY MONITORING SYSTEM IN THE CITY OF BELGRADE

Adrijana Babić[1], Zoran Čepić[1], Jelena Radonić[1], Zorana J. Andersen[2]
[1] Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
[2] Section of Environmental Health, Dept of Public Health, University of Copenhagen, Copenhagen, Denmark
e-mail: babic.dz2.2020@uns.ac.rs

Abstract: Monitoring of the atmosphere and determination of the types and amounts of pollutants is becoming more important issue in complex and global monitoring of the environment. On the geocomponent and geocomplex level problem of monitoring the environment is attracting the attention of the scientific experts of different profiles (chemists, physicists, geographers, biologists, meteorologists), both in the national and international projects. Because of the general characteristics of the Earth's atmosphere (dynamically balanced instability) and the potential contribution to climate change solutions air-pollution monitoring has become particularly important field of environmental research. In accordance with the Law on Air Protection and accompanying regulations in Republic of Serbia, the available results of measuring the concentrations of pollutants, within air quality monitoring, are collected and stored in the Serbian Environmental Protection Agency. Based on these results, and according to the criteria defined in the Law on Air Protection, SEPA assesses AQ in zones and agglomerations. This is the official AQ assessment in Serbia that applies standards in accordance with the EU practice.
Key words: air pollution, monitoring system

INTRODUCTION

The Law on Air Protection, adopted in 2009, which is the first independent law on air protection (before that it was part of the law on environmental protection, History of changes in the administration system for air quality management), defines air quality monitoring criteria. Today, the EU Air Quality Directive has been transposed and integrated into national legislation. The chronology of changes in the value of the criteria can be seen by year on the website of the Environmental Protection Agency [1].
In accordance with the Law on Air Protection and accompanying regulations [2] in Republic of Serbia, the available results of pollutants concentrations obtained/measured within air quality monitoring, are collected and stored Environmental infor, system that is operated by the Serbian Environmental Protection Agency (SEPA). Based on these results, and according to the criteria defined in the Law on Air Protection, SEPA assesses air quality (AQ) in zones and agglomerations. This is the official AQ assessment in Serbia that applies standards in accordance with the EU practice.
In the nacional air quality monitoring network of air quality monitoring stations, reference methods are used to measure concentrations of sulfur dioxide, nitrogen dioxide and nitrogen oxides, suspended particles, lead, benzene, carbon monoxide and ground ozone defined in accordance with Regulation on monitoring conditions and air quality requirements.

Table 1. Air quality standards for the protection of health, as given in the EU Ambient Air Quality Directives, applied in SEPA assessment of AQ in the Republic of Serbia [1]

Pollutant	Averaging period	Legal concentration	Comments
PM_{10}	1 day	Limit value: 50ηg/m^3	Not to exceed more than 35 days/year
	Calendar year	Limit value: 40ηg/m^3	
$PM_{2.5}$	Calendar year	Limit value: 25ηg/m^3	
O_3	Maximum daily 8 hour mean	Target value: 120ηg/m^3	Not to exceed more than 25 days/year, over 3 years
	1 hour	Information threshold: 180ηg/m^3	
		Alert threshold: 240ηg/m^3	

NO_2	1 hour	Limit value: 200ηg/m^3	Not to exceed more than 18h/year
		Alert threshold: 400ηg/m^3	To be measured over 3 consecutive hours over 100km^2 or an entire zone
	Calendar year	Limit value: 40ηg/m^3	
BaP	Calendar year	Target value: 1ng/m^3	Measure as content in PM_{10}
SO_2	1 hour	Limit value: 350ηg/m^3	Not to exceed more than 24h/year
		Alert threshold: 500ηg/m^3	To be measured over 3 consecutive hours over 100km^2 or an entire zone
	1 day	Limit value: 125ηg/m^3	Not to exceed more than 3 days/year
CO	Maximum daily 8 hour mean	Limit value: 10mg/m^3	
C_6H_6	Calendar year	Limit value: 5ηg/m^3	
Pb	Calendar year	Limit value: 0.5ηg/m^3	Measure as content in PM_{10}
As	Calendar year	Limit value: 6ng/m^3	Measure as content in PM_{10}
Cd	Calendar year	Limit value: 5ng/m^3	Measure as content in PM_{10}
Ni	Calendar year	Limit value: 20ng/m^3	Measure as content in PM_{10}

METHODS

National system for air quality monitoring

The nacional network is established to monitor air quality in: settlements, industrial and uninhabited areas, in protected natural areas and protected environment of immovable cultural assets as well as in areas affected by certain sources of pollution, including mobile sources.

The nacional network is regulated in accordance with the Law on Air Protection. Air quality control in the nacional network is performed within the network of meteorological stations, the network of urban stations for measuring the level of pollutants in the air and the network of automatic measuring stations. The nacional network is determined in the Program of air quality control in the nacional network which is defined in the Regulation on the establishment of air quality control programs. The nacional network is an integral part of monitoring the quality of the environment and is financed from the budget of the Republic of Serbia. The program determines the number and arrangement of measuring stations and measuring points in certain zones and agglomerations, as well as the scope, type and frequency of measuring the levels of pollutants in the air at the level of the Republic of Serbia.

Competence of the Environmental Protection Agency in the field of air quality

The Environmental Protection Agency (SEPA) has been appointed as responsible executor of the operations of the system for automatic air quality monitoring in the Republic of Serbia, under Art. 13 on Law on Air Protection. SEPA is state authority responsible for collecting, updating and processing the results of the automatic air quality monitoring from the national network of the automatic measuring stations for air quality, for the purposes of reporting on the national and EU level.

The competencies of the Environmental Protection Agency in the field of air quality derive from the provisions of the Law on Ministries and the Law on Air Protection. Executing legal obligations, with the application of regulations contained in bylaws, the tasks of the Environmental Protection Agency in the field of air quality protection represent the following competencies:

- Performs state air quality monitoring, including the implementation of prescribed and harmonized air quality control programs
- Runs the air quality information system for the Republic of Serbia
- Informs the public about air quality
- Performs assessment of air quality in zones and agglomerations and categorization of air quality based on measurement results according to the level of pollution, starting from the prescribed limit and tolerance values
- Prepares and publishes the Annual Report on the State of Air Quality in the Republic of Serbia
- Exchanges air quality data with the European Environment Agency (*EEA*), the European Information and Observation Network (*EIONET*) and for reporting purposes in accordance with international commitments (*EMEP* Protocol)
- Participates in the development of laws and bylaws in the field of protection and improvement of air quality

Figure 1. Air quality monitoring stations and measuring equipment [3]

In order to improve air quality and implement the adopted regulations, the Ministry of Environmental Protection constantly cooperates with numerous institutions and ministries such as the Ministry of Energy, Transport and Agriculture. This cooperation is also defined at the level of the Working group for systemic solution of air protection issues organized by The Government of the Republic of Serbia.

Ministry of Environmental Protection

Responsibilities of the Ministry of Enironmental Protection are prescribed In the Law of Ministries ("Official Gazette of RS" No.128/2020 - Law on Ministries) under article 6. Organizational scheme of the Ministry of Environmental Protection - Organizational scheme and jurisdiction of Ministry of Environmental Protection - MoE jurisdiction.
The Ministry of Environmental Protection proposes conditions for air quality monitoring, proposes the Air Quality Control Programme in the state network and takes care of implementation of the Programme. The Ministry also prescribes air quality requirements. The Ministry supervises the work of the Agency, the competent authority of the autonomous province, the competent authority of the local self-government unit, as well as the authorized legal entities in carrying out the delegated tasks.

The Ministry issues license to authorized legal entities to measure emissions and levels of pollutants in the air.
The ministry gives consent to programmes establishing a local air quality monitoring network, which are under the jurisdiction of local self-government units. The ministry consents to air quality plans of local self-government units, as well as short-term action plans. In the case of cross-border air pollution, the Ministry, together with the competent authorities of another state, undertakes joint activities.

Serbian Environmental Protection Agency

The competencies of the Environmental Protection Agency (SEPA) in the field of air quality derive from the provisions of the by the Law on Air Protection (Official Gazette of the Republic of Serbia, Nos. 36/09 and 10/13, available on the link Law on Air protection) the Law of Ministries ("Official Gazette of RS" No.128/2020 - Law on Ministries).
SEPA is responsible institution on national level for collection of environmental data and the National focal point of the Republic of Serbia for cooperation with the European Environment Agency. The organisational structure of the SEPA comprises the Sector for Quality Control and Environmental Status, consisting of four departments: Air Quality Monitoring, Water and Sediment Quality Monitoring, Indicators, Reporting and Information System and National Register of Pollution Sources, while the National Laboratory is a separate department within the Agency.

City of Belgrade Secretariat for Environmental Protection

Air quality monitoring on the territory of the city of Belgrade is carried out according to the program provided by the competent authority – the Secretariat for Environmental Protection and the Ministry of Environmental Protection consents to the proposed programme. It is important to note that the implementation of air quality control programmes in the city of Belgrade is provided from the city budget. In accordance with the legal provisions, the Secretariat conducts coordination of all activities of the established local city network of stations for measuring air quality. In order to do this work, the City of Belgrade must authorize the competent institution/authorized legal entity to make measurements, and in this case, it is the City Institute of Public Health Belgrade. The City Secretariat for Environmental Protection of the City of Belgrade is legally obliged to publish data on the results of air quality monitoring measurements publicly and submit it to the Serbian Environmental Protection Agency.

City Institute for Public Health

The City Institute for Public Health Belgrade has been conducting air quality control for more than 30 years on the territory of Belgrade, within the Local Network in cooperation with the Secretariat for Environmental Protection, the City of Belgrade and within the State Network in cooperation with the Ministry of Environmental Protection, Republic of Serbia in 30 measuring places where automatic measuring stations are deployed in 8 measuring stations. Information to the public from automatic monitoring stations is available on the link http://www.beoeko.com/.
In addition, in accordance with applicable legal regulations, detailed monthly reports with air quality data in Belgrade are formed and submitted to the Secretariat for Environmental Protection of the City of Belgrade (available on the link Secretariat for Environmental Protection).

RESULTS

Pursuant to the Law on Air Protection, the Environmental Protection Agency has the obligation to prepare and publish the Annual Report on the State of Air Quality in the Republic of Serbia every year. The annual report includes data submitted to the Agency by institutions that perform measurements and participate in air quality monitoring at the national and local levels.

National network of automatic stations for air quality monitoring provides the public presentation of the results of automatic air quality monitoring, in real time, from national network and local networks in Vojvodina, Pancevo and Belgrade, available on the link www.amskv.sepa.gov.rs.
Air quality monitoring in Belgrade is performed within the local network, which is managed by the City Institute for Public Health at 3518 measuring points on the basis of a contract with the Secretariat for Environmental Protection. Data on the state of air quality in Belgrade through the application available on the City's website http://www.beoeko.com. The Air Quality Index is calculated on the basis of the criteria included in the "Common Air Quality Index", which was developed within the project of the European Union and is used in more than 80 EU cities. This application also gives a recommendation of doctors and experts from the City Institute of Public Health Belgrade on behaviour in cases of increasing air pollution.

Table 2. Local Network of Measuring Stations for Air Quality Monitoring on the city of Belgrade

Place – municipality name	Address	Coordinates	Area type	Parameter	Data middle
Savski venac	Miloša Pocerca 6	44°48´14.9´´ 20°27´15.0´´	Urban	Soot, SO_2, NO_2	24 hours
Novi Beograd	Goce Delčeva 30	44°46´57.8´´ 20°24´40.1´´	Urban	Soot, SO_2, NO_2	24 hours
Vračar	Bojanska 16	44°47´50.6´´ 20°23´02.5´´	Urban	Soot, SO_2, NO_2	24 hours
Rakovica	Dr Milivoja Petrovića 6	44°44´47.55´´ 20°26´21.56´´	Urban	Soot, SO_2, NO_2	24 hours
Zemun	Trg JNA 7	44°50´23.6´´ 20°24´46.8´´	Urban	Soot, SO_2, NO_2	24 hours
Palilula – Krnjača	Blok G. Andrijanovića 8	44°50´41.2´´ 20°29´31.4´´	Urban	Soot, SO_2, NO_2	24 hours
Čukarica	Požeška 72	44°46´45.6´´ 20°24´55.4´´	Urban	Soot, NO_2	24 hours
Savski venac	Heroja M. Tepića 1	44°46´41.43´´ 20°27´27.36´´	Urban	Soot, NO_2	24 hours
Zvezdara	Olge Jovanović 11	44°47´31.9´´ 20°30´15.4´´	Urban	Soot, SO_2	24 hours
Stari grad	Obilićev venac 2	44°48´59.44´´ 20°27´20.46´´	Urban	Soot, SO_2, NO_2	24 hours
Savski venac	Železnička 4	44°48´34.3´´ 20°27´15.1´´	Urban	SO_2, NO_2	24 hours
Palilula – Krnjača	Pančevački put 39	44°50´28.80´´ 20°29´55.46´´	Suburban	Soot, SO_2	24 hours
Savski venac	Bulevar Oslobođenja 18	44°47´38.72´´ 20°27´55.22´´	Urban	Soot, SO_2, NO_2	24 hours
Lazarevac	Slobodana Kozareva 1	44°38´42.15´´ 20°26´52.48´´	Suburban	SO_2 – NO/NO_2 – O_x/O_3 – PM_{10}	1 hour, 24 hours
Zemun	Jerneja Kopitara bb	44°50´07.2´´ 20°24´12.7´´	Urban	SO_2 – NO/NO_2/N_x – PM_{10}	1 hour, 24 hours
Ovča	Prvog maja 2a	44°53´90.74´´ 20°53´12.54´´	Urban	SO_2 – NO/NO_2/N_x – CO - O_3 – BTEX - $PM_{10/2,5}$	1 hour, 24 hours
Veliki Crljeni	7.jula 19	44°53´90.74´´ 20°53´12.54´´	Rural	SO_2 – NO/NO_2/N_x – CO – BTEX - $PM_{10/2,5}$	1 hour, 24 hours

Local authority – City of Belgrade Secretariat for Environmental protection and City Institute for Public Health on the web page of the Secretariat presents the monthly data on environmental parameters – for Air Quality.
Annual Reports on Quality of the Environment in Belgrade is available on the Secretariat's web page for the period 2012-2018. Annual Reports on Quality of the Environment in Belgrade are available on the web page of City's Institute for Public Health for the period 2007-2021.
Statistical Yearbooks contain the Chapter on topography, climate and environment in which the annual data on air pollution are presented. All yearbooks are available on the web site of this organization.

Trenutni podaci

Kvalitet vazduha ocenjen je 19.09.2022. 06:00 - 06:59

Kvalitet	Stanica	Mreža	PM10	SO2	PM2.5	CO	NO2	O3	UVI
ODLIČAN	Beograd Ovča	IPH-BGD	6.85	14.4	5.64	0.7	4.65	8.38	
ODLIČAN	Beograd Zemun TB	IPH-BGD	11.7	5.47	8.88		13.7		
ODLIČAN	Beograd Despota Stefana	IPH-BGD	11.4	3.73	8.53	0.44	29.3		
ODLIČAN	Beograd Oml. brigada	IPH-BGD	11.8	8.47	8.83		24.4		
ODLIČAN	Beograd Obrenovac Ušće	IPH-BGD	10.1	9.62	8.66		8		
ODLIČAN	Beograd Lazarevac	IPH-BGD	3.93	5.53	2.3		0.05	24.8	
ODLIČAN	Beograd Vinča	IPH-BGD	10.7	4.19	8.97	0.18	6.97	25.2	0
ODLIČAN	Beograd Dragiša Mišović	IPH-BGD	5.17		4.51		17.4	21.1	
	Beograd ADA	IPH-BGD							0
ODLIČAN	Veliki Crljeni	IPH-BGD	4.73	36.5	3.66	0.09	2.57		
ODLIČAN	Beograd Topčiderska Zvezda	IPH-BGD	11.5		8.81		24.5	5.57	
ODLIČAN	Beograd Vračar Dom zdravlja	IPH-BGD	11.4		8.18		25		
ODLIČAN	Beograd Bežanijska kosa	IPH-BGD	11.1		8.63		19.8		
ODLIČAN	Beograd Banovo brdo	IPH-BGD	9.08		7.07		26.5		
ODLIČAN	Beograd Ada petlja	IPH-BGD	14.9		10.5		31.2		
ODLIČAN	**Srednja vrednost**		**9.6**	**11**	**7.37**	**0.35**	**16.7**	**17**	

Figure 2. An example of a daily review of air pollution by measuring station, with air quality assessment published by City Institute for Public Health

CONCLUSION

Exposure to air pollution has unfortunately numerous harmful consequences for human health but also quality and length of life. Pollution levels in most cities in Serbia and especially Belgrade, according to official measurements, exceed the level of WHO recommendations. In particular, vulnerable groups of people such as children, senior citizens and people whose health has already been affected are exposed. Such research was conducted and presented through numerous reports by the UNDP in Serbia, UNICEF in Serbia and other organizations.
The Government of the Republic of Serbia formed the Working group for systemic solution of air protection issues on January 17, 2020, with Prime Minister as the president of this body. The main task of the WG is to monitor, analyze and consider the most important issues in the field of air protection from pollution in Serbia, with special reference to systemic problems.
The working group will coordinate the work of all state and other competent bodies and institutions and will propose and analyze the effects of measures implemented by the competent bodies in order to protect and improve air quality. The group consists of the relevant Ministry of Environment, Ministry of Energy, and Ministry of Health, Belgrade city Mayor, Police Director, Institute of Public Health of Serbia "Dr Milan Jovanović Batut", Environmental Protection Agency and representatives of other relevant institutions.
A complex and unified system of measuring and monitoring air pollution, as well as public pressure, led to the formation of a Working group and the publication of publishing real-time air pollution results.
A uniform and improved monitoring system can also lead to better control of air pollution and its reduction in the future.

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AIR QUALITY ASSESSMENT OF TYPICAL LARGE COAL FIRED ROMANIAN STEAM BOILERS WITH POSSIBLE BIOMASS CO-FIRING SOLUTION FOR ENVIRONMENTAL IMPACT REDUCTION

Francisc Popescu[1], Bogdana Vujić[2], Una Marčeta[2]
[1]University Politehnica Timisoara, Timisoara, Romania
[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: francisc.popescu@upt.ro

Abstract: The paper presents several case study scenarios applied for typical 420 t/h coal fired steam boilers. In attention is the possibility to apply coal and biomass co-firing technology on these boilers, with emphasis on stack emission environmental impact on local and regional level. Several tools are used, the US National Oceanic and Atmospheric Administration – Hysplit trajectory model and Cambridge Environmental Research Consultants – ADMS5 advanced new generation Gaussian plume air dispersion model characterized by the boundary layer depth and the Monin-Obukhov length. The study also will focus on local and national availability of biomass resources, in a sustainable approach. Primary pollutants are taken into account (SO_2, NOx, CO, CO_2, particles) however, the focus is on possibilities to directly reduce SO_2 emission and to mitigate CO_2 emissions thru direct biomass (waste) co-firing at high rates. In developed countries co-firing biomass in coal power plants is widely implemented as is the simplest way to reduce CO_2 emissions. Recent focus on high biomass co-firing ratios brings (or total conversion to biomass) in attention operational issues in technical operation of existing coal fired boilers, especially due to ash biomass content and ash deposition on heat exchangers surfaces.
The pollutants concentration dispersion charts will be resulted from scenarios with different coal/biomass co-firing rates, from 30 to 80 %.
Key words: ADMS5, HYSPLIT, air quality, CO_2 mitigation, environment, biomass, coal

INTRODUCTION

In case of coal combustion in combined heat and power (CHP) power plants the most relevant pollutants are CO_2 and SO_2. If SO_2 and other relevant criteria pollutants emissions such as NOx and particles are relatively easy to reduce the CO_2 emissions are not possible to reduce directly. If in some cases CO_2 separation, capture and storage are possible in Romanian energy sector this is not an option. However, in Romanian case the most relevant renewable resource is represented by biomass, with an estimated potential of around 88 TWh, making the coal biomass co-combustion a solution to reduce both CO_2 and SO_2 emissions, directly. However, for utility scale power plants with high fuel consumption, even if biomass co-firing scenarios are appealing the difficulty resides mainly in acquiring steady year-round biomass resources. As all Romanian boilers used in power generation are fluidized bed boilers with injection of pulverized coal with a granulation in millimeter range, the biomass should either be supplied directly at required granulation (such as mill saw waste) either in a form that can be introduced directly with the coal in the crusher. However, if the least expensive method for biomass co-firing is to blend biomass with coal fuel mix enters the existing pulverizer's only about 3% of the boiler heat input can be obtained. [1] To reach higher biomass co-combustion rates separate processing, handling and storage systems must be deployed for biomass injection thru dedicated ports.
Biomass co-firing is considered an option, even if transitory, to a carbon free power sector in most European countries, including Romania. Romania has mandatory regulation to increase renewable share and important policies for renewable energy production but almost entirely focused on promotion of wind and sun applications. However, even if the biggest onshore wind farm in Europe is in Romania at Cogealac with 600 MW installed, the national required energy is much higher and the reduction of coal based power plants for next decades is not possible.
Extensive studies exist on co-firing of biomass with coal, proving that co-firing ratios up to 20% have no adverse effect on boiler efficiency, on fluidized bed combustion technology and co-firing rations of up to 30% will reduce boiler energy efficiency with less than 1%. [2]

Policies should seek the most efficient use of the given biomass potential by encouraging co-firing in CHP plants where district heating systems are available and in connection with industrial facilities. The benefits from burning waste, which would otherwise constitute a disposal challenge, should also be considered. [3]
Several CO_2 mitigation options exists, more relevant being reduction of energy intensity, reduction of carbon intensity and carbon sequestration. [4] In Romanian case CO_2 mitigation thru reduction of energy intensity is not an option due to its developing country characteristics, industrial development and mostly the population goal to achieve a better quality of life, similar with those in developed countries. Carbon sequestration impose significant challenges and only reduction of carbon intensity in Romanian energy sector is a valid, short term achievable CO_2 mitigation option. Reduction of carbon intensity in Romanian energy sector is the most important option especially as about 30% of energy produced is based on coal power plants. This gives a significant opportunity for biomass co-firing option in existing (or new) power plants especially as Romania has significant biomass resource potential for sustainable exploitation.

METHODS AND RESULTS

The case study scenario was performed on a typical medium size Romanian cogeneration CHP (combined heat and power) power plant. The Halanga power plant, in Mehedint County, was selected because the authors have performed monthly direct flue gas measurements, starting from 2003 - 2014 with availability and certainty of measured concentrations for criteria pollutants of the study, SO_2 and CO_2. If the largest coal powered Romanian power plant typically use 1035 t/h steam boilers Benson type, such as Turceni power plant with an installed power of 2310 MW or Rovinari power plant with an installed capacity of 1320 MW, the medium size CHP power plant have CR1244 type boilers, with a maximum capacity of 420 t/h of superheated steam delivered at maximum 140 bar. The Halanga power plant has no NOx and SO_2 emission reduction installations.
The Halanga power plant has 6 identical boilers, all CR1244 type. The boilers exhaust gases are ejected thru two stacks, one of 243 meters and second of 280 meters in height. Each stack serves 3 boilers. The CHP plant has 6 electric generators, 4 of 50 MW, one of 25 MW and sixth of 21 MW, with 4 cooling towers.
The case scenario for simulations is based on the following main input data:

- four boilers are running at nominal rate, two at each stack;
- the meteorological data (wind speed and direction, temperature, humidity, global irradiation and atmospheric pressure) measured hourly;
- average mass concentration for CO_2 and SO_2 were calculated from direct measurements for 2003 – 2014 period for all 4 boilers considered, resulting: C_{SO2} = 3922.63 mg/m^3_N and C_{CO2} = 266.31 g/m^3_N;
- average fuel (lignite coal) per boiler: B = 118 t/h;
- average total dry exhaust gases mass volume: (Vgt) λ = 3.45 m^3_N/kg calculated at average air-fuel ration λ = 11.67 [-]
- average exhaust flue gas temperature: t = 144.3 °C (calculated from direct measurements);
- average flue gas speed at exhaust: w = 14.7 m/s (calculated from direct measurements);
- calculated (average) emission factor E_{SO2} = 458.3 g/s for one boiler and E_{CO2} = 110 t/h;
- for the scenarios with 50% and 80% biomass replacement of lignite coal the emission factors were reduced accordingly.

The air dispersion modelling software used was ADMS5, developed by Cambridge Environmental Research Consultants. ADMS 5 is an advanced dispersion model based on a new generation Gaussian plume air dispersion model, with atmospheric boundary layer properties are characterized by the boundary layer depth and the Monin-Obukhov length rather than in terms of the single parameter Pasquill-Gifford class. [5]
The NOOA Air Resources Laboratory's Hybrid Single-Particle Langragian Integrated Trajectory (HYSPLIT) model is a complete system for computing both simple air parcel trajectories and complex dispersion and deposition simulations. The model calculation method is a hybrid between Langragian approaches and the Eulerian approach [6]. HYSPLIT web interface was used, starting from emission

data and stack characterization to compute the advection of a single particle, emitted from Halanga power plant in two scenarios, one for a winter month (December) and one for a summer month (May).

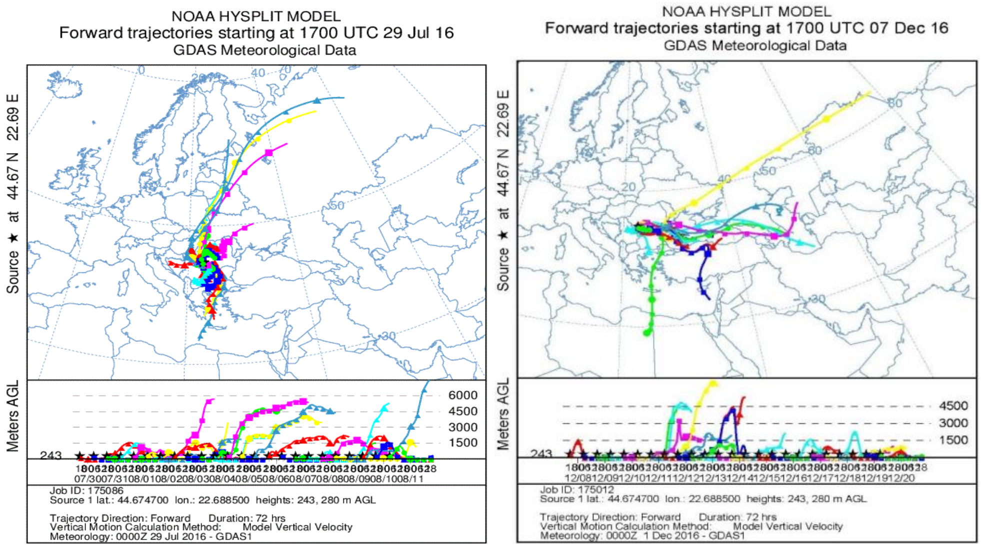

Fig. 1. Single particle trajectory. Halanga CHP power plant, summer (left) and winter (right)

The single particle trajectory study was done mostly to observe the area and the time frame spent by emitted particle into atmosphere. As noted in previous studies the air masses move north in summer months and east in winter months, covering large distances.

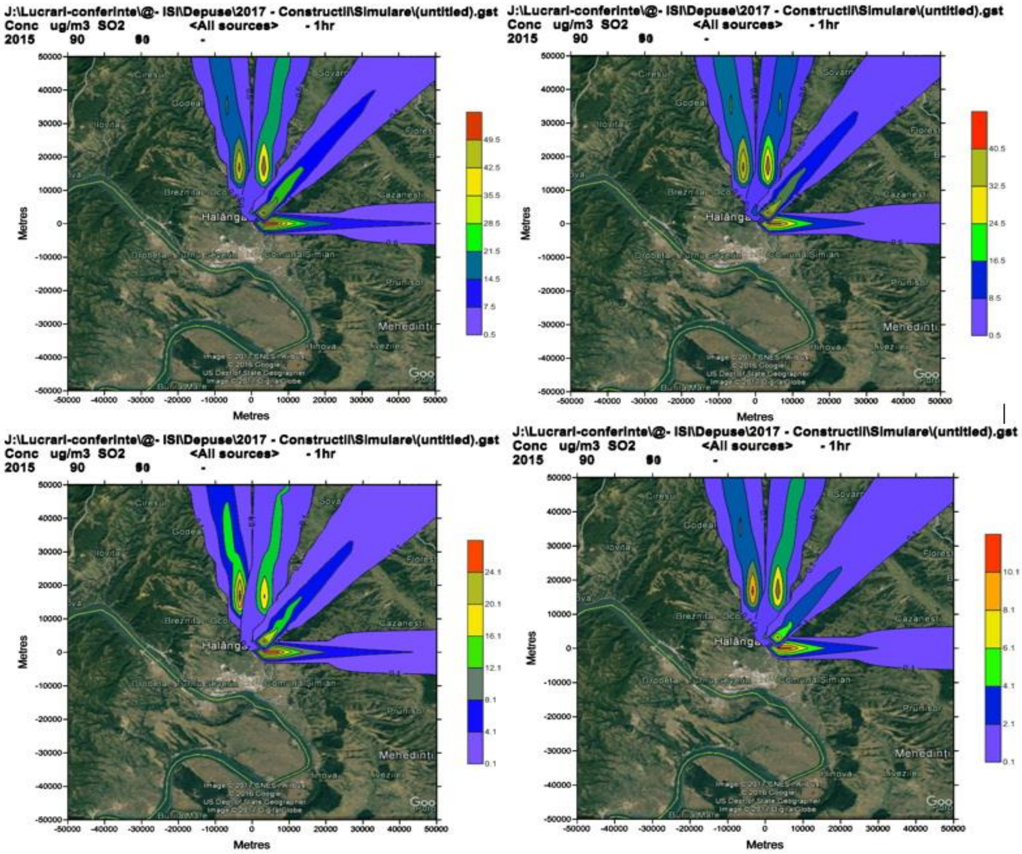

Fig. 2. SO_2 dispersion and concentrations at 100% coal combustion (top left), 20%, 50% and 80% (right down) biomass co-combustion

From figure 2 one can observe that, as expected, use of biomass co-combustion in lignite coal based large boilers can significantly reduce SO_2 emissions and consequently the impact on regional air quality. If in the case of coal combustion SO_2 in ambient air can reach up to 40 µg/m^3_N in case of biomass co-combustion the environmental impact is not only reduced at high concentration but significantly on the area affected.
In case of SO_2 another issue is the reduction of emission values, limited by national and EU regulation, in general at 400 mg/m_{3N}. Romania has significant coal reserves but most of it is lignite with a Sulphur content varying from 1 to 2%, leading in combustion to concentrations from 3000 up to 6000 mg/m^3_N. If in case of some Romanian large coal power plants SO_2 reduction technologies have been applied, in the case of midsize cogeneration power plants, most of them mainly used as supply of heat and hot water to major cities, SO_2 reduction is not applied mainly due to high costs.

CONCLUSION

A way to reduce the emission of carbon dioxide and other harmful substances is the implementation of biomass co-firing processes with coals, in existing power plants.
Even if the SO_2 reduction technologies will be applied the use of co-combustion with biomass is still an option in order to reduce limestone usage and plant operational costs, due to reduction of acid gas abatement. [7]
Another significant advantage of biomass co-combustion, not sufficiently discussed or acknowledged in Romania, is the potential to significantly reduce mercury emissions. Even if mercury content of coal is at trace levels, due to high fuel consumption (in this case 118 t/h for one boiler) the mercury emissions are significant, according to relevant studies [8] about 40% of global mercury emission are caused by coal fired power plants. So, use of biomass co-combustion will also lead to mercury emission reduction. If one take into account that only about 1.2% of mercury contained in coal will remain in bottom ash [9], and more than 98% will be emitted with flue stack gases than biomass option becomes relevant. Especially if figure 2 is analyzed one can note that emitted pollutants disperse and affects large areas.
However, other factors must be considered for biomass co-combustion conversion of power plant, main ones been the investment costs of biomass co-combustion versus cost of SO_2 reduction installations, the reliability and security of the biomass supply chain, advantages given by the implication of local and regional economy, i.e. The availability of biomass is the main factor and in Romanian case one may note, that in Romania biomass is main renewable source at about 88.33 TWh potential. From this potential about 36% is used in household heating [10] as firewood.
Another relevant aspect is the possibility to reduce by mitigation CO_2 emissions. In the case of CR1244 boiler the CO_2 emissions at nominal rate is about 110 t/h, in case of 4 boiler operation at nominal rate, 440 tons of fossil CO_2 will be released into atmosphere every hour. Even if the biomass co-combustion is applied at 20% rate – that will require no modification to boiler – the yearly CO_2 reduction thru mitigation is significant.

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REMOVAL OF POLYETHYLENE AND POLYVINYL CHLORIDE FROM THE SURFACE WATER BY COAGULATION AND FLOCCULATION

Sanja Vasiljević[1], Radivoj Tomić[1], Maja Vujić[1], Jasmina Agbaba[1], Aleksandra Tubić[1]
[1]University of Novi Sad, Faculty of Sciences, Novi Sad, Serbia
e-mail: sanjav@uns.ac.rs

Abstract: The results of numerous studies have shown that the consequences of the presence of microplastics are particularly endangered aquatic ecosystems, and in recent years there have been current studies of the presence, sources and behavior of these pollutants in waters around the world. In wastewater treatment plants, over 30 different types of polymers were detected in the influent and effluent, with the most commonly detected types of microplastics in wastewater being polyethylene (PE), polypropylene (PP), polyamide (PA), polyvinyl chloride (PVC), polystyrene (PS), polyethylene terephthalate (PET), etc. Given that wastewater treatment plants are considered a place where microplastic particles are collected, one of the subjects of research in this area was to examine the efficiency of microplastic removal in wastewater treatments. Therefore, the aim of this study was to investigate the efficiency of removing PE and PVC from water by treatment of coagulation and flocculation, as one of the processes used in water treatment. The coagulation and flocculation process were performed using two coagulants, ferric chloride ($FeCl_3$) and polyaluminium chloride (PACl) in the surface water. The particle sizes of the microplastics were 0.5 mm and 0.171-0.279 mm for PE and PVC, respectively. Based on the obtained results, it can be observed that by using $FeCl_3$ as a coagulant, PE removal of 21-72% can be achieved, while for PVC the removal efficiency values ranged from 69-96%. Using PACl as a coagulant, the obtained values indicate that both materials were removed quite well, as indicated by the values of 26-85% for PE, and 63-97% for PVC. Based on research, results were established that the removal of microplastics by coagulation and flocculation is influenced by several different factors, such as the characteristics of microplastics themselves, as well as the dose of coagulant.
Key words: microplastics, removal, coagulation and flocculation, ferric chloride, polialuminum chloride

INTRODUCTION

Microplastics represent fibers, granules and small fragments of plastic, with different size ranges from <1mm to <5mm. Because of its size it is difficult to identify, so we often identify it using a microscope [1]. According to literature data, it is known that microplastics are found in toothpastes, cosmetic products, but also in the pharmaceutical industry. By using these products, for example facial scrubs, when washing it off, microplastic ends up in the drain, then in municipal waste water, and thus comes into direct contact with nature [2, 3 ,4]. The presence of microplastics in the environment is increasing year by year, and for this reason we can find it in the atmosphere, soil, ocean, fresh water, and even in the sediment of an Arctic freshwater lake. It can be carried by the winds and thus transport substances and microorganisms from one ecosystem to another [5, 6]. The most common types of microplastics found in the environment are polyethylene (PE), polypropylene (PP), polyamide (PA), polyethylene tetraphthalate (PET), polyvinyl chloride (PVC), polyurethane (PUR), polystyrene (PS) and other polymers.

The sources of microplastics in the environment can be different, and most common source is the use of cosmetic products and plastic waste that is thrown away after use (bottles, cups, various plastic packaging, bags). Using cosmetic products, small plastic particles are washed away and end up in municipal wastewater. In addition to cosmetic products, the plastic industry also represents a significant source, because during its production, plastic may be lost during the washing of the production plant.

Microplastics are present in all spheres of modern life, but their distribution depends on anthropogenic (human activity) and environmental factors (wind, current, tide...). Microplastics are also present in the terrestrial environment, especially in agricultural lands and industrial areas [7, 8].

Furthermore, the degree of pollution of water is reflected in the amount of harmful substances that they carry with them. In order to return polluted water to nature or return it to some process, it must be purified, which is done by mechanical, chemical and biological methods [9].
Various methods have been used in water treatment, but their application is limited due to the use of chemicals, generation of disinfection by-products, time spent and economic aspects [10].
Coagulation and flocculation are treatments applied for water treatment, based on the principle of removing suspended and colloidally dispersed substances, natural organic substances and inorganic substances from water [11, 12].
Coagulation is applied to overcome the factor that ensures the stability of substances in water. By destabilizing, we affect the surface of the particle and thus ensure the conditions for small particles to merge into larger ones. Through coagulation and flocculation, particles lose their stability, group together and create larger aggregates. When the aggregates grow large enough, they settle under the force of Earth's gravity and begin to separate from the water phase [11, 13].
In order to remove very small particles and their negative charge, we apply the process of coagulation and flocculation. It is based on the addition of a certain concentration of coagulant, which destabilizes, aggregates and binds particles. Various coagulants are used for wastewater treatment, which can be divided into non-branched coagulants (ferrous sulfate, ferrous chlorosulfate, aluminum, ferric chloride, calcium hydroxide and iron), organic polymeric coagulants (polyethyleneimine and polyacrylamide derivatives) and natural coagulants (tannin and starch) [14].
During the removal of microplastics by the process of coagulation and flocculation, it was established that the efficiency of removing microplastics from water is affected by the size of the particles. At the same time, particles <0.5 mm were effectively removed using high doses of coagulant, while when using realistic doses of coagulant, the removal efficiency decreased to 8% [15, 16].
Therefore, the aim of this paper was to investigate the efficiency of removing microplastics (polyethylene and polyvinyl chloride) from surface water using coagulation and flocculation treatment, as one of the techniques for removing microplastics in water treatment plants.

MATERIAL AND METHODS

The aim of this work was to determine the efficiency of polyethylene (PE) and polyvinyl chloride (PVC) removal from a real matrix, i.e., surface water. The particle size for PE was 0.5 mm, while the size for PVC was 0.171-0.279 mm. Two series of experiments were conducted for both types of microplastics. The first series included the use of $FeCl_3$ as a coagulant and UNIFLOC M27 as a flocculant, while the second series included the use of polyaluminum chloride (PaCl) as a coagulant. The mass of microplastic used was 50 mg in 500 ml of real water matrix.

Chemical and reagens

In this experiment 2 types of powdered microplastics were used: PE (Alfa Aesar) and PVC (Aldrich Chemistry). In addition, solid $FeCl_3$ manufactured by Superlab was used in the work, and the solution was made by adding 5 g of solid substance to 50 ml of distilled water. The PaCl solution was prepared by adding 7.7 ml of the solution to 100 ml of distilled water. The flocculant stock solution (UNIFLOC M27, Unichem KFT) was prepared by dissolving 2.5 g of the substance in 100 ml of distilled water and put to the Jar test for 120 minutes at 10 rpm. A work solution was prepared from the basic flocculant solution (c=0.05 ml/ml) by dissolving 2.5 ml of the stock solution in 50 ml of distilled water, so its concentration in the experiment was 0.025 ml/ml.

Coagulation and flocculation experiment

Coagulation as a method of removing microplastics from water was done using the Jar test aparatus (FC6S VELP *scientific*), which consists of paddles that can move at a speed of 10-300 rpm. Two types of coagulants, $FeCl_3$ and PaCl, were used, in the doses shown in table 1.

Table 1. Doses of coagulants used in the experiment

Dose of $FeCl_3$ (mg $FeCl_3$/l)	Dose of PaCl for PE (mg Al/l)	Dose of PaCl for PVC (mg Al/l)
20	25	10
40	50	20
60	75	30
100	100	40
140	125	50
180	150	
220		

In 500 ml of the real matrix, 50 mg of microplastic was added and left to stay for 24h before coagulation. Coagulation is performed by addition of a certain dose of coagulant with mixing at 120 rpm for a period of 2 minutes, followed by flocculant for 30 minutes at 45 rpm. After 30 minutes, the glasses were removed from the Jar test and sedimentation was carried out for 30 minutes. The solution was filtered on a vacuum filtration, through a cellulose-membrane filters with a pore size of 0.45 μm.
After filtering, the filter papers were dried in Petri dishes for 24h, at room temperature, and then their individual masses were measured, on the basis of which the efficiency of microplastic removal from water was later determined.

RESULTS AND DISCUSSION

In this paper, the possibility of applying coagulation and flocculation to the removal of PE and PVC from surface water was investigated, using two coagulants ($FeCl_3$ and PaCl). Based on the measured mass of the filter after filtration, the efficiency of microplastic removal from water was determined, expressed in percentage.
Figure 1 graphically shows the efficiency of removing PE from the water using $FeCl_3$ as coagulant.

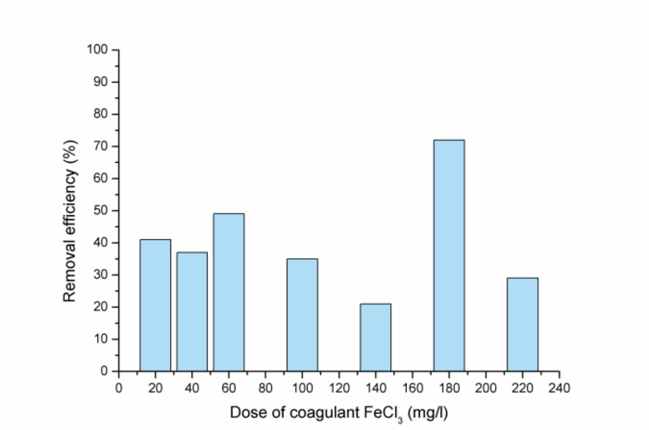

Fig. 1. PE removal efficiency depending on the dose of coagulant $FeCl_3$

Based on the results shown in the graph, it can be seen by application of coagulation and flocculation with $FeCl_3$ the removal of PE by 21-72% can be achieved compared to the initial value. The highest efficiency is achieved when the $FeCl_3$ concentration is 180 mg/l, while the lowest removal efficiency was at the $FeCl_3$ concentration of 140 mg/l.
Figure 2 shows a graphic view of the efficiency of PVC removal from the water of the Danube River using $FeCl_3$ as a coagulant. Based on the obtained results, it can be seen that the highest values of PVC removal efficiency was established at $FeCl_3$ concentrations of 20 and 60 mg/l, where the removal

efficiency was 96% for both doses. The lowest removal efficiency was achieved at the $FeCl_3$ concentration of 140 mg/l, with a removal efficiency of 69%.

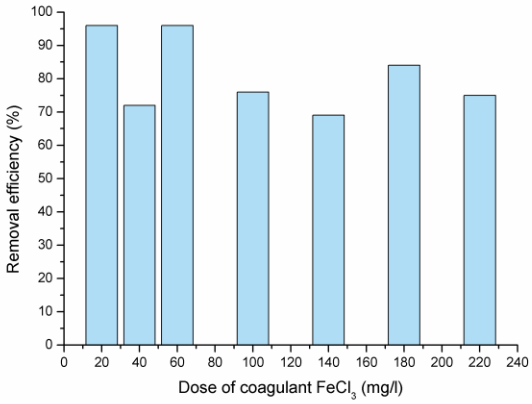

Fig. 2. PVC removal efficiency depending on the dose of coagulant $FeCl_3$

According to the results obtained using $FeCl_3$ as a coagulant, we can conclude that $FeCl_3$ behaves as a fairly effective coagulant in removing PE and PVC from the water by coagulation and flocculation treatment. A higher percentage of removal efficiency was achieved with PVC, where removal efficiency ranged from 69 to 96%, while PE removal efficiency values were significantly lower (21-72%). The big differences in the removal efficiency of these two types of microplastics are significantly influenced by their properties, as well as the dose of coagulant used in the treatment.
Based on the calculations, on Figure 3 was presented PE removal efficiency values with PaCl achieved by this treatment.

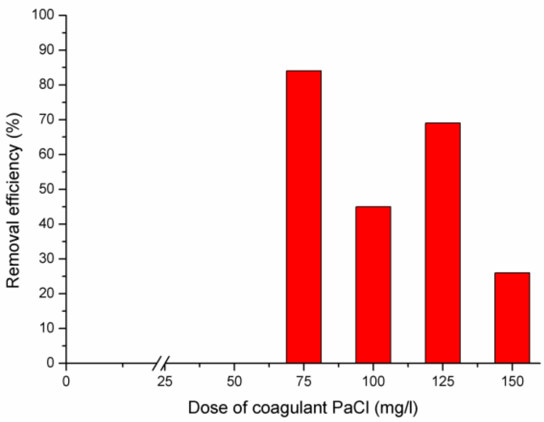

Fig. 3. PE removal efficiency depending on the dose of coagulant PaCl

The obtained values indicate that the highest removal efficiency of PE with PaCl was achieved at a PaCl concentration of 75 mg/l, while the lowest removal efficiency was at a PaCl concentration of 150 mg/l, as indicated by the values of 85% and 26%, respectively. In this case, doses of 25 mg/l and 50 mg/l were also tested, but they did not prove to be adequate doses for removing PE from the water of the Danube River. The reason for this may be the low concentration of coagulant, considering that with an increase in the concentration of coagulant, a significant efficiency of PE removal was obtained, but it may also be influenced by the matrix itself. Considering that, for the removal of PVC, it was necessary to change the doses of the coagulant PaCl, in order to remove microplastics from the water as efficiently as possible.

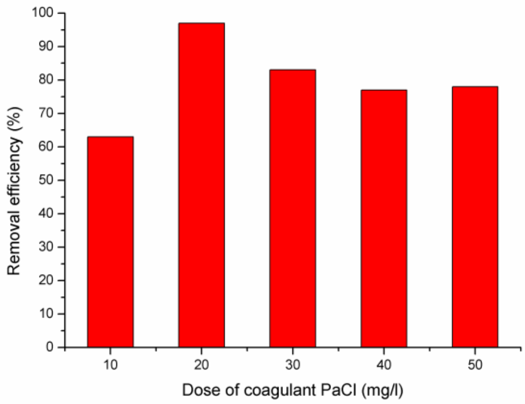

Fig. 4. PVC removal efficiency depending on the dose of coagulant PaCl

Based on the obtained results and the graphic view (Figure 4) using PaCl as a coagulant, we achieved a higher percentage of removal efficiency with PVC, where the removal efficiency ranged from 63 to 97%. This can be explained by its different characteristics compared to PE, but also by the different doses of coagulant that were used, in order to remove microplastics from the water as well as possible. By comparing these two coagulants, based on the obtained results, we conclude that both coagulants proved to be effective in removing both types of microplastics from the Danube River. PaCl could be characterized as more efficient compared to $FeCl_3$ as indicated by the values of 85% for PE and 97% for PVC, while for $FeCl_3$ the removal efficiency values were 72% for PE and 96% for PVC. The concentration of PaCl required for the removal of PVC was much lower (10-50 mg/l), while the removal of PE required a higher concentration of coagulant (75-150 mg/l).

CONCLUSION

In this paper, the efficiency of removing microplastics from the water of the Danube River, through the treatment of coagulation and flocculation, was examined. Polyethylene and polyvinyl chloride were used as representatives of microplastics, and $FeCl_3$ and PaCl were used as coagulants. According to the obtained research results, we can conclude that both coagulants proved to be effective in removing PE and PVC from the surface water. However, PaCl proved to be slightly better than $FeCl_3$, because at its optimal concentration it achieved a PVC removal of as much as 95%, while the use of $FeCl_3$ removed 70%. By comparing the types of microplastic used in the test, a better percentage of removal was achieved for PVC than for PE, regardless of the coagulant used. Based on previous research, it was established that the removal of microplastics with this treatment is influenced by several different factors, such as the characteristics of microplastics themselves, as well as the dose of coagulant.

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INTEGRATED AIR QUALITY MONITORING IN ČAČAK CITY

Srećko Ćurčić[1]
[1]University of Kragujevac, Faculty of technical science in Čačak, Svetog Save 65, Serbia,
e-mail: srecko.curcic@ftn.kg.ac.rs

Abstract: All cities that are constantly expanding, have increasing demands for the quality of life of the inhabitants. The air quality is one of the most important parameters, and the city of Čačak had no integrated system for collecting and presenting data on the state of air pollution in the city. As a result of this paper, sensor nodes for measuring and collecting air quality data are installed in the city of Čačak. Sensor nodes collect data on the amount of harmful particles in the air brand 2,5 um (PM 2.5) and 10 um (PM 10). The data collected are sent to the server, and then displayed on the website https://cacak.vazduh.net/. In this way, the number of citizens of Čačak who have access to information on air quality is not limited.
Key words: air quality, PM 2.5 and PM 10, WEB APLICATION, city Čačak

INTRODUCTION

One of the main challenges faced by a modern society during the sudden development, which followed as a result of the fourth industrial revolution, are climate change. The World Health Organization (WHO) marked the air quality problem in urban areas, but also households as a problem of high priority. Data from 2016 show that as many as 91% of the population lives in environments where the quality of air is below the standard that prescribes the WHO and that the diseases caused by poor air quality have led to 4.2 million fatalities [1]. It is generally accepted that the degree of air pollution is presendent through the air quality index (AQI). There are different scales for the air quality assessment today. In Europe, the Common Air Quality Index was used by 2017, and 2017 was presented to the European Air Quality Index. Countries such as United States, India, Canada also adopted local air quality assessment scores. What is the same for all are agents detected in the air and on the basis of which results are scaled. Parameters are monitored: Particulate matter with dijametar smaller than 2.5 um (PM 2.5) and smaller than 10 um (PM10), sulfur dioxide, ozone, nitrogen dioxide [1,2].
In the city of Čačak, three sensor platforms were installed in the previous period. These nodes were not connected in the network and information on pollution concentration was not available to citizens. As part of the implementation of Serbian cross-border cooperation in 2021, through the Airpolisca project, these sensory nodes are connected to the appropriate database. Also, a domain for Web application and web application is set.
In order to expand air monitoring network, eight more sensory nodes were installed in the city Cacak.

MATERIAL AND METHODS

Project goals and activities

The main goal of the Air quality monitoring project is to collect information on air quality. Unified air quality monitoring devices are set to appropriate locations in the urban part of Čačak. The device consists of two hardware units: modules with sensors and control module. The control module performs the tasks of collecting and processing measurement data, WiFi communications and power supplies. The sensor module has been hammered as an energy efficient consumer with average consumption of 3W. The nominal supply voltage is 220Vac [3]. The communication of the sensor node with the routers is realized as WiFi, so that the sensor node, as well as the network of sensor nodes fit in the concept of internet things and smart city solutions.
As part of the sensor node, which is designed as upgraded with a sufficient input and output number, the connection input and pressure is on. Also, in the coming period if an interest in expanding the volume of detection of harmful gases in the air, the sensor node can be extended with sensors for

detecting and other harmful gases. In order to inform all interested entities, as well as all citizens of air quality information will be available on the website https://cacak.vazduh.net/. The web page also shows the active map of the city of Čačak, which will be marked by polygons related to the closer location of the sensor node. The polygon selection opens a form of widget with a pictorial view of air quality (emoticon, smiley) and the current results of particle concentration, with the date and time of measurement.

The level of perception covers a sensor network associated with the microcontroller. The sensor network consists of three sensors. The PMS7003 sensor measure PM2.5 and PM10 concentration in the air and communication with the sensor is provided via the UART interface.

The microcontroller used in the implementation of this project is ESP32, which comes with the XTENSA 32-bit LX6 microprocessor. It has 448 KB ROM memory, 520 KB Sram [4]. The peripheral is available 32 programmable GPIO PIN, two 8- important to converter, a 12-bit SAR analog-digital converter. Communication is possible over three peripherals for UART communication, two for I2C communication. The microcontroller has a WiFi standard standard 802.11 b / g / N where speed 802.11 N will reach 150 Mbps. Data via WiFi adapters come to server.

The PMS7003 sensor detects and measures particles concentration of a diameter of 0.3 μm in real time. The maximum concentration measured by the sensor exceeds 1000 $\mu g/m^3$, with a total response time of less than 10s. The operating temperature of the sensor is from -10 ° C of 60 ° C, and the power supply is 5V.

During the initial release of the sensor node, it is necessary to configure parameters to establish a WiFi connection, which includes the access point name to which the device connects and the password is connected. The microcontroller is used to validate the device when sending data to the server. Only those devices sending data to the server, and the token is in the database, can establish a connection to the server. When establishing an internet connection, the device sends the server information about your MAC. If there is no device with the Sent MAC address on the server, within the database, a new sensor with a unique address and readings are automatically created on the server. Also, the microcontroller establishes a connection with NTP server, and thus allows you to synchronize the time on the microcontroller. MQTT (MESSAGE QUEUING Telemetry Transport) Protocol is used to receive data from the server [5]. The microcontroller is "overpaying" on the "topic" that represents the MAC address of the microcontroller itself. In this way, server connection is realized towards the microcontroller and configuring individual parameters. This serves that the time interval of the data sending from the website and send commands for the current data reading, and to send a firmware file to update the microcontroller software. Compared to other protocols, MQTT protocol is characterized by less use of traffic when exchanges messages. For this reason, it is used to connect to devices where the price of network traffic is high, reducing system costs.

If the connection is achieved, the microcontroller checks inside the SPIFFS memory whether there are data not sent to the server, if the same exist, send them to the server. The microcontroller periodically performs the data from the sensor, and the read data attempts to the server. In case the data you have not successfully sent, they are saved with the readout time in the Spiffs memory, and, when establishing a WiFi connection, they send to the Internet. For sending data to the server, a HTTPS proclation is used with SSL safety layer. Authentication was created using the OAuth 2.0 Direct Authentication. With the token, the microcontroller can access the server resources to which it has access rights, ie the microcontroller can be sent to the server and be stored in the database.

Thanks to the YII2 work environment, it is possible to save and display the data that the sensor sends. The data is received from the sensor via the HTTPS Protocol method, using the RestFul Web Service Apis. The data received, then stored within the Matia DB relational database.

RESULTS AND DISCUSSION

WEB APPLICATION

The web application allows citizens of Cacak to follow air pollution. When it activates the link www/vazduh.net will appear on the display of the Figure 1.

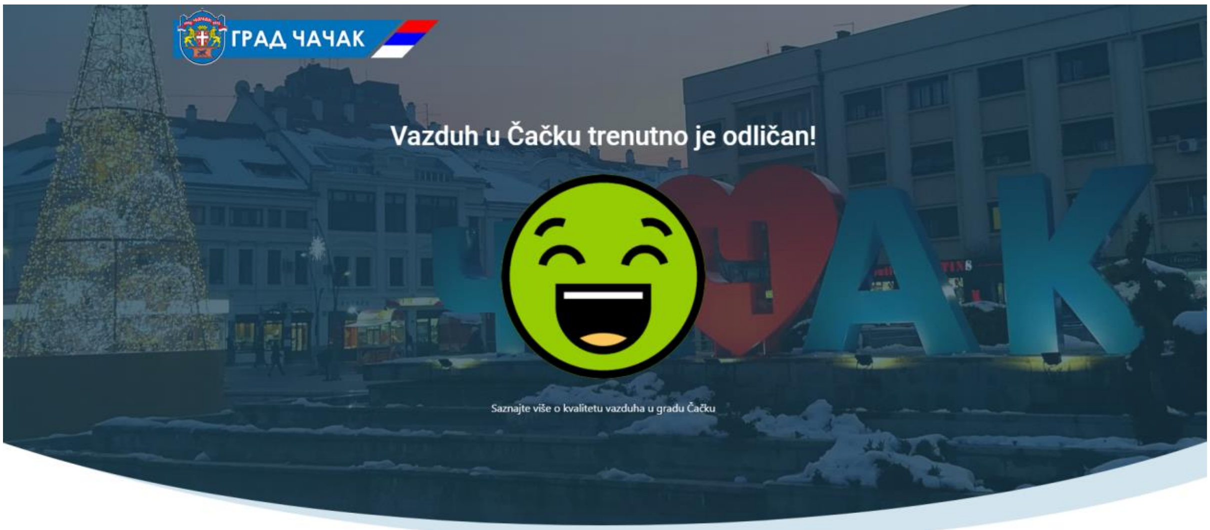

Fig. 1. Display of air quality in image form [6]

The presentation of air quality with with emoticons is selected to provide information to persons with weak and damaged vision, as well as all other users for simpler and faster information. With this This kinde of presentation will be available, the information will be available to any user who has Internet access. The air quality index represents the air quality assessment scale. European Environmental Agency (EEA) together with the European Commission Ecology Directorate (European Commission's Directorate General for Environment). In 2017, adopted European Air Quality Index.
The equation for calculating air quality index:

$$I_Z = \frac{I_{VN} - I_{NN}}{GZ_{VN} - GZ_{NN}} (C_Z - GZ_{NN}) + I_{NN} \quad (1)$$

Where is the contaminator index; *Ivn* and *Inn* are higher/lower values of the index threshold; *GZvn* and *GZnn* pollutants restrictions for this index (higher and lower value) and *Cz* concentration of pollutants.
The web page also displays air quality assessments together with population recommendations (Figure 2).
The Sensor Mapping is enabled using the Leaflet library. Leaflet is a leading open-source JavaScript library for mobile devices, weighs only about 32KB, and has all the functions to work with majority of developers, and if there are any additional things there are various accessories. Leaflet is designed for easy use, speed and quality. It works easily and efficiently on almost all desktops and mobile platforms, there is also the possibility of extensions with plenty of plugins. Moves data used are obtained by the OpenStreetMap platform.
The layout of the map with the sensor nodes is shown in Figure 3.

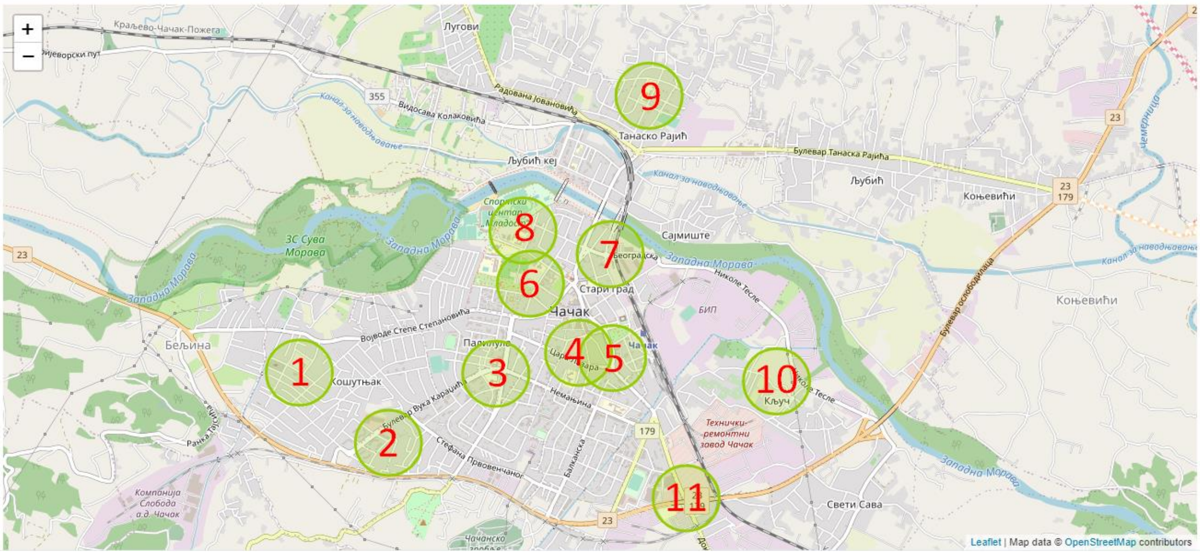

Fig. 3. Appearance of a map with sensor nodes [6]

Locations in the urban part of Čačak where eight sensor platforms are set to accurate locations and names are:
1. JKP Gradsko zelenilo - 43.886670, 20.368440 (Figure 3 number 10),
2. FTN Čačak - 43.896931, 20.344821 (Figure 3 number 8),
3. Obdanište Majski cvet - 43.888257, 20.353166 (Figure 3 number 5),
4. Zelena pijaca Čačak - 43.888615, 20.350000 (Figure 3number 4),
5. Obdanište Boško Buha - 43.887267, 20.323979 (Figure 3 number 1),
6. Osnovna škola Dr Dragisa Mišović - 43.887190, 20.342290 (Figure 3 number 3),
7. Osnovna škola Tanasko Rajić - 43.906096, 20.356562 (Figure 3 number 9),
8. Mašinsko – Saobraćajna škola - 43.878716, 20.360024 (Figure 3 number 11).

The map also includes sensor nodes covered by the Transboundary Cooperation Project of AIRPOLISCA, which were already set in the area of the city of Čačak before
1. Prehrambeno ugostiteljska škola - 43.88249, 20.3328 (Figure 3 number 3 number 2),
2. Medicina rada- 43.895325, 20.35295 (Figure 3 number 3 number 7),
3. Gradski Park - 43.893316, 20.345513 (Figure 3 number 3number 6).

Each sensor on the map is painted with appropriate color depending on current pollution at Čačak site. Clicking on a specific folder sensor, a new window opens to which air quality, the exact amount of particles and the last measurement is displayed (PM2.5 and PM10 concentrations and measurement time) (Figure 4).

Clicking on the sensor name opens a new window, which shows the air quality chart in the time range to the last measurement (Figure 5).

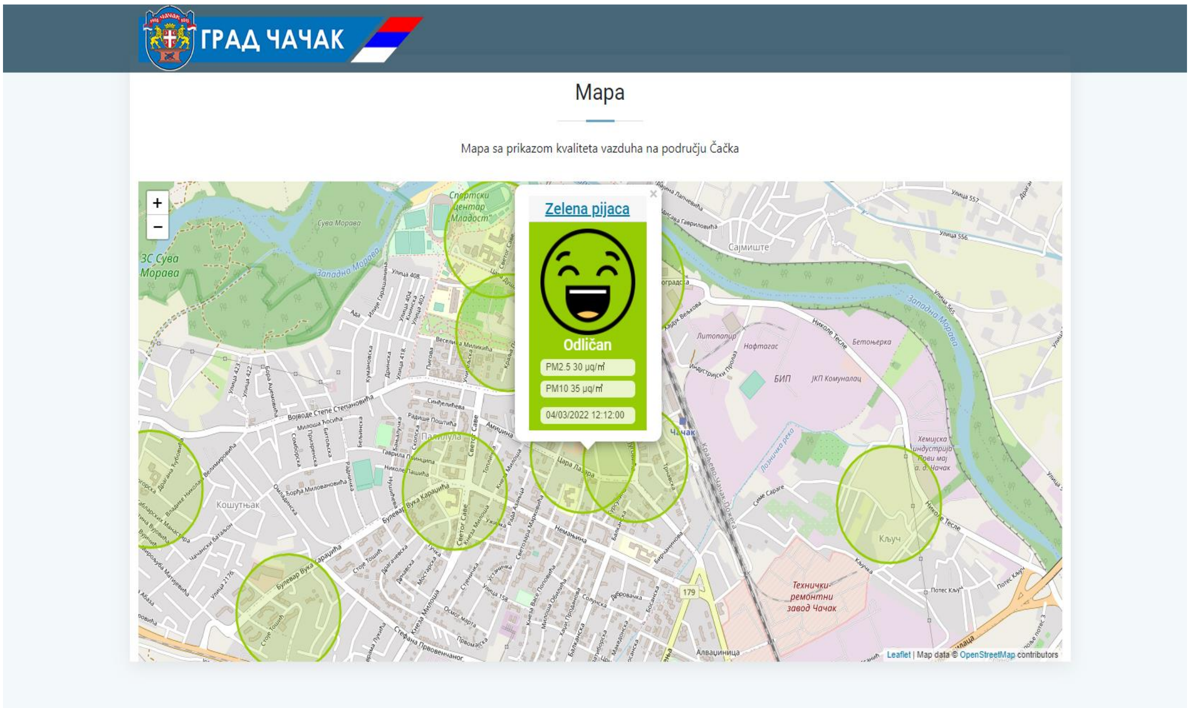

Fig. 4. City map Čačak with installed sensory nodes for air quality [6]

At the bottom of the home page there is a graph quality of air from all sensor nodes and additional information on PM 2.5 and PM 10 particles (Figure 6).

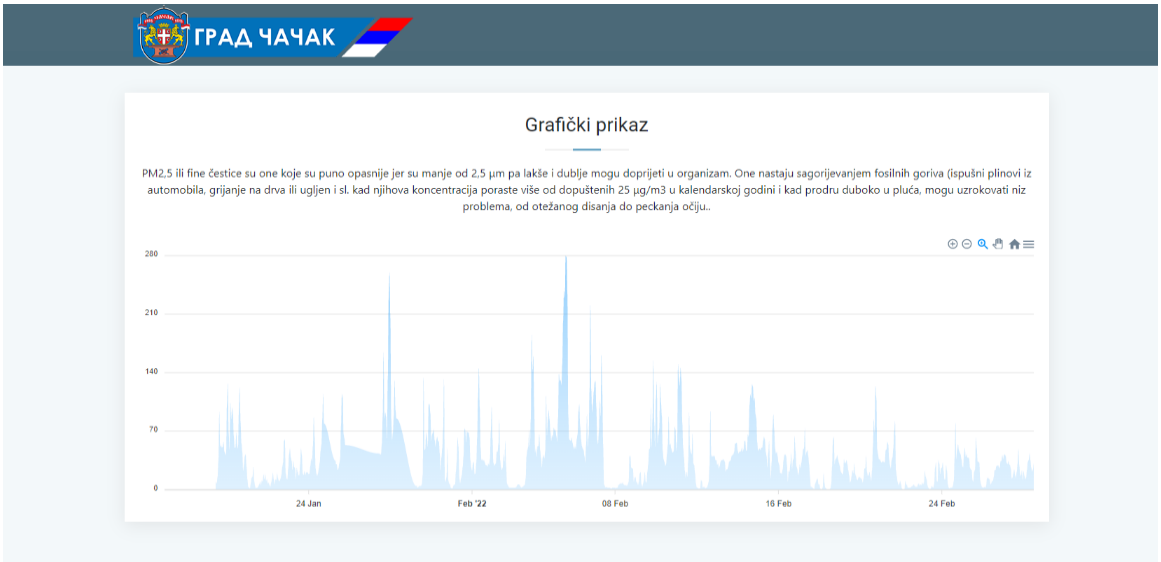

Fig. 5. Graphic view of air quality in Čačak [6]

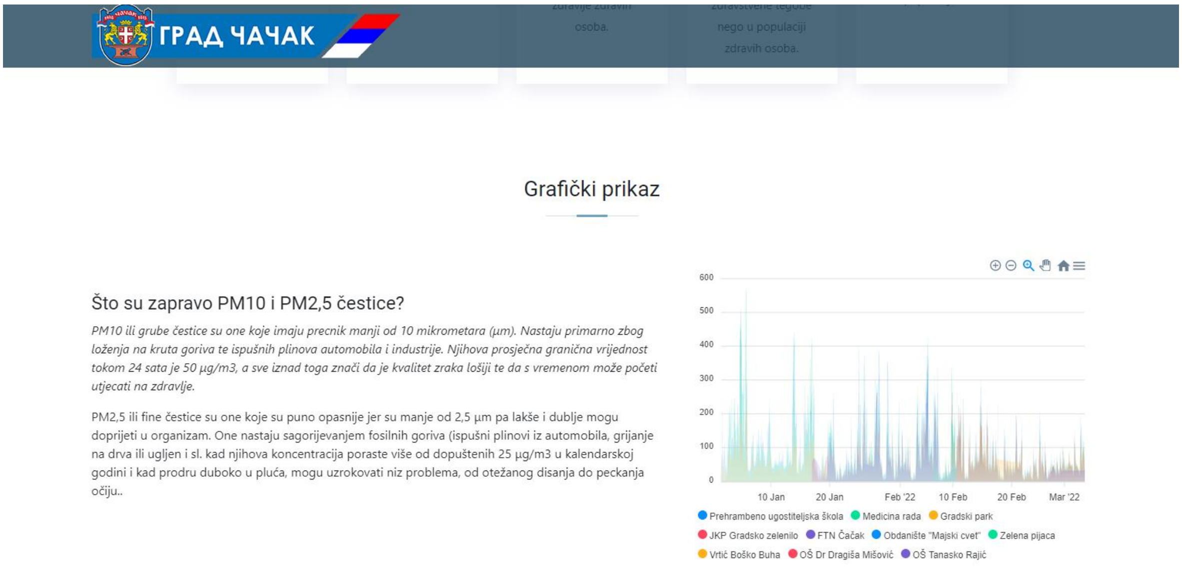

Fig. 6. Graphical view of air quality in time intervals [6]

CONCLUSION

In the city of Čačak, sensor nodes are installed for measuring air quality. Air quality is one of the most important questions for the quality of life, and the city of Čačak has an integrated system for collecting and presenting data on the state of air pollution in the city. Sensor nodes at eleven locations collect data on the amount of harmful particles in air PM 2.5 and PM 10. The data collected are sent to the server and then displayed at https: /www.vazduh.net Čačak.

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ENVIRONMENTAL IMPACTS OF RECYCLED PLASTIC FROM FISHING NETS AND LIMITATIONS OF THE LCA APPROACH

Jure Gramc[1], Leja Goljat[2], Mitja Mori[1]
[1]University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia
[2]Research and Innovation Department, Plastika Skaza d.o.o., Velenje
e-mail: mitja.mori@fs.uni-lj.si

Abstract: This work assesses two environmental impacts of generic plastic product – carbon footprint and entanglement of marine animals. The reference product is made from recycled granulate from discarded fishing nets, which represents a danger to marine animals. The results of LCA indicate that the granulate from fishing nets has a higher carbon footprint, than the alternative. However, carbon footprint solely is not a sufficient criterion for evaluation of environmental impact. When discarded fishing nets are collected and recycled into granulate, we not only save marine animals' life but also reuse plastic waste. Therefore, this study suggests new methods for the evaluation of environmental impact, beyond the limitations of conventional LCA. In the paper, we also discuss the insufficiency of the LCA and the need for the development of a new end-of-life treatment method, since a significant share of waste leaks into the oceans. We need to properly assess the treatment of waste if we want to successfully follow the sustainable development guidelines for a better future.
Key words: carbon footprint, marine plastic debris, sustainable development, recycled plastic

INTRODUCTION

Science is the driving force behind progress. New technologies bring more comfort to people at the expanse of natural resources. Today's society practically depends on technology. Everything is powered by electricity, digital, and manufactured in big factories that consume enormous amounts of energy. The main source of the energy are fossil fuels which are also the main reason for climate change, which we are already experiencing. To mitigate climate change, we must limit the consumption of fossil fuels and other greenhouse gas (GHG) emission sources. This is incredibly hard if we want continuous progress, as energy consumption is rising and we do not have adequate alternatives for all power plants on fossil fuels. Furthermore, fossil fuels are also used to produce plastic, which is practically irreplaceable in our society. The production of plastic is not the only environmental problem of plastic. The end of life is arguably even more problematic and too often neglected.

The end-of-life phase for plastic products can be very different. Plastic products could be recycled, landfilled, or burned in incineration plants. Which technology is used for end-of-life depends on geographical location, type of plastic, and awareness of consumers. Unfortunately, many plastic products are not deposited in containers for subsequent removal to landfills, recycling centers, or incinerators, but are improperly disposed of in natural environments: soils, freshwater, and oceans. According to Borrelle et. al. [1], 11 % of plastic waste generated in the year 2016 ended in aquatic ecosystems. Despite that horribly high percentage, we do not have LCA models for waste that ends up directly in the natural environment. We neglect the waste and its direct and indirect adverse impacts on natural ecosystems.

Plastic pollution has become a global concern in the last decade, especially in terms of the harmful impacts it has on marine and coastal environments. Around 80% of anthropogenic debris found in the oceans are plastics, [2]. Despite over 35 years of international legislation and efforts to reduce marine debris, the rate of accumulation of marine debris continues to increase, particularly plastic debris, [3], [4]. It is estimated that every year at least eight million tonnes of plastic leak into the ocean and in a business-as-usual scenario, the ocean is expected to contain more plastics than fish (by weight) by 2050, [5].

In this paper, we will focus on both environmental problems: global warming and marine plastic pollution. We conducted an LCA study of the carbon footprint of two generic plastic products with the same functionality, but with different plastic granulates. In the reference case, the basic plastic granulate is from recycled fishing nets that have been discarded in the oceans, and in the alternative case another, also partly recycled, polymer is used. LCA models and results for both cases are presented. We also discuss shortcomings of the LCA methodology as many positive environmental impacts of recycled plastic granulate cannot be included in the LCA methodology. In the second part of the paper, we present a detailed view of the environmental impacts of the recycled plastic granulate, that are not included in the LCA study.

CARBON FOOTPRINT

Methodology

The Carbon footprint is calculated based on LCA methodology. LCA methodology is standardized according to the ISO standards 14040, [6] and 14044, [7] and is used to analyze the environmental impacts of products or activities throughout their entire life cycle. Normally many environmental impacts would be considered, but because of the lack of data, we consider only carbon footprint – the analyzed environmental impact indicator is the global warming potential, within the CML2001 Life cycle Impact Assessment methodology. The calculation is made in GaBi software with ecoinvent databases.

Carbon footprint (or Global warming potential) is a term for total GHG emissions caused by an individual, event, organization, service, place, or product, expressed as carbon dioxide equivalent (CO_2 eq.). The most common GHG are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3), [8].

The study is conducted for generic plastic products. We consider the production and end-of-life (EoL) phase of the life cycle of the product. The scope of the study is therefore cradle-to-grave with the exclusion of the use phase which is in the plastic industry usually emissions-free. Two cases are presented with different materials, but the same functionality of the product. The functional unit is 1 piece of the product.

LCA models and Inventory data

The inventory data present all input data of the study – all mass and energy flows, which are used in the LCA models. In the reference case, the product is made from three different plastic granulates as presented in Table 1 and Fig. 1. Akulon is a recycled granulate partly made from discarded fishing nets. It contains 100% recycled polyamide 6 (PA6) base polymer, at least 50% of which is obtained from discarded fishing nets. ECO Meplen is also recycled granulate – polypropylene (PP), but only a minimum of 47%. TPE SOLPLAST is a granulate from thermoplastic elastomer (TPE), which is a virgin polymer. Electricity presents the energy input of the product. European Union (EU28) electricity grid mix is selected as the source of electricity.

Table 1. Mass and energy input data for the reference case (Akulon)

Input	Value	Unit
Akulon RePurposed	2,087	kg
ECO Meplen	1,053	kg
TPE SOLPLAST	0,057	kg
EU28 electricity grid mix	12,56	MJ

Reference case LCA model considers all three different End-of-life technologies – recycling, landfill, and incineration with the quantity of waste flow to each technology. In the LCA model is also considered that 10% of waste flow ends up in oceans, but there is no existing methodology for quantifying these environmental impacts.

We also considered credits in End-of-Life processes. Credits mean lower environmental impacts because of by-products of certain processes which could be used instead of “virgin” products. Therefore, we need to produce fewer products and consequently have lower environmental impacts. For example: because of the production of recycled granulate within the recycling End-of-Life process, we need to produce less virgin granulate, which means credits on account of virgin plastic granulate.

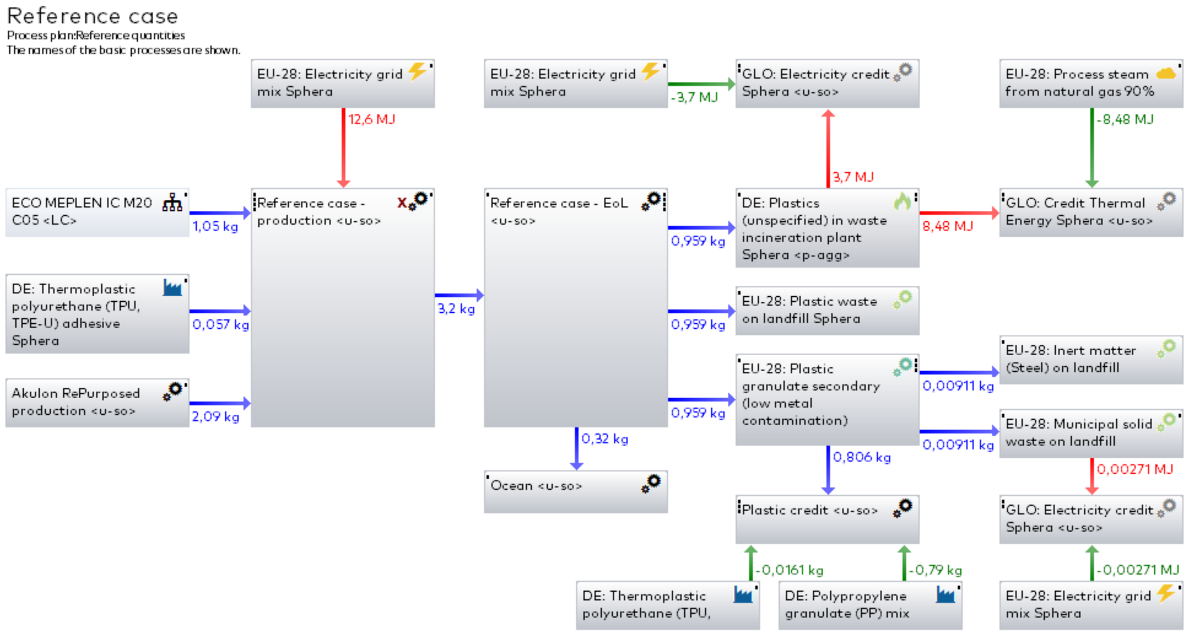

Fig. 1. LCA model for reference case (Akulon)

In the alternative case, as is presented in Table 2 and Fig. 2, we substitute Akulon with ECO Meplen since it has similar characteristics and the functionality of the final product is not changed. Because ECO Meplen is not the same polymer as Akulon we expect a different carbon footprint of the product. ECO Meplen also has a lower density than Akulon, that's why we use less material in the alternative case. With less used material is also lower energy consumption. The energy source and End-of-life phase are the same in both cases.

Table 2. Mass and energy input data for the alternative case (ECO Meplen)

Input	Value	Unit
ECO Meplen	2,801	kg
TPE SOLPLAST	0,057	kg
EU28 electricity grid mix	11,42	MJ

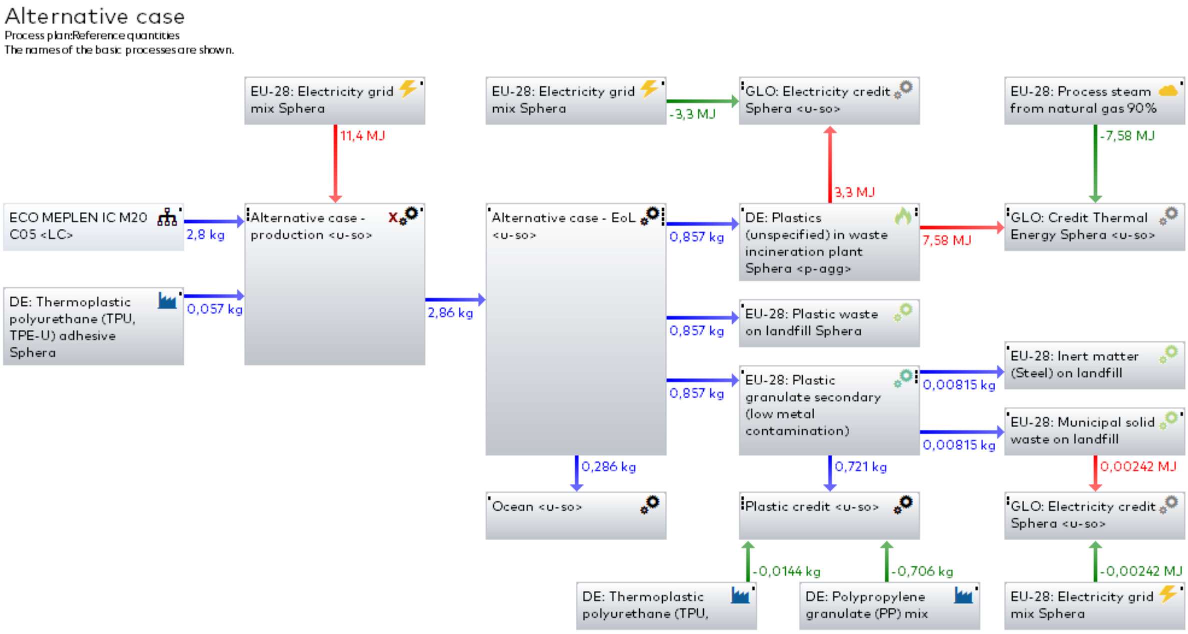

Fig. 2. LCA model for alternative case (ECO Meplen)

Results

Results of carbon footprint for plastic product in his whole life cycle for reference case are presented in Fig. 3. Product made mainly from Akulon granulate emits 7,23 kg CO_2 eq. in his production and End-of-life life cycle phase. As is also seen in Fig. 3 production of plastic granulate is responsible for 5,69 kg CO_2 eq. which represents 79% of the total carbon footprint. Production of granulate is clearly a hot spot. Electricity and incineration have a similar impact, around 17%. The landfill has practically neglected impact, only 0,9%. Recycling, on the other hand, has a negative impact, which means that have credits higher environmental impacts than the process of recycling. With recycling, we “save” 1 kg CO_2 eq.

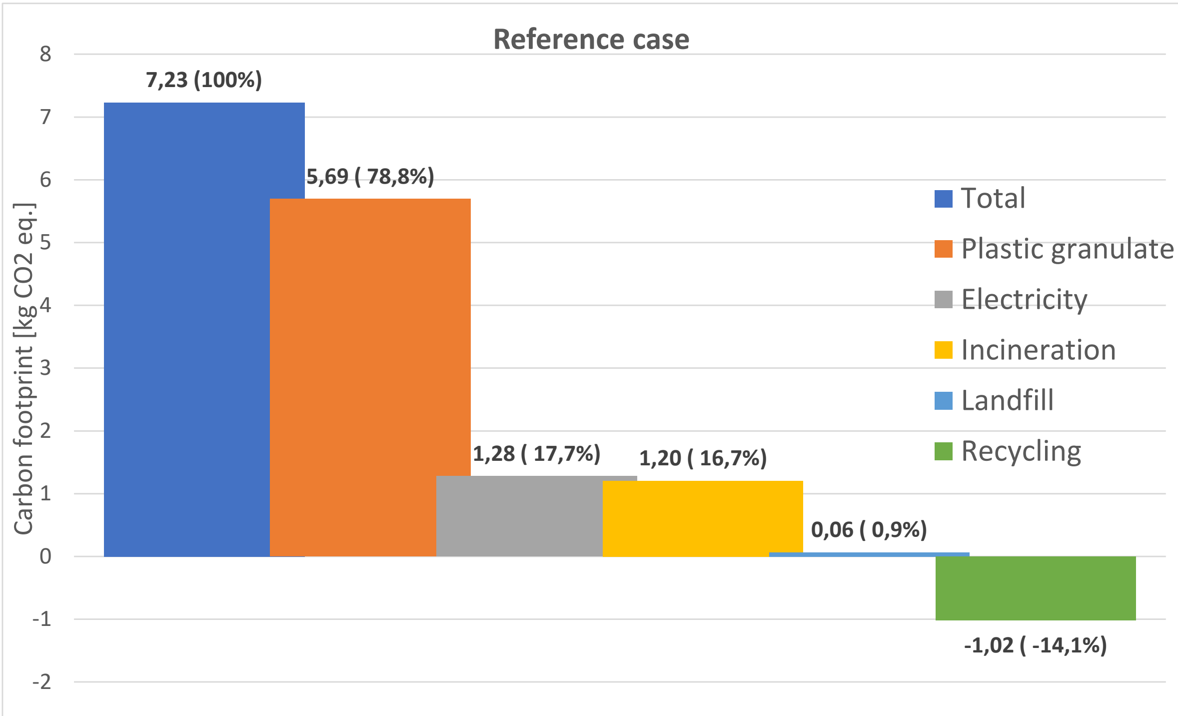

Fig. 3. Carbon footprint of reference case (Akulon)

The production phase (production of granulate and electricity production) is responsible for 96% of the carbon footprint, on the other hand, the End-of-life phase is responsible for only 4%, mainly because of the credits of the recycling process. From the global warming perspective is therefore crucial to optimize the production phase. On the other hand, the end-of-life phase represents a smaller share of total carbon footprint and should consequently be additionally assessed with other environmental impacts, not only global warming potential. For specific plastic granulate made from recycled fishing nets, we only have data about carbon footprint. To avoid inappropriate interpretations of environmental impact, plastic producers should measure and transparently disclose wider range of environmental aspects. Nevertheless, some environmental impacts of using recycled granulate from fishing nets, which go beyond LCA analysis, will be discussed later in the paper.
Because the production phase has so big impact on the total carbon footprint and because is carbon footprint often the only environmental indicator that is assessed, the end-of-life phase is too often neglected. Reasons for that are in many cases justifiable (lack of data, lack of knowledge of what really happens in the end-of-life phase, etc.), but in some cases, end-of-life assessment is not in the interest of the company or evaluator and is therefore not considered in the LCA. A wholesome LCA study must include an end-of-life phase since is a very important part of the life cycle and sustainability. Because we are so focused on the production phase, end-of-life models and data are missing, since there was no need to develop them. Databases should gather more specific data on end-of-life processes, experts should make more detailed models of end-of-life processes especially models for plastic and other waste that ends up in oceans, and LCA analysis makers should make effort to include end-of-life in LCA study.
Results for the alternative case are presented in Fig. 4. Because of the substitution of granulate Akulon with ECO Meplen, which has a lower carbon footprint, total carbon footprint of the product is lower by 37%. The absolute value of carbon footprint for the alternative case is 4,58 kg CO2 eq. Shares of GHG sources are similar to the reference case. The hot spot is still the production of plastic granulate (70%), electricity and incineration have almost the same share (25%), landfill could be neglected (1,3%), and recycling has a negative impact (-20%).

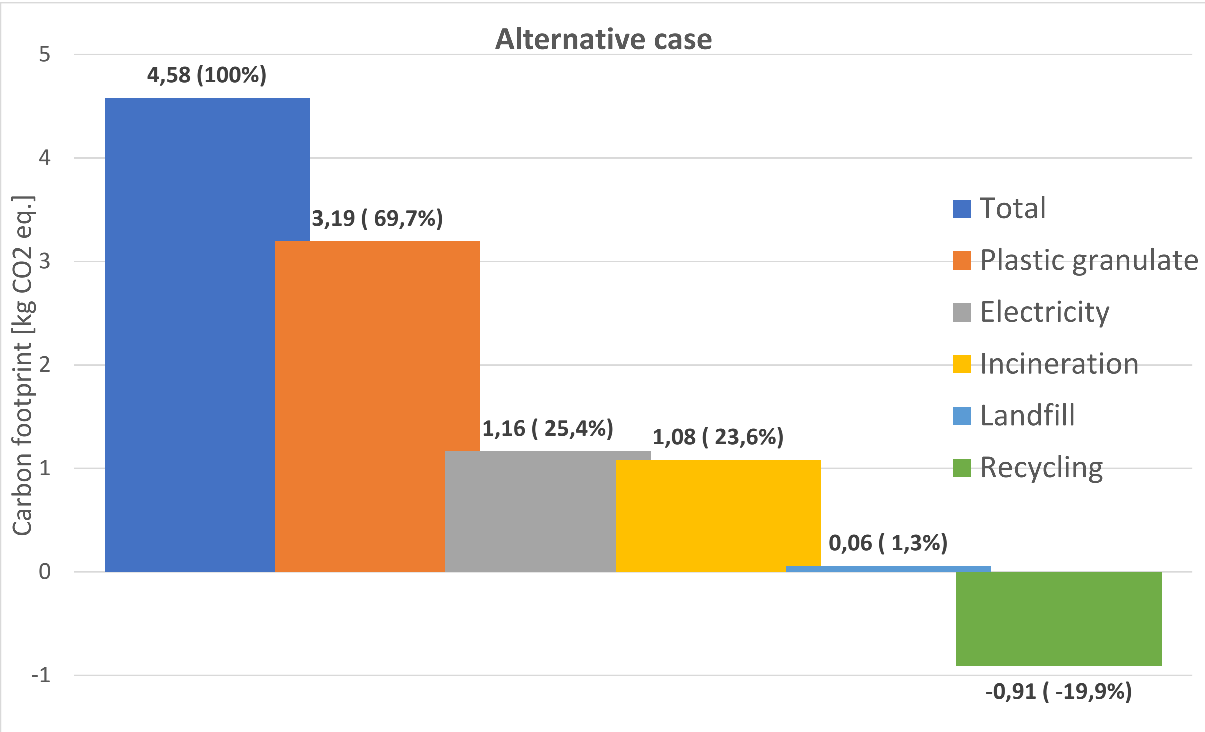

Fig. 4. Carbon footprint of alternative case (ECO Meplen)

Change in plastic granulate contributes greatly to lowering the carbon footprint of the product. The main reason for that is a different polymer. Akulon is 100% recycled polyamide, while is ECO Meplen only 47% recycled polypropylene. The fact that ECO Meplen is not 100% recycled does not have a big impact since has virgin polypropylene a lower carbon footprint (1,63 kg CO_2 eq.) than 100% recycled polyamide (2,1 kg CO_2 eq.). Production of polyamide is very carbon intensive since has a virgin polyamide carbon footprint of 6,52 kg CO_2 eq.
Although have Akulon higher carbon footprint than ECO Meplen, it contributes to solving marine plastic debris by using discarded fishing nets and recycling them into plastic granulate. With the recycling process, we not only produce less virgin plastic but also reduce plastic waste from the environment. Waste, especially plastic, is a growing problem for society since we produce more waste every year and do not have a sustainable solution for waste management. According to the World Bank's global review of solid waste management – What a Waste [9] we will generate 2,2 billion tonnes of solid waste by the year 2025. Almost half of today's waste is landfilled, which is not sustainable in the long term. Waste management, along with the LCA end-of-life phase, will be a great challenge as for now we do not have suitable practice for solving waste problems or methodology to even correctly assess the environmental impacts of the generated waste.

BEYOND LCA ANALYSIS

Marine debris is a global and pervasive threat to marine biodiversity. In remote coastal areas, plastic debris is causing environmental harm to otherwise pristine coastal environments relatively free from human disturbance, [10], [11]. Marine debris has a lethal and sub-lethal impact on all marine species through ingestion, entanglement, and chemical contamination, [12], [13].

Ghost nets

Since is granulate Akulon made from discarded fishing nets, we will only discuss environmental problems connected to fishing nets and not whole plastic waste. Ghost nets (derelict fishing gear) are, along with packaging, the most dangerous marine debris for marine mammals, [12]. Ghost nets in particular are of major concern because, although they make up to 10% of marine debris, they can have very damaging effects on marine fauna, [14]. Studies estimates, that every year more than 640 000 tons of fishing gear are lost worldwide, [12].
Impacts of ghost nets on global marine organisms have significantly increased in the past decades, in part due to advances in fishing gear, escalation in fishing efforts, and expansion of fishing grounds, [10]. The industry manufacturing fishing gear made a transition from traditional natural (biodegradable) materials to synthetic fibers, which are cheaper to manufacture, weigh less, and, due to their high resistance to degradation, are stronger and more durable. These properties, while beneficial for fishing, also make them more buoyant, longer-lasting, and more difficult for trapped animals to break free from, substantially increasing the damage associated with ghost nets, [12], [14]. The use of high-quality plastics makes fishing nets the preferred choice for recyclers – however, nets do have to be cleaned and processed before they can be recycled, [15].
Ghost nets, which mainly entangle marine animals, can continuously and indiscriminately entangle marine animals for up to multiple decades, [14]. Entanglement can lead to drowning, starvation, inflict severe lacerations, increase drag while swimming and foraging, prevent diving and feeding, increase exposure to predators, which can also become entangled, reproductive disruption, behavioral alterations, and stress, [10], [16].

Impact on marine animals

Based on studies and reports, we can very roughly estimate the number of marine animals that could be saved from entanglement. We propose that 10 000 products are produced in a year, which means the consumption of 21 tonnes of plastic granulate Akulon. We also propose that we need at least 1,2 kg of fishing nets for the production of 1 kg of granulate. Therefore, 25 tonnes of discarded fishing nets are used in a year. Based on the Archimedes report, [17], the average weight and area of the

fishing nets are calculated. With that estimate, calculations show consumption of 618500 m^2 of fishing nets in a year. If we compare the area of fishing nets with the results of Wilcox et. al. study, [14], we can roughly estimate that around 1400 marine animals could be saved from entanglement in a year, because of the removal of the ghost nets.
This is a very rough estimate. Entanglement depends on different types of nets, depth of the nets, types of animals in the area, etc. Also, the area of the ghost nets is just an approximation based on an unrelated study. Nevertheless, many lives of marine animals are saved because of the use of the granulate Akulon. With Akulon granulate we not only save lives but also reuse plastic waste, which is one of the main goals of sustainable development.

DISCUSSION

Some environmental impacts cannot be implemented in the LCA because of their complexity. LCA methodology is too rigid to assess very specific environmental impacts. It shows only a few most common environmental impacts. With LCA analysis we can get a general assessment. In specific cases, we must not forget other environmental impacts, which are usually very hard to get and assess, for example, an entanglement of marine animals. We must be aware of all environmental impacts of the product even if these impacts are not considered in the LCA. Without an assessment of important environmental impacts, we cannot successfully implement sustainable development.
More often than not, one product will have better certain environmental impacts and other product other environmental impacts. It’s hard to assess which one is more important when comparing two products. It depends on the environment, social atmosphere, and personal preference. Regardless of which product we say it’s better, the important thing is that we are aware of all the environmental impacts of that product and could justify the choice of one product over another as well as to react in time with mitigation measures.
Regardless of difficulties and possible incompleteness, the LCA methodology should implement a new process for the end-of-life phase, which would consider the environmental impacts of waste in the natural environments: soils, freshwater, and oceans. We blindly believe that all waste is treated accordingly, which is unfortunately not true. The LCA models should represent truth and not our wishes about how things should be, regardless of how ugly the truth is. Acknowledging waste problem is the first step of solving it.
For solving a complex waste problem interdisciplinary cooperation is crucial. Transparent communication on all levels, efficient governance projects, and awareness of people and companies are needed. But most importantly, care for the environment, not only for profit, is the biggest step we need to overcome if we want to solve the waste problem.
In that regard, we propose a definition of a new circularity index, which would at least partly address these problems. The index should be defined widely enough to assess different kinds of materials or processes and as many environmental impacts as possible.

CONCLUSION

In the study, we assessed the carbon footprint of generic plastic product from recycled granulate from discarded fishing nets. We compare the carbon footprint of the product to the alternative product, which is made from different plastic granulate. The alternative product has a much lower carbon footprint because of the more carbon-friendly granulate. For the reference case, we also assessed avoided impacts of entanglement of marine animals, because of used granulate from discarded fishing nets, which are gathered from the oceans. Assessment is very rough since many estimates and generalizations have been made. If the reference product is used, we save 1400 marine animals in a year from entanglement, despite the fact that the product has a 37% higher carbon footprint compared to the alternative product.
We also presented the limits of the LCA analysis. The LCA is not capable of assessing all environmental impacts, which could be important for a certain product. Even more worrying is the limitation in the end-of-life phase of the product. The LCA does not have a developed model for the waste that leaks into the oceans. Around 10% of the produced waste eventually ends up in the oceans,

which is not a neglectable share. Only with LCA models which represent real situations, can we contribute to sustainable development and help create a better world for future generations and not only exploit natural resources for economic benefit.

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BIOCHEMICAL PROPERTIES OF SINGLE AND MIXED FUNGI CULTURES AS REACTION TO THE PRESENCE OF SODIUM TRIPOLYPHOSPHATE

Violeta Jakovljević[1]
[1]State University of Novi Pazar, Department of Natural-Mathematics Sciences,
Novi Pazar, Serbia
e-mail: vjakovljevic@np.ac.rs

Abstract: Sodium tripolyphosphate (STPP) is used as a component of various domestic and industrial products. It is an excellent detergent additive. Because the most widely used, STPPs discharge into the environment from both indoor and outdoor use. The main environmental problem that has been linked with the use of STPP is eutrophication of groundwater and surface waters. The current study investigated the biochemical properties of pure cultures of *T. viride* and *F. lateritium* and their consortium to the presence of 0.5% sodium tripolyphosphate (STPP) in growth liquid medium for 19 days. The changes in the pH value, proteolytic activity of liquid growth media and total dry weight biomass (DWB) of cultures were measured periodically, on the 4th, 7th, 10th, 14th and 19th days. The addition of STPP in the growth medium had influence on a significant decrease in the pH values of pure and mixed cultures compared to control. STPP treatment had an inhibitory effect on protease activity of all fungal cultures in the following order: *T. viride* (3.60%), mixed culture (25.38%), and *F. lateritium* (57.82%). The dry weight biomass of *T. viride* and *F. lateritium* was slight and moderately inhibited (1.06 and 18.88%, respectively), whereas mixed culture achieved higher biomass (for 2.91%) compared to control. These results indicate the potential role of tested cultures in polyphosphate removal from industrial and waste water treatment plants and their potential application in biotechnological processes.
Key words: *biomass, sodium tripolyphosphate, pH, proteolytic activity, pure and mixed cultures*

INTRODUCTION

Sodium tripolyphosphate (STPP), an inorganic compound, has a wide industrial application and is present in many products that people use every day. These products include detergents, toothpastes, ceramics, textiles, rubber, food, medicines, etc. This chemical was historically prevalent in significant concentrations (20-45%) in laundry detergents, causing environmental damage, i.e. eutrophication [1]. Phosphates are used in machine wash detergents to bind calcium and magnesium and retain other particles, which contribute to their removal from dirty surfaces during washing. They also soften the water, preventing limescale buildup in the machines.
Phosphates are banned throughout the United States and the EU, as well as in many other countries. Although they are neither poisonous nor hazardous to people, their presence in watercourses can disrupt the equilibrium of aquatic life forms. As fertilizers, phosphates cause accelerated algal growth [**2**]. This so-called flowering has a negative impact on other aquatic creatures. Because most wastewater treatment plants are incapable of completely removing phosphates from household wastewater, some phosphates ultimately find up in natural waterways. The EU Urban Wastewater Treatment Directive 91/271/EEC explicitly addresses requirements for reducing phosphate and nutrient fluxes from sewage (of which detergents constitute a tiny component of phosphate).
It is known that some microorganisms can accumulate polyphosphates (PAO), i.e., they can store phosphate as intracellular polyphosphate (polyP), which results in phosphate removal from the liquid phase in waste activated sludge [3,4]. This category of microbes includes *Acinetobacter*, *Aeromonas*, *Vibrio, Pseudomonas*, and coliforms [5]. Among fungi, species of the genus *Aspergillus, Trichoderma*, and *Penicillium* have been identified as phosphate-solubilizing fungi [6]. In vitro studies on fungi have also revealed that some species may effectively grow and metabolize in the presence of STPP. Apart from individual species, relatively little research has focused on examining the ability of fungal communities to remove phosphate. In this regard, this paper aims to examine the potential of the mixed fungi *Trichoderma viride* and *Fusarium lateritium* and their combined cultures to eliminate STPP.

MATERIAL AND METHODS

Isolation and identification of fungi from wastewater

The procedure for isolating pure fungi cultures consists of the following: from water sample taken at the point of municipal wastewater discharge into the Lepenica riverbed (Kragujevac, Serbia) in laboratory conditions, dilution with distilled water was performed, and then water was sown on Potato-dextrose-agar (PDA) with streptomycin. The PDA of the following composition (g/L): potato-200, dextrose-20, agar-15 was sterilized in an autoclave at 121°C for 15 min. After cooling, Petri dishes were inoculated and incubated at (28±2)°C for 5 to 7 days. The procedure was repeated until the pure fungal cultures were isolated. Pure cultures were determined using a Systematic key based on microscopic and macroscopic characters. Cultures were maintained at 4°C in nutrient agar. The fungi were periodically sub-cultured under aseptic conditions.

Preparation of spore inoculum¶

Spore suspensions were prepared according to the procedure described in our previous work. The concentration of spores in the suspension was evaluated by microscopic enumeration with a cell-counting hemocytometer, Neubauer chamber (Lonza Cologne AG, Germany) and adjusted to 5.0×10^6 spores/ml.

Experimental conditions

A 200 ml Czapek-Dox liquid medium prepared from (g/L): $NaNO_3$-3, K_2HPO_4-1, $MgSO_4\times7H_2O$-0.25, $FeSO_4\times7H_2O$-0.01, sucrose-0.01 was transferred to Erlenmeyer bottles of 250 ml. This medium served as a control (C). Media was prepared in an identical manner but with the addition of STPP 0.5% (obtained from Henkel, "Merima" Kruševac, Serbia) served as a treatment (STPP). The pH value of the control medium was measured before sterilization at 6.8±0.2 (without adjustment). The media were sterilized in an autoclave, cooled to room temperature, and inoculated with 1 ml of spore suspension. Thereafter, the Erlenmeyer bottles were placed on a shaker (Kinetor-m, Slovenia) at 150 *rpm* and incubated for 19 days. After treatment, the mycelium was collected by filtration of the fermentation broth using Whatman No.1 filter paper (Germany).

Determination of biomass dry weight (BDW)

The contents of each Erlenmeyer flask were filtered through filter paper to separate the mycelium. The mycelium was washed 2 to 3 times with distilled water and, together with the filter paper dried in an oven at 80°C to a constant weight. The dry weight of the mycelium was determined by subtracting the initial weight of the filter paper from the weight of the mycelium and the filter paper.

Measurement of pH and redox potential

A pH-meter (type MA-5705, the product "Iskra", Kranj) was used for measuring the pH value and electrochemical potential.

Measurement of proteolytic activity

The protease activity was assayed by the Anson method [**7**]. A casein solution (0.65%) was prepared in 50 mM Tris-HCl buffer pH 7.4 and used as a substrate. The reaction mixture was made up of 5 ml of the casein substrate and 1 ml of the culture supernatant. After 30 min of incubation at 37°C, the reaction was terminated by adding 1 ml of trichloroacetic acid. The tubes were allowed to stand for 30 min at 37°C. Then, each test solution was filtered, and 1 ml of the above filtered solution was taken into another test tube. Each test tube was incubated for 30 min at 37°C after adding 5 ml of 0.5 M sodium carbonate and 1 ml of Folin's reagent, and absorbance was measured at 660 nm using a UV spectrophotometer.

RESULTS AND DISCUSSION

The biochemical properties of *T. viride*, *F. lateritium* and their mixed cultures grown in control (C) and medium with the addition of 0.5% STPP were assayed by measurement of pH value, proteolytic activity (from 4th to 19th day) and total DWB (at 19th day).

Figure 1 illustrates changes in the pH values of pure and mixed cultures growth media. The pH value of the fungus *T. viride* in the control medium declined from the time of inoculation to the 10th day, whereas the pH value of *F. lateritium* in the same medium decreased only during the first four days. In the medium of the mixed culture, a decrease in pH value was detected in the period from inoculation to the 7th day. In the medium with 0.5% STPP, the pH values of *T. viride* and *F. lateritium* were decreased at the same period of cultivation but much stronger compared to C, particularly *T. viride*. In contrast to control, the pH value of the STPP mixed medium recorded higher fluctuations during cultivation. Namely, the pH value reached two minimums, on the 4th and the 10th day. These changes in the pH values of growth media are the result of the utilization of nutrients from the media and the release of organic acids [8]. The most intensive fluctuations in pH levels suggest that cultures are growing rapidly. The obtained results are in line with results of other research that revealed alterations related to pH of the culture medium, depending on phosphorus concentration and polyP chain size, in distinct growth stages (stationary and logarithmic) of different microorganisms, including fungi [9, 10]. Study results by Bilecen and Kiliç [4] indicated that STTP increased pH. In addition, the formation of organic acids by fungal cells either during exponential or during the stationary growth phase significantly contributes to the acidity of the growth media [11]. According to Hamilton and coworkers [12], tripolyphosphate hydrolysis is substantially faster in acidic conditions, whereas the alkaline nature of soils lowers the abiotic hydrolysis rates.

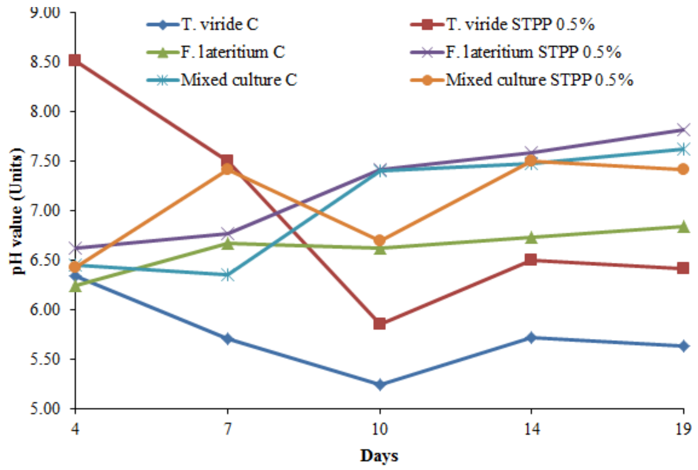

Fig. 1. The changes in pH values of cultures cultivated in control and sodium tripolyphosphate media

As Figure 2 shows, the proteolytic activities of cultures in C media were detected during all cultivation time, with the maximum observed at the 4th day in the case of *F. lateritium* and mixed culture or at the 19th day in the case of *T. viride.* Among cultures, the best enzyme activity was noted in the medium of *F. lateritium* (1.131 IU/ml), followed by *T. viride* (0.990 IU/ml) and mixed culture (0.902 IU/mL). The STPP treatment resulted in both a minor and a very strong suppression of the proteolytic activity. A slight inhibition of protease activity caused by STPP was measured in the medium of *T. viride* (3.60%), whereas a medium to very strong inhibitory effect was observed in the medium of mixed culture (25.38%) and *F. lateritium* (57.82%). Jakovljević and Vrvić [13] discovered a high level of stability of alkaline protease activity of *P. verrucosum* (80.1%) in medium with STPP after 8 days of cultivation. An inhibitory effect of STPP on the protease secretion of *Aeromonas hydrophila* was confirmed by Venugopal et al. [14]. Marsh [15] discovered that STPP at concentrations of 0.8% and 1% influences the protease activity of *Pseudomonas fragi*.

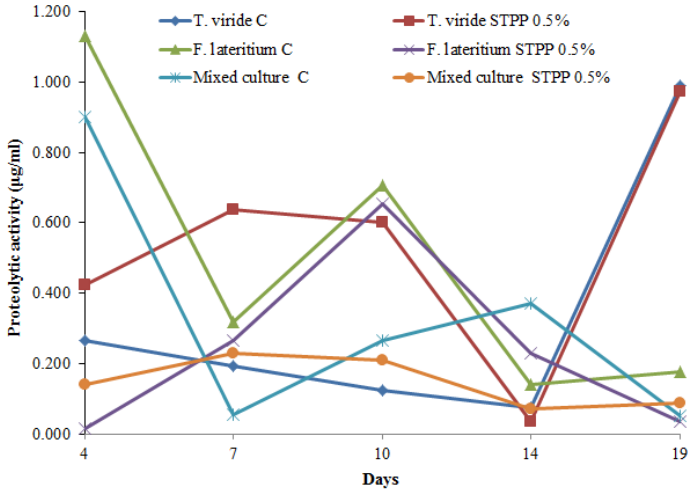

Fig. 2. The alkaline protease activity of cultures cultivated in control and sodium tripolyphosphate media

The biomass of all cultures was measured and compared after 19 days of cultivation. In C medium, *F. lateritium* achieved the greatest biomass production (2.33 g). *T. viride* and mixed cultures generated significantly lower amounts of biomass (1.88 g and 1.72 g, respectively) in the same medium. The treatment with STPP affected the inhibition of BDW of pure cultures, but to a different degree depending on the culture strain. In this medium, the biomass of *T. viride* was slightly inhibited since the fungus produced 1.85 g DWB. Unlike *T. viride*, *F. lateritium* produced a significantly lower quantity of BDW (1.89 g) compared to C. In percentage, STPP inhibited the biomass of pure cultures by 1.60% and 18.88%. In STPP media, mixed culture was more productive and produced more biomass (1.77 g) than pure cultures. In other words, mixed culture biomass was stimulated by STPP by 2.91%. Previous studies found that the effect of STPP on BDW production of pure cultures and consortia varied depending on the species of fungi. The mentioned pollutant, for example, stimulated BDW of *G. candidum* (0.58%) and *T. viride/G. candidum* consortia (9.53%), but had a slight inhibitory impact on *P. verrucosum* biomass (0.59%) [13]. Moon et al. [16] evaluated the effects of STPP on total growth and biofilm formation of single bacterial strains and their co-culture: *Fusobacterium nucleatum, Prevotella intermedia*, and *Porphyromonas gingivalis*, and discovered that STPP inhibited all examined parameters. Lee et al. [17] found that STPP at concentrations of 250-750 mg/L showed excellent *in vitro* antimicrobial activity against the *Porphyromonas* species by disturbing the cell membranes and/or by inhibiting energy metabolism and cell envelope biosynthesis. Post et al. [18] reported that polyP has antimycotic properties against the most frequent fungal spoilers, *Penicillium expansum*, *Rhizopus nigricans*, and *Botrytis sp*. De Oliveira et al. [19] revealed that STPP species-dependent inhibitory action against several *Candida spp*. strains being particularly active on *C. glabrata*, followed by *C. guilliermondii*. It has been reported by Dzurendova et al. [20] that the effect of low phosphorus concentrations (Pi less than 0.25 and 0.5) was directly linked to a drop in pH. Because acidic pH is such an aggressive stress factor that inhibits fungal growth, determining the influence of metal ions on growth and lipid formation under limited phosphorus substrate availability was challenging.

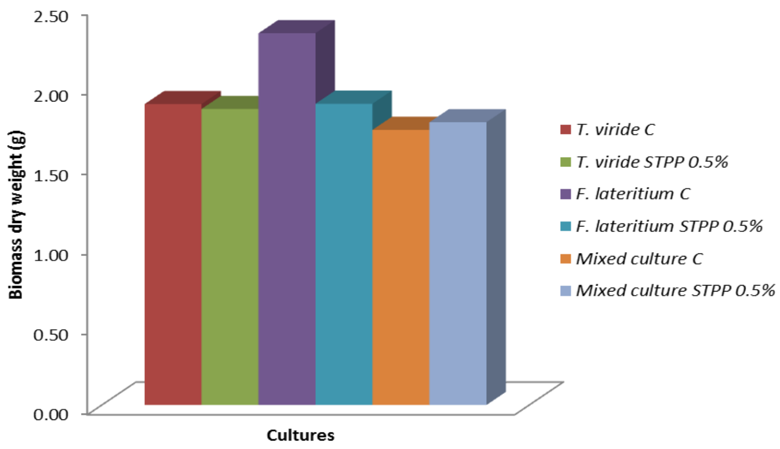

Fig. 3. The biomass dry weight of cultures cultivated in control and sodium tripolyphosphate media

CONCLUSION

The current findings reveal that pure and mixed cultures of fungi have different biochemical responses to STPP at a concentration of 0.5%, which is reflected in the pH value changes, activity of alkaline protease activity and biomass production. STPP decreased the proteolytic activity of all cultures, but the enzyme preserved extremely high stability in the case of *T. viride* and intermediate or moderate activity in the case of mixed culture and *F. lateritium*, respectively. The treatment with STPP affected the growth inhibition of BDW production of pure cultures but promoted BDW of mixed culture. The presented results indicate the potential of mixed culture in the accumulation of polyphosphates, and suggest that it might be used in biotechnological operations.

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Session 5

Environmental Management and Occupational Safety

DEVELOPING A METHODOLOGY FOR ESTIMATING THE COSTS OF ACCIDENTS AND ILLNESSES AT THE WORKPLACE

Ljupco Trajcevski[1] , Vangelce Mitrevski[1], Cvetanka Mitrevska[2]
[1]University St.Kliment Ohridski, Faculty of Technical Sciences, Bitola, North Macedonia
[2]International Slavic University Gavrilo Romanovic Derzavin,
Faculty for Safety Engineering, Sveti Nikole, North Macedonia
e-mail: vangelce.mitrevski@uklo.edu.mk

Abstract: The Republic of Macedonia is a country in which a large number of its citizens are faced with numerous dangers and hazards every day at their workplaces, which in turn lead to one death per week throughout the year. Inadequate working conditions, constant economic pressure, infinite uncertainty, complicated internal and external political situation, the inability of social partners to fight for their role in society, are only part of the numerous justifications of the various interested parties who participate in the process of creating an additional value. For this purpose, following other countries, the Republic of Macedonia implemented the European Law on Safety and Health at Work, with which all organizations, according to certain standards and regulations, are instructed to prepare and implement appropriate training for employees, to prepare a risk assessment report at the workplace and to measure the working conditions in which they work, to conduct medical examinations for each employee and to carry out tests of the equipment and machines used in the work process. In the world, different methodologies have been developed to estimate the costs in case of an accident at the workplace.
This paper presents a methodology for estimating the costs of accidents and illnesses at the workplace. The costs that can arise in the event of an accident at the workplace can greatly burden the budget of enterprises and change the plans for the development of the enterprise due to unforeseen financial losses, which also lead to the loss of important human resources, and thus a stoppage in business.
Key words: safety, health, costs, risk assessment methodology.

INTRODUCTION

The relationship between man and his work and the development of the productive force is becoming more and more complex. With his work activity, man did not express himself only as a productive person, but in the class society there was also a detachment and dehumanization of work, i.e. a gap between the human generic essence, that is, between his "character" and his work activities. The negative impact of the means of work and the work process of man, which is expressed through the increasing number of injuries at work and occupational diseases, has gained wider proportions with the development. Work injuries and occupational diseases are the subject of study from different aspects: technical, organizational, economic, psychological, medical, social, etc.
Health and well-being are the basic goals of both individuals and society. Good working conditions are a key element in achieving these goals, and can lead to good financial benefits. Conversely, a better understanding of the economic factors and social costs resulting from a poor work environment can lead to better occupational safety and health conditions and safer work practices. Economic factors are important in making any decisions. But in decisions about issues of human health and safety at work, ethical and economic needs often come into conflict. This is especially important where economic factors are viewed only for a short period of time or in an overly constructive manner.
In the world, and here in the Republic of Macedonia, Safety and health at work is defined by the Law on Work, that is, the Law on Safety and Health at Work. For this purpose, it is necessary to take care of safety and health at work and to constantly monitor the changes that these laws bring with them.
In this paper, a unique methodology has been established for estimating the costs of a company in case of workplace injuries (accidents) or occupational diseases that cause temporary or permanent absences from work, and ultimately the death of the employee.

WORKPLACE RISK ASSESSMENT METHODOLOGY

The methodology for implementing risk assessment is defined as an algorithm, tools and methods of the assessment procedure, and the procedure for implementing the risk assessment procedure is defined by a standardized series of steps that ensure the implementation of procedures in accordance with the recommendations of the relevant laws, regulations and recommendations. Risk assessment is primarily an empirical process of making engineering decisions based on knowledge and experience in order to increase safety and health at work using selected and up to now recognized and known methods. In the world there are a number of recognized risk assessment methods formed by various associations and associations. No risk assessment method prescribes the selection of preventive measures to reduce, eliminate and prevent risk.

The correct choice of risk assessment methods and the working environment enables the adequate application of measures, which would ensure a safe workplace and working environment, as well as a reduced probability that diseases and injuries will occur to employees.

Depending on the risk assessment criteria, all methods applied in the field of safety and health at work can be divided into:

1. Quantitative;
2. Semi-quantitative;
3. Qualitative.

The methodology presented in this paper is implemented through a specific example, i.e. a cost-benefit analysis for a worker performing the grinding process (Fig.1).

Fig.1. Worker performing the grinding process

Worker steps:

1. Approaching the machine, taking the item to be sanded and carrying it to the sanding stone.	2. Place the item on the wheel and tear off the excess material.	3. Placing the finished piece to the left of the machine

After recording the appropriate steps, each step is immediately checked to determine the hazards that exist or may occur. If we re-observe the image shown above we can identify any existing or potential hazards:

1. Hand injury from edge, metal box or casting; cutting the hand; sticking metal dust on the worker's fingers.
2. Injury to the hand from the whetstone; Grinding stone breaking; To grip the sleeves of the worker's protective equipment with the grinding stone.
3. Hand injury from the metal box or casting.

Then the recommendations for new steps and protection measures are defined.

1. Wearing gloves and protective shoes to protect the feet.

2. Provision of grinding stone guard. Installation of a local dust aspiration system. Mandatory wearing of safety glasses and recommendation to wear short or tight-fitting sleeves.
3. Security when removing the finished piece.
A workplace safety analysis can do much to reduce workplace accidents and injuries, but they are only effective if they are regularly reviewed and updated periodically. If an illness or injury occurs in a particular workplace, a workplace safety analysis should be reviewed immediately to determine if changes in work procedures are needed.
At any time the workplace hazard should be analyzed and revised, training should be provided on new workplace methods, procedures or protective measures for all employees affected by the changes. A workplace safety analysis can also be used to train new employees.

RESULTS AND DISCUSSIONS

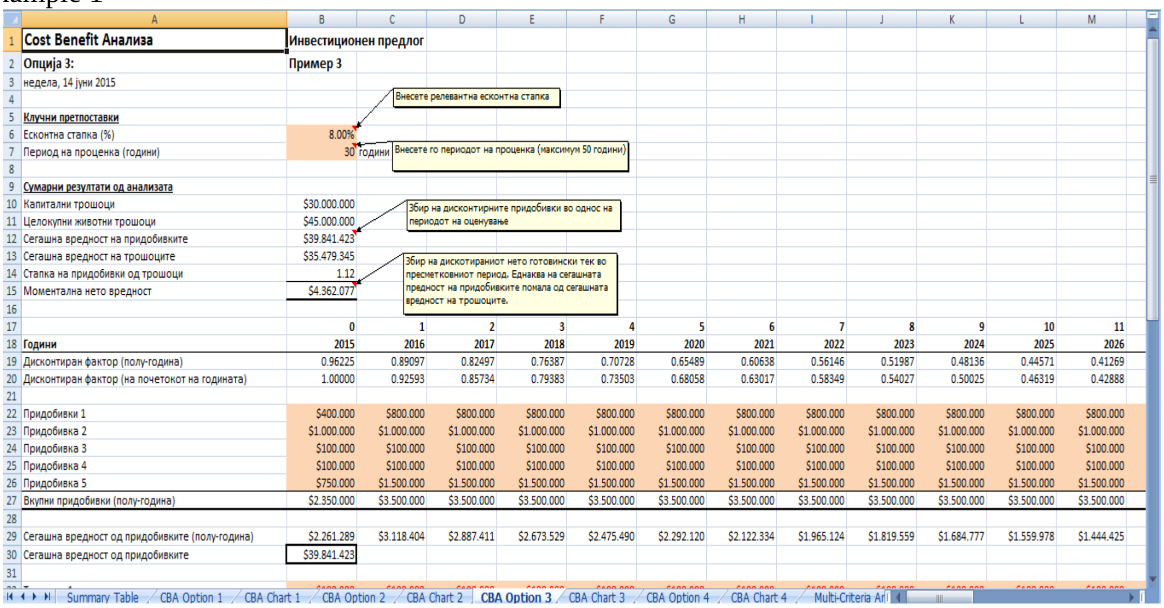
The following shows the software with the help of which we can calculate the benefit from the appropriate preventive measures for safety at work expressed through economic indicators - money. For this purpose, an EXCEL program has been developed with the help of which we can demonstrate the Cost-Benefit Analysis model.

The theoretical design of the cost-benefit analysis through different types of benefits, safety research and direct/indirect costs from accidents are implemented in the software. Different types of costs from accidents caused by the fault of the employer in a certain industry as a result of avoiding compliance with the measures and principles set by the occupational safety and health management are shown. These costs can be crucial in the economic sustainability of the project itself. Based on that, we divide the costs of this nature into two groups: costs incurred to improve the safety of workers and reduce the risk of an accident and costs incurred as a result of an injury to a worker due to non-compliance with occupational safety and health standards.

Due to the need to unify the respective benefits and costs during the Cost-Benefit analysis in the program Cost-Benefit-Analysis.xls the costs are declared as: Costs 1, Costs 2, ...Costs 5 and the benefits as Benefit 1, Benefit 2,... Benefit 5. They can be, for example: costs caused by a reduction in production due to an injury to a worker at the workplace, due to illness of the employee, medical costs, court costs, etc., while the benefits can be from reducing accidents, reducing medical cases, increasing productivity, reducing sick days, etc.

In the model itself, two different examples are shown, and finally, a multi-criteria analysis of intangible costs and compensations, if any, is shown, where two different criteria are defined.

Example 1



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Cost Benefit Анализа	Инвестиционен предлог											
2	Опција 3:	Пример 3											
3	недела, 14 јуни 2015												
4													
5	Клучни претпоставки												
6	Есконтна стапка (%)	8.00%											
7	Период на проценка (години)	30	години										
8													
9	Сумарни резултати од анализата												
10	Капитални трошоци	$30.000.000											
11	Целокупни животни трошоци	$45.000.000											
12	Сегашна вредност на придобивките	$39.841.423											
13	Сегашна вредност на трошоците	$35.479.345											
14	Стапка на придобивки од трошоци	1.12											
15	Моментална нето вредност	$4.362.077											
16													
17		0	1	2	3	4	5	6	7	8	9	10	11
18	Години	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
19	Дисконтиран фактор (полу-година)	0.96225	0.89097	0.82497	0.76387	0.70728	0.65489	0.60638	0.56146	0.51987	0.48136	0.44571	0.41269
20	Дисконтиран фактор (на почетокот на годината)	1.00000	0.92593	0.85734	0.79383	0.73503	0.68058	0.63017	0.58349	0.54027	0.50025	0.46319	0.42888
21													
22	Придобивки 1	$400.000	$800.000	$800.000	$800.000	$800.000	$800.000	$800.000	$800.000	$800.000	$800.000	$800.000	$800.000
23	Придобивка 2	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000
24	Придобивка 3	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000
25	Придобивка 4	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000
26	Придобивка 5	$750.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000
27	Вкупни придобивки (полу-година)	$2.350.000	$3.500.000	$3.500.000	$3.500.000	$3.500.000	$3.500.000	$3.500.000	$3.500.000	$3.500.000	$3.500.000	$3.500.000	$3.500.000
28													
29	Сегашна вредност од придобивките (полу-година)	$2.261.289	$3.118.404	$2.887.411	$2.673.529	$2.475.490	$2.292.120	$2.122.334	$1.965.124	$1.819.559	$1.684.777	$1.559.978	$1.444.425
30	Сегашна вредност од придобивките	$39.841.423											
31													

Внесете релевантна есконтна стапка

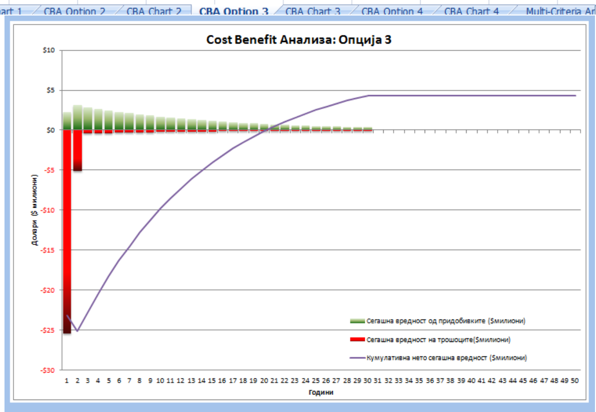
Внесете го периодот на проценка (максимум 50 години)

Збир на дисконтирните придобивки во однос на периодот на оценување

Збир на дискотираниот нето готовински тек во пресметковниот период. Еднаква на сегашната предност на придобивките помала од сегашната вредност на трошоците.

Summary Table / CBA Option 1 / CBA Chart 1 / CBA Option 2 / CBA Chart 2 / CBA Option 3 / CBA Chart 3 / CBA Option 4 / CBA Chart 4 / Multi-Criteria An

	A	B	C	D	E	F	G	H	I	J	K	L	M
32	Трошоци 1	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000
33	Трошоци 2	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000
34	Трошоци 3	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000
35	Трошоци 4	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000
36	Трошоци 5	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000
37	Вкупни трошоци (полу-година)	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000
39	Капитални трошоци (на почетокот на годината)	-$25.000.000	-$5.000.000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	Вкупни трошоци	-$25.500.000	-$5.500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000
41	Вкупни капитални трошоци	-$30.000.000											
42	Вкупни целокупни животни трошоци	-$45.000.000											
44	Сегашна вредност на трошоците (полуmгодина)	-$481.125	-$445.486	-$412.487	-$381.933	-$353.641	-$327.446	-$303.191	-$280.732	-$259.937	-$240.682	-$222.854	-$206.346
45	Сегашна вредност на трошоците (на почетокот од годин	-$25.000.000	-$4.629.630	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
46	Сегашна вредност на трошоците(во тековнат година)	-$25.481.125	-$5.075.116	-$412.487	-$381.933	-$353.641	-$327.446	-$303.191	-$280.732	-$259.937	-$240.682	-$222.854	-$206.346
47	Сегашна вредност на трошоците	-$35.479.345											
49	Нето паричен тек	-$23.150.000	-$2.000.000	$3.000.000	$3.000.000	$3.000.000	$3.000.000	$3.000.000	$3.000.000	$3.000.000	$3.000.000	$3.000.000	$3.000.000
50	Моментална нето вредност (за тековна година)	-$23.219.837	-$1.956.712	$2.474.924	$2.291.596	$2.121.848	$1.964.674	$1.819.143	$1.684.392	$1.559.622	$1.444.094	$1.337.124	$1.238.078
51	Кумулативна NPV	-$23.219.837	-$25.176.548	-$22.701.624	-$20.410.028	-$18.288.180	-$16.323.505	-$14.504.362	-$12.819.971	-$11.260.349	-$9.816.254	-$8.479.130	-$7.241.052
54	**Податоци за исцртување на графиконот:**												
55	Година	0	1	2	3	4	5	6	7	8	9	10	11
56	Сегашна вредност од придобивките ($милиони)	$ 2.261	$ 3.118	$ 2.887	$ 2.674	$ 2.475	$ 2.292	$ 2.122	$ 1.965	$ 1.820	$ 1.685	$ 1.560	$ 1.444
57	Сегашна вредност на трошоците($милиони)	-$ 25.481	-$ 5.075	-$ 0.412	-$ 0.382	-$ 0.354	-$ 0.327	-$ 0.303	-$ 0.281	-$ 0.260	-$ 0.241	-$ 0.223	-$ 0.206
58	Кумулативна нето сегашна вредност ($милиони)	-$ 23.220	-$ 25.177	-$ 22.702	-$ 20.410	-$ 18.288	-$ 16.324	-$ 14.504	-$ 12.820	-$ 11.260	-$ 9.816	-$ 8.479	-$ 7.241



Example 2

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Cost Benefit Анализа**	**Инвестиционен предлог**											
2	**Опција 4:**	**Пример 4**											
3	недела, 14 јуни 2015												
5	**Клучни претпоставки**												
6	Есконтна стапка (%)	8.00%											
7	Период на проценка (години)	30	години										
9	**Сумарни резултати од анализата**												
10	Капитални трошоци	$55.000.000											
11	Целокупни животни трошоци	$70.000.000											
12	Сегашна вредност на придобивките	$47.718.390											
13	Сегашна вредност на трошоците	$43.903.348											
14	Стапка на придобивки од трошоци	1.09											
15	Моментална нето вредност	$3.815.042											
17		0	1	2	3	4	5	6	7	8	9	10	11
18	**Години**	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
19	Дисконтиран фактор (полу-година)	0.96225	0.89097	0.82497	0.76387	0.70728	0.65489	0.60638	0.56146	0.51987	0.48136	0.44571	0.41269
20	Дисконтиран фактор (на почетокот на годината)	1.00000	0.92593	0.85734	0.79383	0.73503	0.68058	0.63017	0.58349	0.54027	0.50025	0.46319	0.42888
22	Придобивки 1	$400.000	$800.000	$1.200.000	$1.200.000	$1.200.000	$1.200.000	$1.200.000	$1.200.000	$1.200.000	$1.200.000	$1.200.000	$1.200.000
23	Придобивка 2	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000	$1.000.000
24	Придобивка 3	$100.000	$100.000	$500.000	$500.000	$500.000	$500.000	$500.000	$500.000	$500.000	$500.000	$500.000	$500.000
25	Придобивка 4	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000	$100.000
26	Придобивка 5	$750.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000	$1.500.000
27	Вкупни придобивки (полу-година)	$2.350.000	$3.500.000	$4.300.000	$4.300.000	$4.300.000	$4.300.000	$4.300.000	$4.300.000	$4.300.000	$4.300.000	$4.300.000	$4.300.000
29	Сегашна вредност од придобивките (полу-година)	$2.261.289	$3.118.404	$3.547.391	$3.284.621	$3.041.316	$2.816.033	$2.607.438	$2.414.295	$2.235.458	$2.069.869	$1.916.545	$1.774.579
30	Сегашна вредност од придобивките	$47.718.390											

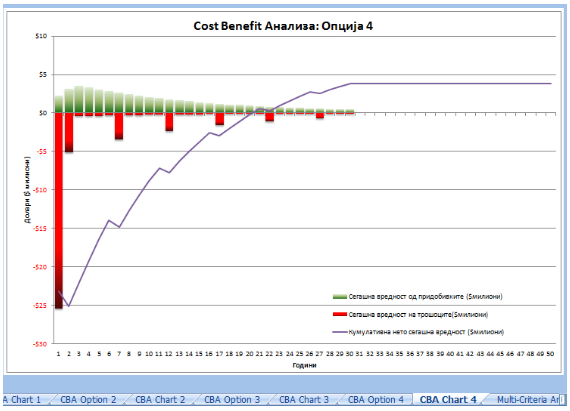
Внесете релевантна есконтна стапка

Внесете го периодот на проценка (максимум 50 години)

Збир на дисконтирните придобивки во однос на периодот на оценување

Збир на дискотиранiот нето готовински тек во пресметковниот период. Еднаква на сегашната предност на придобивките помала од сегашната вредност на трошоците.

	A	B	C	D	E	F	G	H	I	J	K	L	M
32	Трошоци 1	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000
33	Трошоци 2	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000
34	Трошоци 3	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000
35	Трошоци 4	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000
36	Трошоци 5	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000	-$100.000
37	Вкупни трошоци (полу-година)	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$500.000
39	Капитални трошоци (на почетокот на годината)	-$25.000.000	-$5.000.000	$0	$0	$0	$0	-$5.000.000	$0	$0	$0	$0	-$5.000.000
40	Вкупни трошоци	-$25.500.000	-$5.500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$5.500.000	-$500.000	-$500.000	-$500.000	-$500.000	-$5.500.000
41	Вкупни капитални трошоци	-$55.000.000											
42	Вкупни целокупни животни трошоци	-$70.000.000											
44	Сегашна вредност на трошоците (полуmгодина)	-$481.125	-$445.486	-$412.487	-$381.933	-$353.641	-$327.446	-$303.191	-$280.732	-$259.937	-$240.682	-$222.854	-$206.346
45	Сегашна вредност на трошоците (на почетокот од годин	-$25.000.000	-$4.629.630	$0	$0	$0	$0	-$3.150.848	$0	$0	$0	$0	-$2.144.414
46	Сегашна вредност на трошоците(во тековнат година)	-$25.481.125	-$5.075.116	-$412.487	-$381.933	-$353.641	-$327.446	-$3.454.039	-$280.732	-$259.937	-$240.682	-$222.854	-$2.350.761
47	Сегашна вредност на трошоците	-$43.903.348											
49	Нето паричен тек	-$23.150.000	-$2.000.000	$3.800.000	$3.800.000	$3.800.000	$3.800.000	-$1.200.000	$3.800.000	$3.800.000	$3.800.000	$3.800.000	-$1.200.000
50	Моментална нето вредност (за тековна година)	-$23.219.837	-$1.956.712	$3.134.904	$2.902.689	$2.687.675	$2.488.588	-$846.600	$2.133.563	$1.975.521	$1.829.186	$1.693.691	-$576.182
51	Кумулативна NPV	-$23.219.837	-$25.176.548	-$22.041.645	-$19.138.956	-$16.451.281	-$13.962.694	-$14.809.294	-$12.675.731	-$10.700.210	-$8.871.024	-$7.177.333	-$7.753.515
54	**Податоци за исцртување на графиконот:**												
55	Година	0	1	2	3	4	5	6	7	8	9	10	11
56	Сегашна вредност од придобивките ($милиони)	$ 2.261	$ 3.118	$ 3.547	$ 3.285	$ 3.041	$ 2.816	$ 2.607	$ 2.414	$ 2.235	$ 2.070	$ 1.917	$ 1.775
57	Сегашна вредност на трошоците($милиони)	-$ 25.481	-$ 5.075	-$ 0.412	-$ 0.382	-$ 0.354	-$ 0.327	-$ 3.454	-$ 0.281	-$ 0.260	-$ 0.241	-$ 0.223	-$ 2.351
58	Кумулативна нето сегашна вредност ($милиони)	-$ 23.220	-$ 25.177	-$ 22.042	-$ 19.139	-$ 16.451	-$ 13.963	-$ 14.809	-$ 12.676	-$ 10.700	-$ 8.871	-$ 7.177	-$ 7.754



The multi-criteria analysis

It is necessary to define the criteria so that the criterion weight of the four criteria does not exceed the value of 100%. Also, the size of the contribution of the corresponding criterion is evaluated with a value from 0 for a zero value of the criterion to 10 for a high value of the size of the contribution for the corresponding criterion (Fig.2)

Мулти - критериумска Анализа

		Опција 1		Опција 2		Опција 3		Опција 4	
		Пример 1		Пример 2		Пример 3		Пример 4	
Критериум	Тежина на критериум	Придонес (од 1 до 10)	Тежинска вредност	Придонес (од 1 до 10)	Тежинска вредност	Придонес (од 1 до 10)	Тежинска вредност	Придонес (од 1 до 10)	Тежинска вредност
Критериум 1	50.0%	3	1.50	5	2.50	5	2.50	5	2.50
Критериум 2	25.0%	5	1.25	9	2.25	0		6	1.50
Критериум 3	15.0%	4	0.60	6	0.90	8	1.20	8	1.20
Критериум 4	10.0%	4	0.40	3	0.30	5	0.50	8	0.80
Вкупно	100.0%	16	3.8	23	6.0	18	4.2	27	6.0

Fig. 2. Multi-criteria analysis

And finally, the summary overview of all four options ie examples is given in the Summary Table (Fig. 3)

Економска Анализа **Инвестиционен предлог**

Сумарен Преглед

петок, 15 мај 2015

	Опција 1 <пример 1>	Опција 2 <Пример 2>	Опција 3 <Пример 3>	Опција 4 <Пример 4>
Период на проценка (години)	30	30	30	30
Капитални трошоци	$0	$2.000.000	$30.000.000	$55.000.000
Целокупни животни трошоци	$15.000.000	$17.000.000	$45.000.000	$70.000.000
Анализа на трошоците и придобивките од несреќи во претпријатијата преку есконтна стапка				
Сегашна вредност на придобивките	$5.849.716	$7.604.631	$39.841.423	$47.718.390
Сегашна вредност на трошоците	$5.849.716	$7.849.716	$35.479.345	$43.903.348
Стапка на придобивки од трошоците	1.00	0.97	1.12	1.09
Моментална нето вредност	$0	-$245.085	$4.362.077	$3.815.042
Мулти - критериумска анализа на нематеријални трошоци и надоместоци (доколку ги има)				
Критериум 1	1.50	2.50	2.50	2.50
Критериум 2	1.25	2.25		1.50
Критериум 3	0.60	0.90	1.20	1.20
Критериум 4	0.40	0.30	0.50	0.80
Пондериран рејтинг	3.8	6.0	4.2	6.0

Fig. 3. Symmary overview for four examples

In accordance with this research, another program was developed in EXCEL for the simulation of the model using the Monte-Carlo method for predicting the appropriate reliability, i.e. the montecarlomethod.xls file. During the analysis of the same, 5000 random values were taken that were generated by the software itself, which can be replaced with appropriate true values that would be obtained during the research of a specific example. Also, the software itself defines the input data in a range from minimum to a maximum value that the software automatically calculates as 80% of the entered initial value as the minimum and 120% as the maximum value. The software also calculates stochastic (random) values. The input parameters are entered in the yellow fields as shown below (Fig.4) and for input data defined in this way, the following statistical values were obtained (Fig. 4):

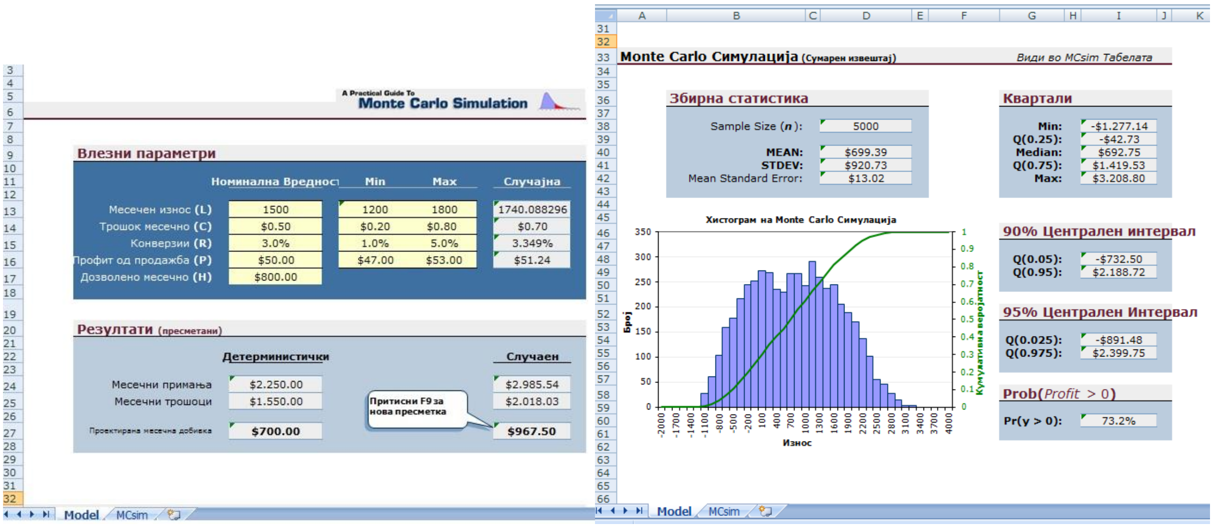


Fig. 4. Input parameters for Monte Carlo calculation and results

These output results are obtained based on 5000 randomly generated values that are calculated in the "MCsim" Table. The corresponding statistical parameters that are also required for the Monte Carlo reliability calculation are given in the same tabular overview. For a better overview, the values are given separately as images.

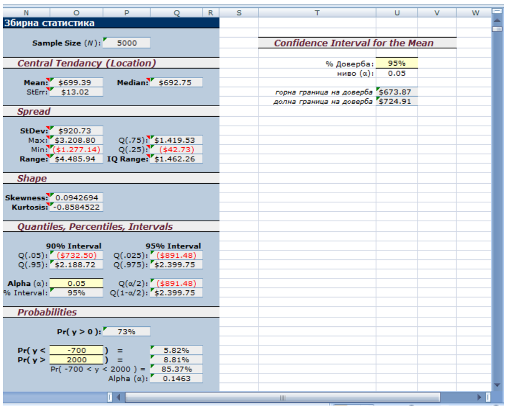


Fig. 5. Summary statistics

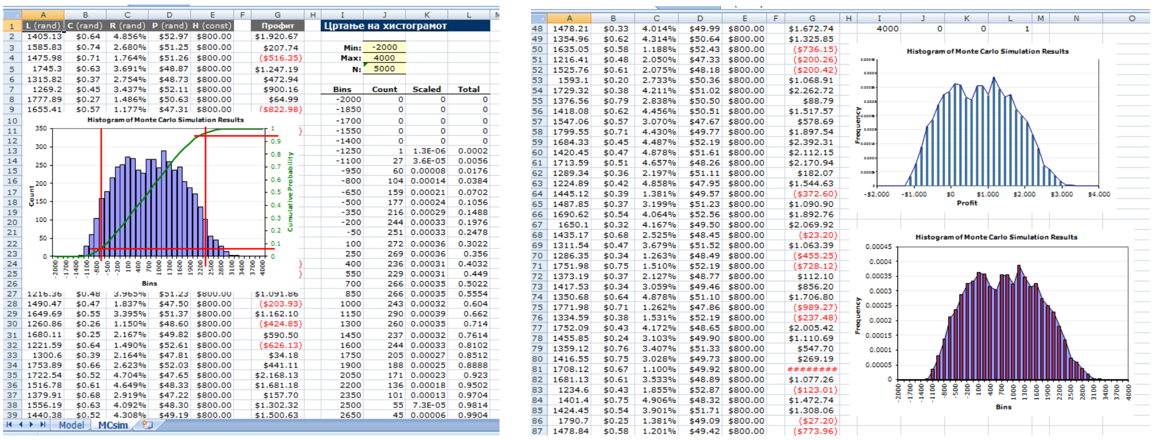


Fig. 6. Histogram of Monte Carlo simulation results

In the previous two examples, and in order to achieve a reduction of accidents in industries, it is necessary to measure the costs and benefits. In the measurement of costs and benefits, two concepts are important in cost-benefit analysis, namely financial costs and resource costs.

Financial costs are the monetary values of the actual goods and services that are used in the execution of a specific policy, the implementation of a service delivery program for example. costs of material, labor, facilities, information, and other costs that usually have market values and can easily be expressed in monetary terms. Resource costs on the other hand refer to the benefits that could be achieved by employing the resources that could be put to their next best alternative use in the absence of these benefits in project costs.

In the case of measuring fatality, problems can arise with placing a value on human life as well as the cost of injuries. However, they can be expressed in monetary terms. In the context of this framework, they are referred to as direct and indirect costs of the accident. Costs and benefits can be weighed against each other to generate decision-making criteria.

There are three criteria used in the decision-making process – parameters for investment analysis – methods used for cost-benefit analysis:

1. NPV - Net Present Value - The net present value must be positive, and a choice must be made and the highest net present value must be selected. However, net present value analyzes the profitability of the investment and has its own problems such as the selected discount rate. The costs and benefits of accident prevention are direct and indirect, the net present value will only take into account the direct costs and not the indirect costs and benefits. This means that whatever results are obtained will be incomplete. It should be noted that the research focuses on the costs and benefits (direct and indirect) of accident prevention, so net present value cannot be used to calculate the costs and benefits of accident prevention

2. IRR - Internal rate of return - or economic rate is the rate of return used to measure and compare the profitability of investments. The project acceptance criterion is that the IRR must exceed the social discount rate. Given the two independent projects and budget constraints, the one with the higher internal rate of return should be chosen over the one with the lower rate. The internal rate of return is that rate of discount that the whole system makes – benefits and costs – equal to zero. The internal rate of return is based on the assumption that cost flows are reinvested at the internal rate of return. Therefore, the internal rate of return cannot be used to calculate costs and benefits, because the internal rate of return may produce results that conflict with the ranking based on the net present value method.

3. BCR – Benefit Cost Ratio - A cost-benefit ratio is defined as the ratio of the present value of benefits to the present value of costs. A criterion for project acceptance is that the discounted cost benefit rate must not exceed one. For choices between mutually exclusive projects, the best choice will be to choose the project with the highest value of the cost benefit rate. However, a typical problem with the discount rate is obtaining accurate cash flows.

We can conclude that the calculations of benefits and costs should be made based on a pure economic principle.

CONCLUSION

In this paper, a methodology has been developed for estimating the costs of a company in cases of accidents and occupational diseases at the workplace, what the costs can be, how to achieve cost reduction and how to predict those costs. For this purpose, a program was developed that measures costs and analyzes the profitability of investing in safety and health at work. Through the examples of research by other authors, we have seen other similar methodologies for calculating costs in the event of accidents or occupational diseases, as well as methods for analyzing the parameters that participate in the construction of those methodologies and cost-benefit analysis for examining the effects of prevention in the creation of prerequisites in work to reduce the risk of an accident or occupational disease.

However, no matter how much we try to improve the conditions related to safety and health at work, as well as the well-implemented system for safety and suffocation at work, we still have accidents and injuries at work, which in turn lead to increased costs related to safety and employee health. The methodology developed in this paper will be able to be applied in several industries and is expected to lead to significant material savings for companies in terms of issuing damages for employee misconduct, damages for occupational diseases, legal and court costs, etc. The action plan for the implementation of the planned activities will be relieved of time interruptions due to accidents and illnesses, it will bring savings in terms of loss of material damages due to delays in the deadlines for implementation, etc.

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KNOWLEDGE ASSESSMENT OF WASTE MANAGEMENT WORKERS IN DEBAR REGARDING OCCUPATIONAL SAFETY AND HEALTH

Hadisa Nasufi[1], Monika Lutovska[2], Vladimir Mijakovski[3]
[1]Faculty of Technical Sciences, "Mother Teresa" University, Skopje, MK
e-mail: hadisa.nasufi@students.unt.edu.mk
[2]Faculty of Technical Sciences, "Mother Teresa" University, Skopje, MK
e-mail: monika.lutovska@unt.edu.mk
[3]Faculty of Technical Sciences, University „St. Kliment Ohridski", Bitola, MK
e-mail: vladimir.mijakovski@tfb.uklo.edu.mk

Abstract: The purpose of this study is to find the relationship between workplace accidents and the lack of education and training for Occupational Safety and Health (OSH) among municipal waste management workers. The study focused on determining the level of understanding of the importance of preventing injuries at work, as well as the level of awareness of employees about the risks they face in the workplace. For this purpose, 26 workers were engaged, checklists were made, and a risk assessment was conducted. The research was carried in the public waste management enterprise in Debar, North Macedonia. The obtained results show that the largest number of identified hazards, as much as 58%, are assessed as high risk, most of workers (all employees were male) belonged to the 46-60 age group and none of them had the necessary training on OSH.
Key words: municipal solid waste, occupational safety and health, risk

INTRODUCTION

The process of waste management consists of several steps: collection of waste, transport and disposal, as well as selection and processing. All this process is important for the public health, as well as for the employees who deal with its realization, without neglecting the aesthetic and environmental reasons, [1].
Every year, about 1.3 billion tons of solid waste is generated worldwide. By 2025, this volume is expected to reach up to 2.2 billion tons per year, which is a cause of concern for governments and the society,[2]. With the excessive generation of waste, serious problems have also been created in landfills, [3].
All activities in solid waste management involve risks for the worker directly involved in the collection of waste, but also for the operators in enterprises, [4]. Hazards occur at every step of the process, from the collection of household waste to final disposal [5]. Workers and waste collectors who handle solid waste are exposed to different hazards, health risks and numerous accidents resulting from the composition of the waste being handled, the emissions from those materials and the equipment being used, [6].
Exposure to biological and chemical hazards can result in musculoskeletal, skin, respiratory and gastrointestinal problems. Moreover, solid waste collection workers are exposed to safety hazards associated with the containers or the truck, such as the risk of being hit or run over by their truck, [7].
In the city of Debar, there are 26 workers engaged in waste collection.
Therefore, it is important to determine the level of awareness of their safety at work, and whether they need adequate education and training for the prevention of work-related injuries, accidents and occupational diseases. This is the first time that research of this nature has been conducted in the Debar region.

MATERIAL AND METHODS

The methodology of the study is based on the collection of data through checklists completed by workers, as well as identification of hazards and implementation of risk assessment by Occupational Safety and Health (OSH) experts.

Research begins with observing the work process. In these facilities, the analysis of work, processes and work materials is carried out, where the research was conducted during the months of July and August 2022, which are considered the busiest months.

This research includes 26 employees classified into 4 groups participating in the work process. Checklists containing a demographic questionnaire, awareness questions, and observational control questions, were developed and used as research instruments. In that way, the necessary methodology was created and consisted of several steps:

- Data collection;
- Identification of risks;
- Conducting a risk assessment;
- Data processing and analysis;
- Presentation of the results.

RESULTS AND DISCUSSION

The results of the demographic questionnaire in the checklists indicate that the most (38.5%) employees are in the age group from 46 to 60 years old, followed by the group from 31 to 45 years old with 26.9%, and with the lowest participation of 3.8% in the work process are in the age group 0-18 years.

Socio-demographic data on waste management workers show that all employees were male and there were no women employed in this sector. Most of the respondents had completed primary education and none of them had completed higher education (Table 1).

Based on respondents' answers, the results show that 30.8% have 5-10 years of work experience, 26.9% are those with 10-20 years of work experience, and 23.1% of participants have 20+ years of work experience. The lowest representation of 19.2% are those with 0-5 years of work experience.

From the responses received from the checklist, the majority of workers (57.7%) deal with house-to-house/container collectors, 34.6% are street sweepers, 23.1% of respondents were drivers and 15.4% are drain cleaners.

Table 1. Sociodemographic characteristics

Variables	Percent
Gender	
Male	100%
Female	0%
Age	
0-18 years	3.8%
19-30 years	15.4%
31-45 years	26.9%
46-60 years	38.5%
61+ years	15.4%
Education	
No education	15.4%
Primary	53.8%
Secondary	30.8%
Tertiary	0%
Work experience	
0-5 years	19.2%
5-10 years	30.8%
10-20 years	26.9%
20+ years	23.1%

Job position	
Street sweepers	34.6%
House-to-house/Container collector	57.7%
Driver	23.1%
Drain cleaner	15.4%

Also, one of the biggest problems is the training of workers for safety and health at work, where they stated (Figure 1) that none (100%) of the employees had training on safety and health at work and only the drivers had training on the use of machinery.

Identifying risks and risk assessment

During the identification of the dangers, all situations are taken into account, especially those that have the greatest potential for creating a high risk. In table 2, the following labels are used: R - risk, H - high risk, M - moderate risk, L - low risk.

Table 2. Identifying risks

	Condition	Hazard	R
1	Mechanical hazards	Catching hands or parts of clothing in moving parts of the truck, during placing the containers on the holders	H
		Detaching the container from the truck supports and pushing the worker	H
2	Hazards due to the characteristics of the terrain work	Slipping or missing the stand on the back of the truck when getting on or off	H
		Slipping due to not wearing proper non-slip shoes	H
		Falling when getting on or off the truck while it is moving	H
		Slippery and dirty handrails that can cause falls when climbing onto the garbage truck stand	H
		Moving on wet or uneven surfaces when picking up, carrying to the truck, and emptying trash cans	L
		Moving past scattered or scattered municipal waste	L
		Danger due to dog attack when working outdoors	H
3	Chemical hazards	Inhalation of unpleasant odors, dangerous volatile substances, gases or dust during garbage collection	M
4	Physical harm	Noise generated by the waste collection truck as well as other sources of noise	L
5	Climatic conditions	Outdoor work, exposure to high or low temperatures, wind, rain, snow and other unfavorable atmospheric influences	H
6	Biological hazards	Infectious agents, microorganisms, allergens and bacteria, hazardous waste and other decomposed substances	H
7	Psycho-physiological eexertions	Manual lifting of garbage cans and placing them in position for emptying in the garbage truck	H
		Eexertions due to a non-physiological state of the body associated with prolonged standing	M
		Bending, pushing and pulling when lifting bins and picking up scattered rubbish	M
		Stress due to performing heavy physical work with increased intensity	M
8	Organization of work	Activities during increased workload, shift work, overtime work	M
		Lack of education about the safety of one's workplace and the	H

		importance of taking care of oneself and one's colleagues	

It can be seen from the identification of hazards and the conducted risk assessment at the workplace of a waste management worker, that the largest number of identified hazards, as much as 58%, are assessed as H. It is characteristic that in this group also belongs the hazard of lack of education about own safety in the workplace, which shows a worryingly low level of awareness about OSH. The remaining hazards are divided so that 26% are of M, and 16% are of L. The conducted analyzes only confirm that this is a high-risk workplace for which the state institutions in the communal area should take more care in educating the workers and building a concept in which the health and well-being of the worker will have a primary position.
As a precondition to the risk assessment, a checklist for the workers in the company is conducted. Considering that all waste management steps pose a risk to workers, personal protection of workers is essential. Personal protective equipment was provided by the company to all workers. However, from the responses received from the checklist presented in Figure 1, we see that the majority of workers lack knowledge, and do not use personal protective equipment (PPE). Gloves are the most used PPE by the workers. Lack of knowledge about PPE can also be a result of low education of workers.

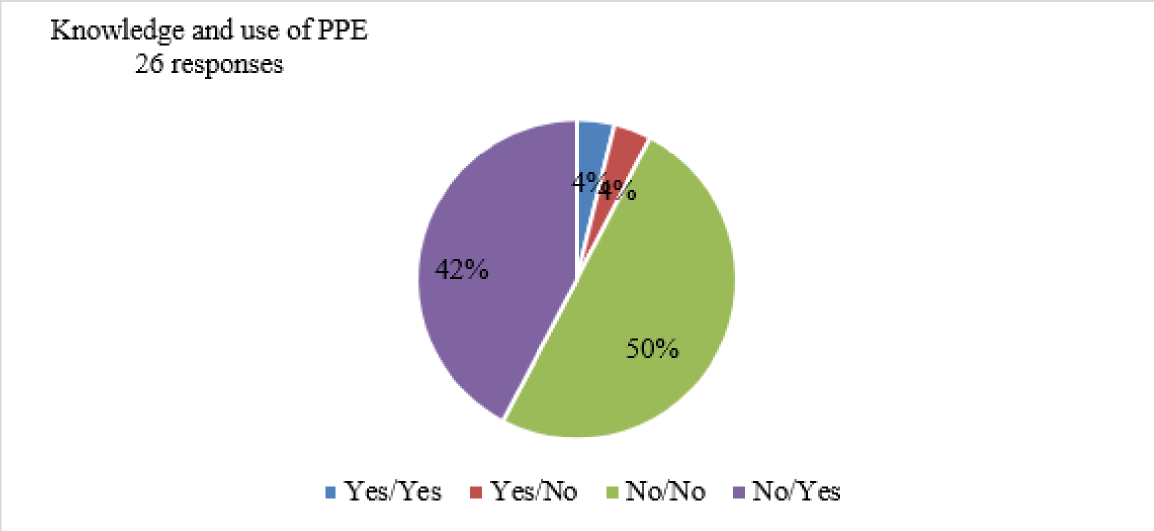


Fig. 1. Knowledge and use of PPE

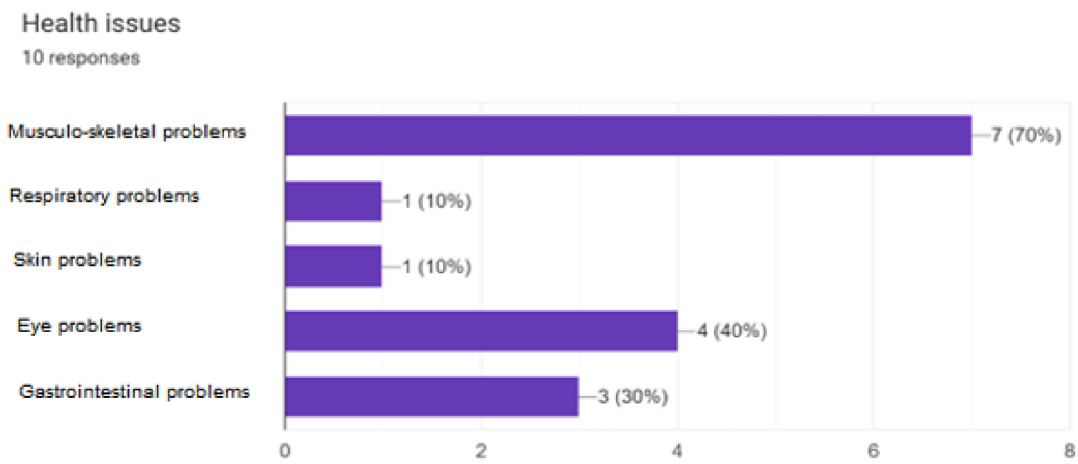
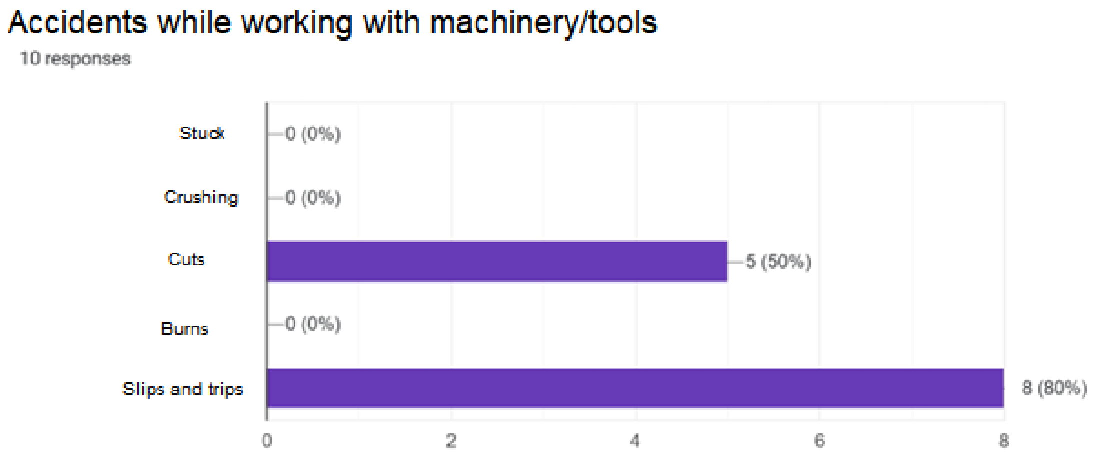


Fig. 2. Health-related issues

As for the questions related to health-related issues and accidents at work with machinery and tools, the majority of the respondents chose not to fill the checklist. From the responses received (Figure 2)

from the interviewed workers on health issues, the majority (70%) stated that they have musculoskeletal problems, 40% stated eye problems, 30% gastrointestinal problems and 10% answered that they have respiratory problems and skin problems.
The literature points out that those workers who deal with waste management are exposed to injuries from sharp objects such as glasses, syringes, nails, spikes and thorns and also some authors also note the risk of slipping and falling,[2]. The most accidents among workers (Figure 3), 80% reported slips/trips, and 50%



cuts.

Fig. 3. Accidents while working with machinery/tools

When the workers were asked about their attitude on the idea of whether they can bypass some security measures when they have practiced a profession for a long time, that is, in some way, by means of this question, overconfidence was assessed. The results (Figure 4) are mixed, where unfortunately 19% of workers chose the answer that they completely agree that security measures could be bypassed. While only 8% answered that they think that security measures should always be followed.

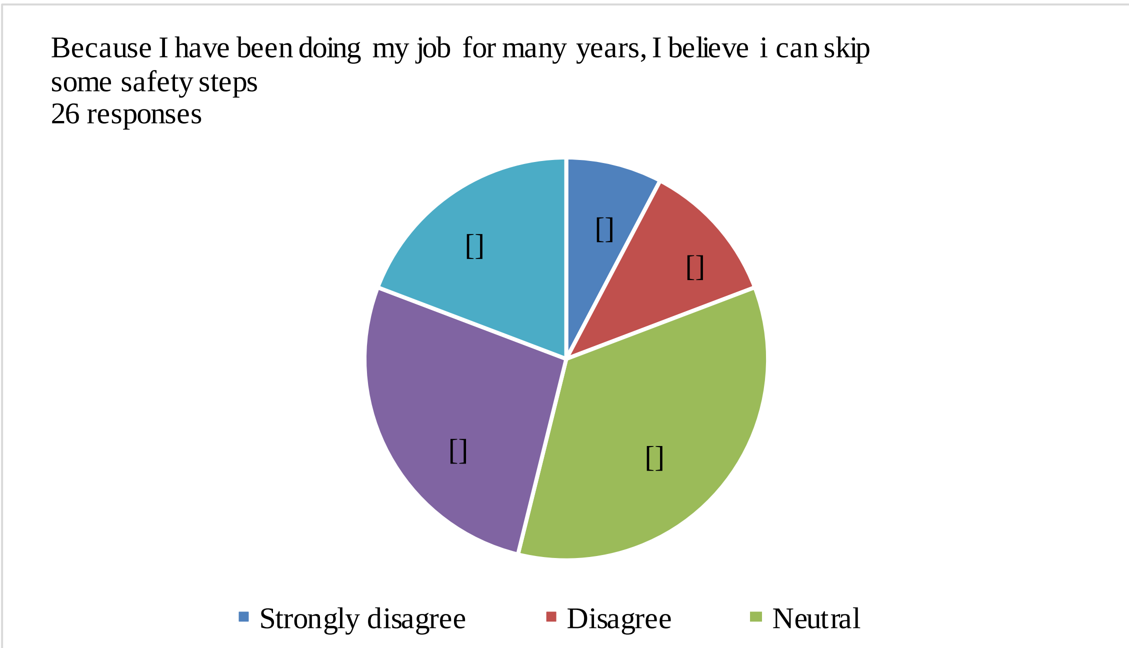


Fig. 4. Results about the question “Because I have been doing my job for many years, I believe i can skip some safety steps”

CONCLUSIONS

Waste management is known as a problem in Debar, since the place where the waste is disposed and stored for a long time is an unregulated and improvised landfill. This becomes even more worrying when the health risks threaten the population and the workers who deal with the waste management are known.

This research highlights the unsatisfactory and unsafe work environment among waste management workers in the city of Debar, which results from the lack of training of workers in relation to OSH, the lack of adequate use of personal protective equipment and the lack of workers' knowledge of the health risks that come as a result of the workplace.

In general, the most common problems reported among workers were Musculo-skeletal problems that pose a risk to their health, and more workers had experienced slips, trips and falls during their work.

Changing the attitude of the workers towards personal protective equipment and towards the safe work should be aimed through education and training on safety and health in the workplace as well as increasing the confidence that the OSH law can bring changes in their lives is necessary.

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ASSESSMENT OF BUILDING STOCK: CASE STUDY OF NOVI SAD

PhD Nikola Karanovic[1]
[1]University of Aveiro, Portugal
e-mail: nikolakaranovic@ua.pt

Abstract: The construction sector is a key industrial economic sector related to the processes construction, renovation, and demolition of buildings. The efficiency related to the use of resources in the construction of infrastructures, has an important impact on energy savings, against climate change and to the environment. One of the greatest challenges of the economy is to integrate environmental sustainability with the economic growth, by decoupling environmental degradation from economic growth. There are large differences between high-income industrial countries and the rest of the world regarding the trends of stock growth as well as their share in global stocks. Methodology related to the estimating of building stock incorporates quantitative analysis of construction stock, which is accumulated in the single-family housing sector in the City of Novi Sad. This work presents status of the construction stock for Novi Sad for the 2010 year. In order to quantify stock (expressed in tonnes), quantity of used construction materials obtained from the project for of one single-family house is multiplied with the housing area in the City of Novi Sad. Highest values related to the single-family housing building stock (t) have city areas Adice, Klisa and Telep. This work shows simplified model of calculation related to the building stock and could be improved. Building materials as a stock embodied in the housing sector could be valuable urban mine in order to obtain new raw products as a measure of prevention considering extraction and usage of natural resources and reducing the environmental impact.
Key words: Construction, environment, stock

INTODUCTION

The construction sector is a key industrial economic sector related to the processes construction, renovation, and demolition of buildings. This sector has strategic importance for many countries across the world as it delivers the infrastructures needed by the economy and society. The efficiency related to the use of resources in the construction of infrastructures, has an important impact on energy savings, against climate change and to the environment. One of the greatest challenges of the economy is to integrate environmental sustainability with the economic growth, by decoupling environmental degradation from economic growth. There is a need for approach which considers resource efficiency through the life cycle of materials. The main focus for sustainable constructions is the reduction of the environmental impact that comes from the use of resources, such as, materials, water and embodied energy. The analysis of the life cycle of buildings, from the extraction of raw materials to demolition process or renovation and the recycling allows assessing those impacts. Buildings have the potential to reach a 90% reduction in their contribution to the greenhouse gas emissions by 2050 [1].

A huge amount of the globally extracted raw materials are accumulated in the buildings and infrastructures. As these materials – practically or theoretically can be reused by society, they are called “material stock” or „anthropogenic stock“. Building material stocks are central driver for resource flows, as housing, transport or energy with the fact that infrastructure require huge amounts of non-renewable materials. Once they are built, stocks also require a steady inflow of resources for its use, as well as for its maintenance. Nevertheless, the decision on how to design the anthropogenic stock also determines long-term patterns of raw materials and energy use, as well as resulting waste flows, recycling potentials and greenhouse gas emissions. Not least against the backdrop of climate change mitigation, more and more research on material stocks or the so called “stock flow service nexus” is carried out to understand the inter relations between material and energy flows (and related carbon emissions) and material stocks. Estimating material stocks is a complex and comparatively new area within material flow accounting [2].

A study by Wiedenhoferet et al. (2019), has shown that about half of the raw materials extracted each year on the globe are used for the building of new stocks or the maintenance of stocks which are currently in use. In the year 2014, globally, the anthropogenic stock increased to 792 billion tonnes. There are large differences between high-income industrial countries and the rest of the world regarding the trends of stock growth as well as their share in global stocks [3].

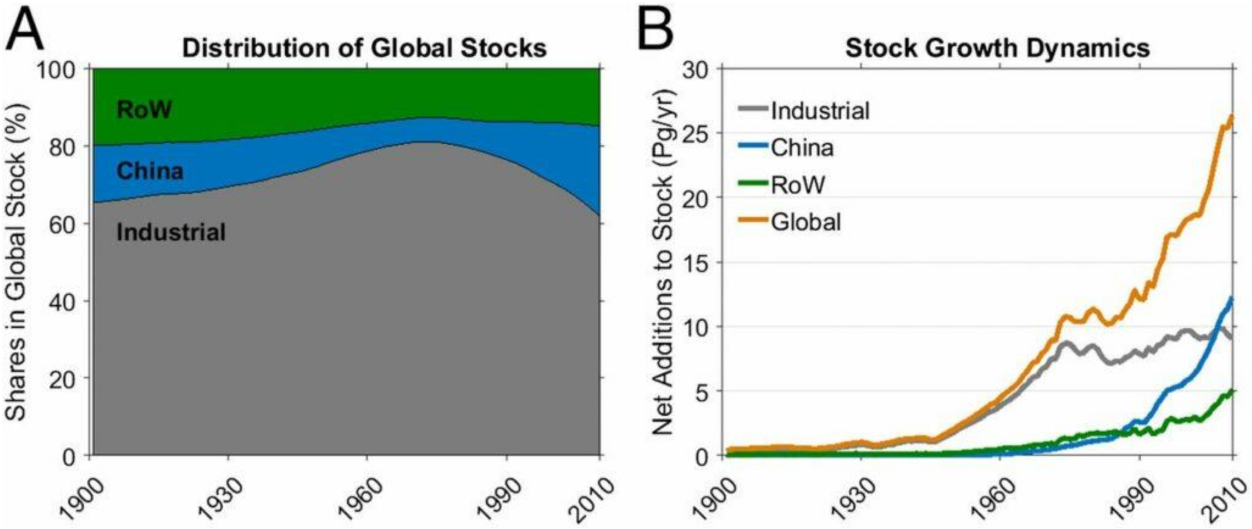

Fig. 1. Share of country groups in global stocks (A) and annual net additions to stock (B), 1990 – 2010 [4]

The figure above shows that from 1900 to 2010, industrial countries held the largest share in global material stocks. The accumulation mainly took place in the period after World War II until 1970. From the 1990s onwards, China was increasing its net additions to stock (balance between inputs and outputs, see above) and surpassed those of the industrial countries. By 2010, China owned 22% of the global stocks, in comparison to 60% located in the industrialized countries. The rest of the world had a share of 18% in global stocks in 2010, whereas its population made up 62% of the global population. Nevertheless, large differences of per capita stocks existed between industrial countries, China and the rest of the world. Since then, more and more countries are developing industrial consumption patterns. Significant growth of global anthropogenic stocks can be assumed for the rest of the world [4].

METHODOLOGY

Methodology related to the estimating of building stock incorporates quantitative analysis of construction stock, which is accumulated in the single-family housing sector in the City of Novi Sad. Main source of data used in this research is study “General urbanism plan of the Novi Sad”, from 2009. Due to the lack of the data related to the multi-family housing sector in the City of Novi Sad, only single-family housing sector is analysed in this work. This work presents status of the construction stock for Novi Sad for the 2010 year.

This research uses data of the construction project for one single-family house provided by the private company in Novi Sad. Data concerning this project include data related to the construction materials (“bill of the materials”). Calculation which is performed in order to obtain quantity of used construction materials for the single-family house has shown the amount of 2087 kg/m^2. In order to quantify stock (expressed in tonnes), quantity of used construction materials obtained from the project for of one single-family house is multiplied with the housing area in the City of Novi Sad.

City areas of Novi Sad which are the subject of this analysis are presented in Table 1.

Table 1. Single-family city areas of Novi Sad, in 2010 [5]

City area of Novi Sad	Housing area/Single-family housing (m^2)
Adice	157504
Bukovac	15938
Cardak	34149
Karagaca	9071
Kip i Bocke	34693
Klisa	248638
Mali Beograd – Veliki Rit	56662
Miseluk II	36514
Sajlovo	46741
Salajka	64198
Sirine	80
Staroiriski put	32130
Sumice I and II	29431
Telep	338935
Veternicka Rampa	18434
Vidovdansko Naselje	33652

Quantity of used construction materials of analysed areas of Novi Sad is calculated as:

For single-family houses:

$$QCM = THA * QCM_{osfh} \quad (1)$$

In which, QCM refers to the quantity of used construction materials, THA to total housing area, and QCM_{osfh} to quantity of used construction materials for one single-family house (2087 kg/m^2).

RESULTS

The largest area of residential use is occupied by single-family housing – 62.4%. This is followed by general residential areas, which occupy 19.5%, followed by multi-family housing to about 15%. A small part of the area is also occupied by single-housing in combination with work activities (about 3%) and the vacation housing areas (about 0.4%) [5].

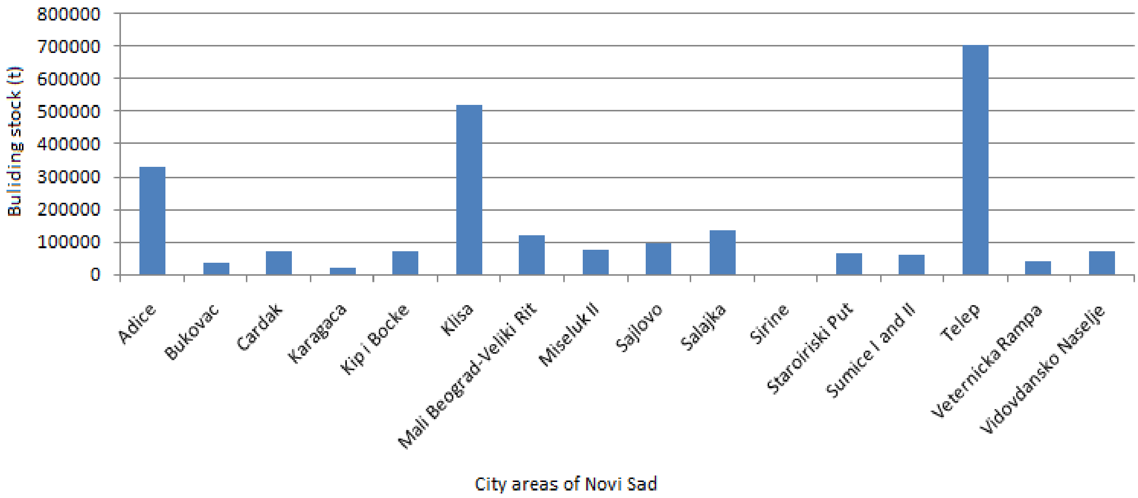

Fig. 2. Building stock (t) in the city areas of Novi Sad, in 2010 [5]

As presented on the Fig. 2, highest values related to the single-family housing building stock (t) have city areas Adice, Klisa and Telep. It is important to amplify that those three city areas have highest housing areas according to the study “General urbanism plan of the Novi Sad”, from 2009.

CONCLUSION

This work shows simplified model of calculation related to the building stock and could be improved. With the fact that this analysis considers only the single-family housing sector in the City of Novi Sad, there is a need for the analysis related to the multi-family housing sector for the City of Novi Sad, which could be the future challenge in order to acquire more aggregated results related to the building stock in this case.

All the processes related to the construction works have a negative environmental impact. Increasing the number of buildings implies the extraction and usage of natural resources, impacting biodiversity, air quality, water, and environment as whole, producing of huge amount of waste. Rational use of natural resources is an essential factor in applying the principles of development with savings. Building materials as a stock embodied in the housing sector could be valuable urban mine in order to obtain new raw products as a measure of prevention considering extraction and usage of natural resources and reducing the environmental impact.

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GREEN MANAGEMENT OF HUMAN RESOURCES AND GREEN BEHAVIOR OF EMPLOYEES IN MODERN ORGANIZATIONS

Dragana Kovač[1], Edit Terek Stojanović[1], Mila Kavalić[1,2], Verica Gluvakov[1], Maja Gaborov[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
[2]University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
e-mail: milosavljevd@yahoo.com

Abstract: Organizations that operate in the modern environment are becoming more and more aware of the changes that are taking place, especially those that concern the environment. Global warming, increased air and water pollution and depletion of natural resources contribute to increasing climate change. Organizations therefore direct their business strategies and practices towards environmental protection. One of the most important factors to influence is employees. This is where the function of green human resource management comes into play, which directs all human resource management activities towards environmental protection and influences employees to develop green behavior. This paper will explain the concept and importance of green management of human resources, green behavior of employees, as well as the impact of green management of human resources on the green behavior of employees in modern organizations.
Key words: green management of human resources, green behavior of employees, sustainability

INTRODUCTION

Climate change has become a major concern for countries around the world, as it is linked to global warming, which further affects food production and human life. Human behavior has the greatest influence on this situation, as well as on air, water, and soil pollution. Organizations additionally contribute to this with their operations, because they create large amounts of waste and irrationally consume non-renewable energy sources [1]. For this reason, in addition to achieving business success and competitiveness, one of the main goals is sustainability and environmental protection. In order to achieve this, organizations adapt their business strategies to environmental protection, and as one of the results of this business practice, green management appeared [2]. Green management represents practices that produce environmentally friendly products and minimize the impact on the environment, through green production, green research and development, green marketing [3]. One of the important functions for competitive business is the green management of human resources.
The human resource management function has a key role in the creation and implementation of sustainable business strategies throughout the organization [4]. As organizations are now changing their business strategies and practices, focusing on environmental protection, the Human resource management (HRM) function is also transforming into green HRM. Green management of human resources implies the greening of all strategies and practices in the field of human resources management, with the aim of greening the organization itself and protecting the environment [5]. It was created as a result of the great need of organizations to integrate environmental sustainability into their business models and is applied to implement green strategies and achieve the organization's green goals [6]. Green human resource management implies the adoption of the following functions of human resource management, with a special focus on environmental protection: recruitment and selection of employees, training and performance management, rewarding, involving employees in improving the environmental performance of the organization [2].
One of the strategies that organizations follow to improve their environmental performance and achieve sustainability goals is green employee behavior. It can be defined as employee behavior that has a beneficial impact on the environment [7,8]. Green behavior can be: voluntary green behavior (personal initiative) and green behavior according to the task (according to the job description) [9]. As concrete examples of green behavior in the workplace, we can mention: eliminating/minimizing the use of paper, sharing employees' transportation, turning off the computer when not in use, working in natural light as much as possible, using the stairs instead of the elevator, etc.

Green management of human resources should have an impact on the green behavior of employees. The adoption of green human resource management strategies and practices will signal the organization's commitment to environmental conservation, which is likely to make employees work toward achieving the organization's green goals [10]. Of course, for green human resource management to be more effective in eliciting green behavior from employees in the workplace, it should ensure that the organization has recruitment strategies that aim to attract employees who have similar environmental values as the organization; development, performance and reward practices that take into account individual environmental performance and effective training programs that develop environmental awareness, attitudes, skills and knowledge [11].

GREEN MANAGEMENT OF HUMAN RESOURCES

The human resources function has a key role in the creation and implementation of sustainable business strategies throughout the organization. Therefore, human resource managers should see themselves as strategic drivers of environmental and sustainability initiatives [12, 13]. Green human resource management means programs, processes and techniques that are implemented in organizations in order to reduce the negative impact on the environment or improve the positive impact on the environment. The ultimate goal of green human resource management practices is to improve the sustainable environmental performance of the organization [14]. To ensure that organizations get the right environmental performance of employees, it is necessary to adopt or modify human resource management functions to be green (Figure 1) [15-17].

Fig. 1. Greening of human resource management functions

Green human resource management refers to all activities involved in the development, implementation and ongoing maintenance of the system, which aims to make the employees of the organization green. Therefore, it is the side of human resource management that deals with the transformation of normal employees into green employees, in order to achieve the organization's environmental goals and make a significant contribution to environmental sustainability [14]. Green human resource management becomes necessary to ensure environmentally friendly products and operations, to successfully manage corporate environmental programs, and to overcome the challenges of implementing corporate environmental programs. Prominent policies in recruitment, performance appraisal, training and development, employee relations and reward systems are considered powerful tools for aligning employees with the environmental strategy. Precisely because of this, the green management of human resources can contribute to the successful management of environmental protection [15, 18].

GREEN BEHAVIOR OF EMPLOYEES

One of the key strategies that organizations follow to improve their performance and achieve sustainability goals is green employee behavior [7]. It is a specific form of employee behavior towards the environment. It can be defined as a form of employee behavior that has a beneficial impact on the environment, that is, the intentional behavior of employees who try to reduce their negative impact on the environment [8, 19]. The green behavior of employees can be divided into two types [9-11]:

- voluntary green behavior of employees - includes personal initiative of the employee and exceeds organizational expectations;
- green behavior of employees according to the task - it is performed within the organizational limits and within the required work duties. It includes activities that are formally described and identified as part of the job description. This specifically refers to employees from who e.g. require them to ensure that toxic waste is not poured into local water systems or that hazardous material is disposed of in accordance with laws and regulations.

Green employee behavior implies three dimensions of employee behavior. The first dimension refers to green organizational citizenship behavior, which is defined as the degree to which an employee engages in positive actions aimed at helping the organization achieve its environmental development. These actions are not part of formal job requirements, but represent voluntary green actions of employees [15]. Some examples of such actions are: double-sided printing of documents (or switch to electronic form of documentation); use public transport, bicycle or walk to work; when not in use, turn off the computer; work with the minimum number of switched-on light bulbs and make maximum use of daylight; use recyclable material etc. Another dimension of green behavior is green interpersonal citizenship behavior, which refers to the degree to which an employee engages in actions aimed at helping coworkers make their jobs "greener." This is not part of the formal conditions for the job, but represents voluntary help that the employee provides to his colleagues [15, 20]. Examples of such behavior are: teaching others to be "green"; stimulating and providing support in carrying out such actions; answering questions about greening. The third dimension of green behavior is green official behavior and is defined as the degree to which an employee engages in the official duties assigned to him by his superior in relation to environmental protection. This engagement is not voluntary, but represents an official obligation that the employee must fulfill. Such duties may include specific procedures that the employee must follow in order to reduce loss and eliminate waste [15, 3].

In order to achieve the organization's green goals, identify and determine the requirements for green human resources. There are four categories of these requirements and they are: green competencies, green attitude, green behavior and green results. Green competences (knowledge and skills that employees possess about environmental protection) and green attitude (constructed positive attitude about environmental protection) are seen as green inputs of employees, and green behavior and green results represent green performance of employees, which contributes to green organizational performance and meets the requirements of socially responsible business (Figure 2) [15, 21].

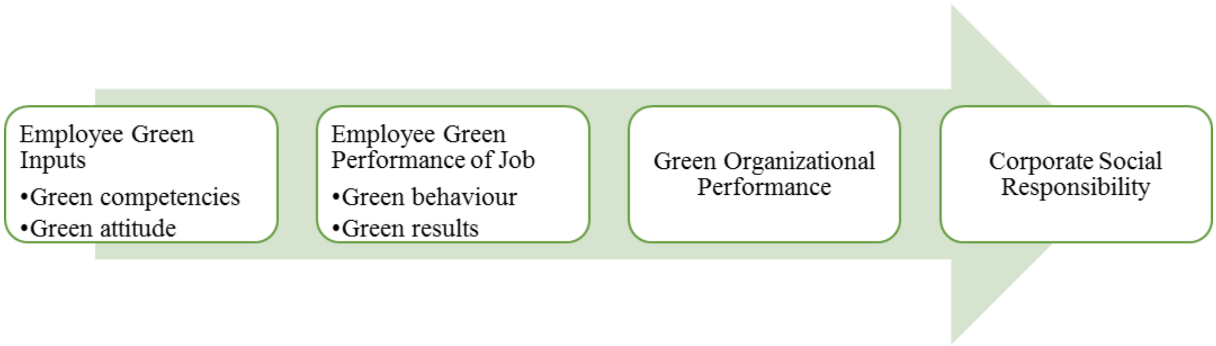

Fig. 2. Employee green inputs and employee green performances of job

THE INFLUENCE OF GREEN HUMAN RESOURCE MANAGEMENT ON THE GREEN BEHAVIOR OF EMPLOYEES

Green human resource management practices refer to human resource management activities that have a positive impact on the environment. These practices can be categorized into three primary activities: developing green employee capabilities, motivating green employees, and providing green opportunities [12]. Developing employees' green capabilities involves the integration of positive environmental thinking in the organization using human resource management activities (recruitment, selection, training) [22]. Once engaged and trained, employees are motivated through performance measurement and building systems to improve their environmental performance in the organization. Therefore, it could be said that human resource management practices influence the improvement of green behavior of employees [23]. Therefore, the reasons why it can be expected that the green management of human resources will influence the green behavior of employees are as follows [10]:

- communicating the organization's preferences for environmental protection during employment and considering the environmental values of individuals in the employee selection process, which is likely to increase employees' awareness of environmental performance;
- involving employees in the implementation of green initiatives and providing green training will improve the knowledge, skills and abilities of employees and make them more available to engage in green behavior;
- the adoption of green human resource management policies and practices will show the organization's interest in contributing to the preservation of the environment, which will likely make employees work to achieve the organization's green goals.

Green human resource management practices will directly influence the green behavior of employees if it is officially valued and rewarded, thus becoming a common behavior in the workplace. However, voluntary green behavior of employees is not necessarily influenced by green human resource management. Voluntary green behavior will be most influenced by knowledge of the organization's green culture, as well as the willingness of the employee to implement such behaviors and habits in his/her daily life [11]. Therefore, integrating the green behavior of employees into the reward and incentive systems of the organization (green profit sharing, green employee of the month and a lump sum based on green performance, additional days off, etc.) improves employees' perception of the attractiveness and fairness of such systems. For this reason, they will build positive attitudes and show a high level of engagement when performing tasks [24].

CONCLUSION

The primary goal of every modern organization is to achieve business success. Over the past few decades, managers have realized that doing business in a highly competitive global economy requires efficiency and effectiveness, but also environmental responsibility. For this reason, the process of greening the business began. One of the functions that is given great importance to, is the green management of human resources. Green management of human resources plays a significant role in achieving sustainable development in the organization, through its functions of recruitment and selection of employees, training, and performance management, involving employees in improving environmental performance, shaping organizational culture, structure, strategy and policy. Also, organizations in order to improve environmental performance stimulate green behavior of employees. It implies employee behavior that increases the positive and decreases the negative impact on the environment. Green employee behavior includes activities such as: rational using of resources, energy saving, recycling, waste reduction, etc. Through its functions, green human resource management influences the green behavior of employees. This especially applies to the recruitment and selection of employees, who already have green preferences. Also, rewarding employees plays a big role in encouraging green behavior, whether it is material or non-material rewards. Therefore, by greening the management of human resources and encouraging green behavior of employees, in addition to achieving their business goals, they also influence organizations to gain a better reputation on the market.

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SIGNIFICANCE OF CONTROL INSPECTIONS OF ELECTRIC TWO-GIRDER BRIDGE CRANE IN ORDER TO INCREASE SAFETY AND SECURITY AT WORK

Jarčević Duška[1], Ljiljana Radovanović[2], Jasmina Perišić[3]
[1] JP Elektroprivreda Srbije, Branch Panonske TE-TO, TE-TO Zrenjanin, Serbia
[2]University of Novi Sad,Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
[3]Faculty of Informatics and Computer science, Belgrade, Serbia
e-mail: duskajarcevic@panonske.rs

Abstract: Productivity and safety of complex mechanical constructions, such as lifting machines, are needs that are named in some of the process systems where certain activities related to the production process are required. Today, high reliability is required from machines or plants in companies in terms of minimizing failure states, downtime, up to the almost complete elimination of critical points, in order to avoid large losses in the manufacturing industry. The work is based on increasing safety and security in the operation of the electric two-girder bridge crane with a capacity of 125/25 t and it's proper maintenance and control testing in order to determine reliability and safety. The research is focused on defining the procedures and control inspections of the electric the electric two-girder bridge crane with a capacity of 125/ 25 t from the aspect of increasing safety and security at work. By analyzing aspects of safety and reliability, regular and periodic maintenance, the importance of control inspections in the field of application of the bridge crane and its operation is determined.
Key words: two-girder bridge crane, safety, security, reliability, production process, failure conditions, inspection ¶

INTRODUCTION

Without machines and equipment, no field of modern engineering, as well as modern man, can function. The most important link in engineering is represented by cranes, machines or tools that facilitate the movement of materials and objects of a certain weight to certain heights and distances. When we focus our attention on industry, a significant part of the activities in various areas of industrial production are performed by cranes, and in this way significant savings in work, time and costs are achieved. Today, they exist in numerous versions, and each of them is adapted for the specific use and according to user requirements [10]. Sometimes the sizes vary from the smallest cantilever cranes used in workshops, to the highest tower cranes, which are used for the construction of tall buildings. In this work, attention will be paid to the large bridge cranes, and one of the most famous types, the electric two-girder bridge crane - crane with a capacity of 125 tons, auxiliary hooks with a load capacity of 25 tons, as well as the importance of inspections in the field of safety and security at work. Cranes and other equipment for lifting loads need to be regularly maintained and checked in order to replace consumable parts and to continue to operate safely, and therefore, safety and security at work is ensured. By ensuring safety and security at work, they prevent possible breakdowns and failures. Unfortunately, preventive maintenance involves replacing parts that are still functional. The reason for this is that, until recently, it was impossible to determine the degree of loading and mechanical stress of critical parts, as well as the time period for their replacement.

MATERIAL AND METHODS

Global production of biodiesel

As part of this research, theoretical analysis methods were used (expert literature, project documentation was analyzed). An experimental method will be used to check the correctness of the mechanical structure of the two-girderbridge cranewith a capacity of 125/25 tons. The following devices and instruments required for maintenance were used as research instruments: Multifunctional measuring device for testing protection in electrical engineering, manufacturer Metrel Slovenia, type Eurotest 61557, serial number 17022473, inventory number 112100; Certificate of certification of gauges, issued by "Measures and precious metals institute" Belgrade, "Control of measures and precious metals" Zrenjanin number 3/6-01-1131, Certificate of calibration of gauges issued by "Metrel; General purpose mechanical dynamometer 0-100 kN, manufacturer USSR, type DPU-10-2, factory number 1493, calibration certificate number 74/08; Laser distance meter BOSHCH-DLE 150; Measuring tape - Meter "KINGKI"; Distance meter "Stanley", type TLM 160; Sliding scale: KPM 01, range (0-150mm); Stopwatch. The research was carried out in the part of the Pannonian Thermal Power Plant - Zrenjanin thermal power plant in the hall of the main operating facility GPO, where the machine structure of the two-girderbridge crane with a load capacity of 125 tons is located for servicing during regular overhauls, which is an integral part of the system in the production of electricity, steam and hot water.

MAINTENANCE AND CONTROL OF CRANEUNITS

Reliable safety in the operation of the crane, depends to a large extent on the correct use of the crane, as well as on timely overhaul. That is why it is necessary to regularly carry out the scheduled inspections and checks of all the crane assemblies. In the inspection control book or the Total Observer inspection program or more recently in a computerized system that is intended exclusively for this type of purpose, the results of the inspection of the crane and all repaired faults on it are entered. At the same time, all stoppages due to faults, a description of the faults and the method of eliminating those faults are entered.

Rope control

The steel ropes on the hoist must be replaced, if they are worn out ort they have fallen off the drums or pulleys under load and become damaged. In case of tearing of individual wires of the rope, the resulting knots should be tightly tightened against the surface of the rope with pliers. The number and position of the broken wires must be constantly controlled, at least once every 10 days. Depending on the safety coefficient and the construction of the rope, the minimum number of broken wires in the length of one ort he the rope can be tolerated and determined in a table. Steel ropes on cranes for transporting molten or hazardous materials must be replaced, if more than half of the broken wires shown in the table show a length of one step at the damaged place. Worn steel ropes must be replaced even when the number of broken ropes is less than 10%, if the total number of broken and corroded or thinned wires along the entire length of the rope reaches 40% of the total number of wires in the rope. The dates of wire changes must be entered in the records. The ropes are lubricated according to the instructions in the lubrication scheme, and the wires are cleaned with a brush soaked in kerosene. Cleaning with a metal brush and other sharp objects are not allowed. When unwinding the new rope, be careful not to create loops that lead to delamination and a decrease in its strength. The ort h such a layered rope is not allowed. The ends of the ropes are attached to the drum using clamps, clamping devices. ort he daily inspection of the crane, during the handover of the shift, it is necessary to carefully check and possibly tighten the fastening joints [9].

Roller control

When checking the reel, the rigidity of the hook, the hook traverse, the protective shields, the condition of the lubricant, the free rotation of the hook, the traverse pulley are checked. Inspection is done daily.

Lugs – Reels

To direct the ropes for loads, turning reels are used, placed on rolling bearings. In order for the ropes to work without crushing and flattening, the radius of the channel on the groove must be equal to R = (0.47 to 0.53) d – JUS M.D1.200. According to the degree of wear of the working surface of the reel, this radius decreases (a recess is machined in the groove), so there is a danger of rope wear. That is why the reels should be checked once, every 6 months. The permissible wear of the grooves ≫i≪ is 2 mm for rope diameter 13-22 mm, 3 mm for rope diameter 22.5-33 mm. If the wear of the working surface is greater than allowed, the profile of the reel should be processed by scraping, while the thickness must not exceed 20%. When inspecting the pulleys, in addition to the condition of the groove, the surface of the pulley rim, which must not have cracks or holes, the correctness of the lubrication system, the free rotation of the pulley on the shaft, the absence of lateral sway and the strength of the connection of the sealing covers are also checked [3].

Control of bearings

The operational reliability and longevity of roller bearings depends to a large extent on its installation, which can be performed incorrectly after overhauling the crane assemblies[11]. Insufficient protection of the bearing from dust, moisture and mud entering the assemblies, lack of the lubricant or insufficient lubrication leads to the destruction of the bearing elements and their premature failure. When looking at the bearings, it is necessary to check the safety of attaching their housings to the structure, as well as the condition of the lubricant and fasteners. Lubricant leaking or ejecting from the bearing occurs due to wear of the sealant or excess, which is manifested by the appearance of stains on the bearing housing. By then, it is necessary to replace the seal, check the fastening of the bearing or remove excess lubricant. A squeak in the bearing indicates a lack or absence of lubricant, damage to the cage or friction of rotating parts on the housing. When inspecting the bearing, on the surfaces of the grooves and rolling elements, wear can be seen as shiny dust. If scratches or other signs of destruction appear on these surfaces, the bearing must be replaced. In case of transverse cracks and breaks on the rings or the cage, the bearing must be replaced without delay. Greater heating of the bearings can occur due to the appearance of dirt, insufficient lubrication or incorrect installation, damage. Bearings are discarded as worn when dents, scratches on the ring grooves or on the ball rollers and greater radial throw of the inner ring towards the outer ring appear. Kerosene is used for washing the bearing housing [3].

Drums control

When inspecting the drum, the condition of the grooves, the strength of the connection of the rope inserts, the condition of the toothed part of the drum with the reducer, as well as the condition of the bearings, which rests on the other end of the drum, are checked. During the periodic inspection, the cover of the toothed part is removed and the condition of the toothed connection as well as the condition of the lubricant are checked.

Gear clutch control

Toothed couplings are used to connect the wheels of the machine or the crane with the output shaft of the reducer of the movement or turning mechanism [3]. Care of the coupling consists in checking: the tightness of the screws that connect the body coupling flanges, the screws that hold the sealing covers, the safety of the body coupling assembly and the shaft (the presence of axial movement), the condition of the working surfaces, the degree of wear of the teeth [7]. Couplings are replaced when the teeth are worn by 40% of the original thickness (for movement mechanisms) [6]. Tooth protrusion is usually caused by insufficient lubrication and an excessive bevel angle of connected shafts. It is necessary to observe the sealing covers and connectors daily, and when necessary, tighten the screws. The amount of lubricant used to fill the coupling must ensure the operation of the teeth in the oil bath. The coupling bodies fitted on the shaft should only be removed using tools. Assembling and disassembling details by hitting is not allowed. [3]

Control of the Elastic Coupling

Elastic couplings are placed on the mechanism for lifting, turning, moving the cat, moving the crane, and are used for the connection between the shaft of the electric motor and the reducer. One part of the coupling is usually designed as a brake drum and is on the side of the reducer. Larger main bevels of the shafts lead to rapid wear of the rings, and in particularly unfavorable conditions the shaft breaks. If, for some reason, the reducer or electric motor had been removed, it is necessary to check the coaxiality of the shaft during new assembly. When setting the shaft correctly, the clearance between one and the other part of the coupling must be the same around the entire circumference. The largest difference must not be greater than 0.1 mm for every 100 mm of the coupling diameter. The concern about the coupling consists in the clamping force of the bolts, the safety of the coupling and shaft assemblies and the wear of the rubber rings on the bolts. The wear of the rubber rings is checked by turning the electric motor shaft on both sides with the brake drum locked, and the maximum gap between the rubber rings and the opening in the coupling body must not be greater than 2mm per side. For solid couplings, the observation is reduced to checking the safety of the assembly on the shafts, checking the screws and tightening the screws [3].

Wheel control

Wheels are attached to the steel structure of the cat or bridge, from which the movements are carried out. Wheels according to JUS M.D1.110 (drive wheels) and JUS M.D1.111 (free wheels) are mostly used, a wheel with an external toothed transmission is used less often. Balancers are used for crane movement mechanisms mounted on 8 wheels. When inspecting the wheels, it is necessary to pay attention to: fixing the casing, the condition of the beds in the cages, fixing the bearing nuts, condition of the wheel tread.

The wheels must not have cracks or worn rims, and the tread surface of the wheel must not have depressions or holes and must not be worn to a greater extent. The wear of the tread of the wheel in width must not exceed 20% of the original thickness of the rim. During the inspection, the amount of lubricant in all bearings and wheels and the correctness of the sealing rings should be checked. In the wheels where the balancer is installed, the fastening of the balancer to the metal construction of the bridge and the wheels to the balancer is checked. [3]

Brake control

The brake levers are attached to the base via pivots, as well as the electrohydraulic lifter. Brake shoes are attached to the brake levers. The brake lever is connected to the electrohydraulic lifter via another lever with a pin. The lever force is transmitted to the brake levers via tension nut. The brake shoe linings are fastened with countersunk rivets. The lifters are powered by alternating current voltage 380V, 50Hz. The braking force is produced by a spring built into the lifter itself, while the yielding (compression of the spring) is achieved by the action of the working fluid on the lifter piston. [3]

Control of Electromagnetic Brakes

The electromagnetic brake is a part of the electric motor itself. They are powered by direct current, which is obtained through a rectifier unit. During normal engine operation, the coil of the electromagnetic brake is supplied via the rectifier unit. During normal engine operation, the coil of the electromagnetic brake is supplied with direct current and creates a magnetic field that pulls the pressure plate with a force that is sufficient to overcome the brake springs, thus releasing the brake disk, which rotates smoothly together with the engine rotor during operation. In the event of a deliberate or accidental interruption of the power supply, the coil of the electromagnet creates a magnetic field. In this way, the forces of the spring - brakes strongly press the pressure plate on the disc brakes, and braking of the electric motor occurs [3]. Before commissioning, the following conditions must be met: the connector of the power cable must be tightened for a good contact, the grounding line should also be ensured to provide good contact. Bearings must be filled 2/3 with grease, before greasing, the electric motor should be dismantled from the winch, and after removing the fan, carefully dismantle the bearing housings. The rubber bearing seals must be in good condition and must be tight against the shaft sleeve. The brake disc must be adjusted so that the axial stroke of the brake rotor is between 1.0 and 1.5 mm.

In the course of exploitation, due to the wear of ferroid linings, the axial stroke of the rotor increases, which leads to an increase in the braking distance. Regulation of the axial stroke of the rotor is performed via the adjustment screw, the position of the hub of the brake disc is adjusted, after which the screw is re-secured against self-unscrewing. [3]

Control of the Reducer for Lifting and Movement of the Crane

In crane constructions, the following are applied: cylindrical, cylindrical-conical (combined), cochlear, And special reducers. The reducer housing is built in a welded construction of steel sheets or cast iron. The shafts are made of Č1530 or Č1730 steel and are placed on roller bearings. On the outside, the bearings are closed with recessed covers or flanged covers. The ends of the input (high-speed) and output (slow-speed) shafts pass through covers with rubber sealing rings [2]. The gears are made of suitable steel and the teeth are bevelled. Real teeth are rarely used. For lifting the reducer, there are lugs on the housing into which hooks or a steel rope can be inserted. The parts of the reducer housing are connected with screws, the correct mutual position of the parts is ensured with conical pins. Gears are lubricated in the reducer box by immersion in oil, and in vertical reducers for high-speed gear pairs, a pump for forced lubrication under pressure is installed. Oil is poured through the opening on the upper part of the box. The required oil level in the reducer is controlled using the built-in oil level indicator. Draining of the produced oil is done through an opening on the lower part of the reducer, with a screw cap. The bearings on the reducer are lubricated because the gears scatter oil on them. In the winter period, during the operation of the reducer, in order to heat up the bearings and the oil, it should work for a certain period of time without any load at idle. The first oil change in the reducer should be done after 250 hours of operation, and the oil must be drained immediately after stopping the drive. In the case of overheating of the bearing in the reducer, increased gear noise or oil leakage, work must be stopped and the malfunction removed. Bearings must be checked against overheating by touching the hand to ascertain whether it is overheated, in which case it can be said that the bearing is either dirty or lacking oil, and the possibility of wear of the working surfaces on which the rolling elements move should not be excluded [2]. Lubrication of bearings, state of working surfaces, heating and damage are checked. The bearings are heated to a temperature of no higher than 120 degrees before being put on the shaft, and also the temperature must be controlled.

Gearbox Control - Special Planetary

Planetary special reducers for lifting are special constructions as part of the winch structure, on the side of the winch body, which provides easy access for checking, assembly and disassembly. It is adapted so that on one side it directly connects the short-circuit electric motor via the flange.

CRANE SPARE PARTS

In order for the crane to have as few downtimes as possible during use and for the downtimes to be as short as possible (if they occur), in addition to taking regular maintenance measures, it is necessary to make a timely purchase of spare parts and fast-wearing parts. Wearing parts: bearings, sealing rubber rings, splits, etc.

CONTROL REVIEW

Periodic control inspections for cranes are a legal obligation and in case of an undesirable situation, it is the first point to check whether the crane is regularly inspected or not. If controls are not carried out properly, the company or owner will be held responsible and fined in accordance with the relevant regulation. Cranes are equipment that work under heavy loads and therefore have low wear tolerances. Controls of cranes and auxiliary equipment must be performed by a qualified professional and the results must be reported. In this way, failures are detected in a timely manner and measures can be taken for situations that threaten safety or cause large economic losses [3]. The reports of the crane in the previous periodic inspections are first reviewed and if any non-conformity is detected, it is checked whether this non-conformity has been removed or not. In addition, it is checked whether the crane operator is authorized to use the crane. After the previous inspections, the inspection of the crane's technical characteristics begins. Control elements for railway towers, drums and ropes on cranes, hooks, tower cranes and cabin control are carried out. Dynamic and static load checks are performed. Finally, function checks are performed in the unretracted state [6].

ELEMENTS AND SCOPE OF EXAMINATION AND EXAMINATION

The review includes:

1. Overview of prescribed documentation: Instructions for use, maintenance and safe operation, prescribed public document - registry book, static calculation of the crane path, supports and attestation documentation [6].
2. Inspection of the crane - Inspection of the supporting structure and parts, welded places: construction condition, mechanical damage, corrosion, correctness of mechanisms and connections, fuses.
3. Checking the crane - Overview of the necessary equipment and devices for crane management: devices for starting and stopping the crane, crane control device - construction and shape, method of use, possibility of accidental activation, indication of the purpose of the control devices.
4. Inspection of staircases, access passages and platforms - Control of data, inscriptions and warnings on the crane: general data, orive class, carrying capacity, warning and danger signs.
5. Lifting mechanism - devices for lifting and lowering loads: marking of commands for lifting and lowering the load, returning the control commands to their original position after stopping the action on them, checking the speed of lifting and lowering the load, control of the correctness of the end stops of the carrying hook.
6. Braking devices:

Checking the working brake of the lifting mechanism (stopping time), checking the movement and stopping of the bridge along the crane path (end disconnectors or bumpers), checking the movement and stopping of the winch (end switches or bumpers on the crane bridge), checking elements for accepting and carrying loads (mechanical damage, correctness of connections and fuses), checking the correctness of sound warning devices – sirens, checking the protection against unauthorized use of the crane (main switch/lock with lock), checking the lifting capacity of the crane: Testing of the nominal load capacity at a dynamic load of 110% of the nominal load capacity, checking the deflection of the crane

7. Checking the electrical installation. Protection against indirect contact is performed by automatic power cut-off, TN-C system. All exposed conductive parts of the equipment are connected to the grounded point of the system using a protective conductor. By testing the continuity of the protective conductor, the resistance value would be Zsh=0.82 Ω [6].

Evaluation criteria

The conclusion is given for the crane with particularly specific remarks that influenced the issuing of a negative conclusion.

RESULTS AND DISCUSSION

In solving the problem of research and implementation of the set goals, the methodology of preventive maintenance of a two-girder bridge crane with a capacity of 125/25 tons of load was chosen, which includes mandatory, legally regulated and prescribed control inspections, carried out based on the request of the company, according to the article of the Law on Occupational Safety and Health (Official Gazette of RS No. 101/2005 and 91/2015) and Articles 2 and 3. Rulebook on the procedure for inspecting and checking work equipment and testing working environment conditions ("Official Gazette of RS" No. 94/2006, 108/2006-corrigendum, 114/2014 and 102/2015). The crane, its parts and its equipment are subject to legally mandatory inspections every three years [6].

Assessments of maintenance, reliability, as well as control measurement and testing of the reliability and safety at work of the two-girder bridge crane with a capacity of 125/25 tons of load, are processed in detail, on the basis of which the control inspection tests regulated by law are followed up, which guarantee safety and security at work [8].

Expert finding

Based on the performed inspection and testing and the specified evaluation criteria, an expert opinion is drawn up and a conclusion is given on the application of occupational safety measures and regulations and the same is submitted to the person ordering the inspection. The expert report is delivered by a licensed legal entity. The conclusion is negative if at least one of the objections mentioned in the chapter is stated. Inspection and testing of the crane mentioned in the previous chapter with the mentioned methodology, based on the performed inspections and checks on the inspected equipment for the operation of MOSNE CRANES, MIN'NIŠ, type EDM 125/25, REG/FAB.BR.d-1471, CAPACITY 450Kn/250Kn , the prescribed measures for safety and health at work were applied, that is, the inspected and checked work equipment is safe for use [5]. A comparative review of expert inspection reports in the period of every three years of inspection is present in Table 1. Then we can be concluded that there were no failures and malfunctions due to regular, periodic and inspection inspections of the crane, and in this way safety and security at work was ensured [4].

Table 1. Comparative overview of control examinations with a condition without cancellation:

Year / Crane tests	Crane reliability			
	2009	**2012**	**2015**	**2018**
Inspection of the supporting structure and parts, welded places	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation
Overview of necessary equipment and devices for crane management	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation
Overview of staircases, access passages and platforms	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation
Control of data, inscriptions and warnings on the crane	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation
Lifting mechanism - devices for lifting and lowering loads	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation
Braking devices	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation
Elements of security	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation
Checking the lifting capacity of the crane	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation
Checking the electrical installation	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation	Fits, without cancellation

The work shows the application of the following procedures for preventive maintenance of a two-girder bridge crane: preventive periodic inspections, preventive periodic replacements, search for and removal of weak points, control inspections. Based on the tests and the results shown in the reliability table, it can be concluded that there were no failures in the past period on the two-girder bridge crane on which preventive maintenance procedures were applied. We can conclude that in this way the reliability of the two-girder bridge crane has been increased and thus the hypothesis has been proven: Conducting control inspections of the electric two-girder bridge crane with a load capacity of 125/25 t affects the increase of safety and security at work.

CONCLUSION

The basic role of control and maintenance is to ensure a high level of reliability and availability (safe functioning) of technical systems during their life cycle. In doing so, it is necessary to perform a series of corrective and preventive maintenance methods and procedures (maintenance technology) on the components of the technical system with optimal maintenance costs (direct and indirect maintenance costs). By showing a series of corrective and preventive maintenance processes, which are followed by control tests of the overhead electric two-girder bridge crane, a clearer picture is obtained of the importance of control inspections, because the ultimate goal is achieved, which is to increase safety and security at work. Following the basic principles of maintenance, that all employees in the company, starting from the top management of the company, all the way down to production workers, observe the maintenance function as a part of integral production, which should be completely defined for each technical system (machine) and for each employee. This way, the lowest maintenance costs will be achieved and ensure maximum production, the highest product quality, and above all, an increase in safety and security at work.

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ROBUSTNESS ESTIMATION OF DISCRETE SYSTEMS WITH UNCERTAIN PARAMETERS

Bojana M. Zlatković[1], Biljana Samardžić[2]
[1]University of Niš, The Faculty of Occupational Safety, Nis, Serbia
e-mail: bojana.zlatkovic@outlook.com
[2]University of Niš, The Faculty of Science and Mathematics, Nis, Serbia
e-mail: biljana@pmf.ni.ac.rs

Abstract: The importance of robustness is well known in engineering systems. In this paper the method for robustness estimation of discrete systems with uncertain parameters is presented. This method is based on the probability of stability estimation method and represents the generalization of Kharitonov's method when system parameters are random variables. The results are illustrated on the examples of the second and the third order discrete systems with different probability distribution of parameters: uniform, exponential and Poisson distribution.
Key words: robustness, Kharitonov's method, probability of stability estimation method

INTRODUCTION

Robustness is the property that a system only exhibits small deviations from the nominal behaviour upon the occurrence of a small disturbances (deviations). For example, parameters are naturally changing and may lead to an undesirable response of the system. Parameters may also vary in time due to age, wear, etc.
Parameters with this property can be find in the process industry, chemical industry, industry of plastic materials and the rubber industry. These parameters depend on values having stochastic character, such as plasticity, elasticity, intensity and compactness of material, so that the performances of the whole system differ from wanted, i.e., projective values. Those deviations can be so large that with no adjustment system can be bring into the normal working state. For that reason it is necessary to estimate the influence of stochastic parameters on system performances in advance which is very important in relation to the system stability, reliability, robustness, [1].
The basic methods for probability of stability estimation are given in [2-5]. These methods refer to the continuous systems of automatic control. For discrete systems the method for the probability of stability estimation is given in [1], [6].
A control system always have some robustness property.There are a variety of techniques that have been developed for robust control, for example parameter estimation techniques. In this paper the method for robustness estimation of discrete systems with random parameters is presented. This method is based on the probability of stability estimation method, [1], and represents the generalization of Kharitonov's method, [7], when system parameters are random variables. The results are illustrated on the examples of the second and the third order discrete systems with different probability distribution of parameters: uniform, exponential and Poisson distribution.
Kharitonov's method has great application in industry (process, chemical, rubber), [8], and environment for robust stability analysis of wind turbine control system, [9].
The robustness is obtained using the system probability stability, thus robustness is in correlation with probability stability. Therefore, the robustness estimation will be accomplished using the estimation of the probability stability of the discrete system given by Eq. (1). In the case of constant parameters, results obtained using presented method are equivalent to the results obtained by Kharitonov's method.

$$\sum_{i=0}^{n} l_i \, x(k+n-i) = u(k), \;\; l_0 = 1 \tag{1}$$

The characteristic polynomial of the equation (1) is:

$$z^n + l_1 z^{n-1} + \cdots + l_n = 0 \tag{2}$$

The necessary and sufficient condition for a discrete system stability is that all zeros of its characteristic polynomial are located inside the unit circle in the z – plane.

Many methods are developed such as the bilinear transform method, the Schur – Cohn Jury criterion, etc., to test this condition These methods are appropriate when the coefficients of the characteristic polynomial are given exactly. In many engineering applications, however, the parameters of a system are not exactly determined.

The stability area, S_n, of the system, (1), in the parametric space $l_1, \ldots, l_n$ is determined using Hurwitz criterion.

Let the parameters $l_1, \ldots, l_n$ have uniform, exponential and Poisson distribution, respectively.

$$p_i = \begin{cases} \dfrac{1}{\left(\bar{l}_i - \underline{l}_i\right)}; & \underline{l}_i < l_i < \bar{l}_i \\ 0; & l_i > \bar{l}_i;\ l_i < \underline{l}_i \end{cases} \tag{3}$$

$$p_i = \begin{cases} \lambda \cdot \exp(-\lambda \cdot l_i) & l_i \geq 0 \\ 0 & l_i < 0 \end{cases} \tag{4}$$

$$p_i = \frac{a^k}{k!} e^{-a} \tag{5}$$

$\bar{l}_i$ and $\underline{l}_i$ are upper and lower limits of the interval of uniform distribution.

If the parameters are independent random variables, then the multidimensional distribution density is given by:

$$p(l_1, \ldots, l_n) = \prod_{i=1}^{n} p_i(l_i) \tag{6}$$

The probability stability of the system (1) whose parameters are random is given by:

$$P = \int_{S_n} \cdots \int p(l_1, \ldots, l_n)\, dl_1 \cdots dl_n \tag{7}$$

THE SECOND ORDER DISCRETE SYSTEM

The second order discrete system is given by:

$$x(k+2) + l_1 x(k+1) + l_2 x(k) = 0 \tag{8}$$

Using the z - transformation and then applying the bilinear transform, $z = \dfrac{s+1}{s-1}$, the discrete system is transformed into the s - domain in the following way:

$$s^2(1 + l_1 + l_2) + 2s(1 - l_2) + 1 - l_1 + l_2 = 0 \tag{9}$$

The stability area S_2 is given with the next set of relations:

$$\begin{aligned} &1 - l_1 + l_2 \geq 0 \\ &1 + l_1 + l_2 \geq 0 \\ &l_2 \leq 1 \end{aligned} \tag{10}$$

The stability area of the second order discrete system, S_2, is given on Fig.1 where N_2 presents the unstability area.

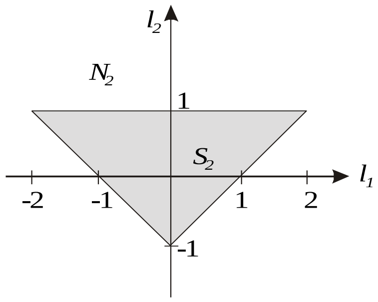

Fig.1. The stability area of the second order discrete system, S_2

The probability of stability of the second order discrete system stability is given by:

$$P = \iint_{S_2} p(l_1, l_2) dl_1 dl_2 \tag{11}$$

Let us consider the case when the discrete system (8) has parameter values under given range ($\underline{l}_i < l_i < \bar{l}_i$). Using the Kharitonov method, the *n*-th order system is stable if the next four polynomials are stable:

$$\begin{aligned} R_1(z) &= \underline{l}_n + \underline{l}_{n-1} z + \bar{l}_{n-2} z^2 + \bar{l}_{n-3} z^3 + \cdots \\ R_2(z) &= \underline{l}_n + \bar{l}_{n-1} z + \bar{l}_{n-2} z^2 + \underline{l}_{n-3} z^3 + \cdots \\ R_3(z) &= \bar{l}_n + \bar{l}_{n-1} z + \underline{l}_{n-2} z^2 + \underline{l}_{n-3} z^3 + \cdots \\ R_4(z) &= \bar{l}_n + \underline{l}_{n-1} z + \underline{l}_{n-2} z^2 + \bar{l}_{n-3} z^3 + \cdots \end{aligned} \tag{12}$$

For the second order discrete system polynomials are:

$$\begin{aligned} R_1(z) &= z^2 + \underline{l}_1 z + \underline{l}_2 \\ R_2(z) &= z^2 + \bar{l}_1 z + \underline{l}_2 \\ R_3(z) &= z^2 + \bar{l}_1 z + \bar{l}_2 \\ R_4(z) &= z^2 + \underline{l}_1 z + \bar{l}_2 \end{aligned} \tag{13}$$

For each polynomial the stability area is determined in the same way as it is described previously. For example, for the polynomial $R_1(z)$, the robustness is given by:

$$P_1 = \iint_{S_2^1} p(\underline{l}_1, \underline{l}_2) d\underline{l}_1 d\underline{l}_2 \tag{14}$$

and the total robustness for the second order discrete system is:

$$P = \prod_{i=1}^{4} P_i \tag{15}$$

The robustness is obtained using the system probability stability, thus robustness is in correlation with probability stability. The robustness estimation will be accomplished using the estimation of the probability stability.

THE THIRD ORDER DISCRETE SYSTEM

The third order discrete system is given by:

$$x(k+3) + l_1 x(k+2) + l_2 x(k+1) + l_3 x(k) = 0 \tag{16}$$

The stability area is given by the following relations:

$$\begin{aligned} & l_1 + l_2 + l_3 > -1 \\ & l_1 - l_2 + l_3 < 1 \\ & l_1 l_3 + 1 > l_2 + l_3^2 \end{aligned} \tag{17}$$

This stability area is given on Fig.2.

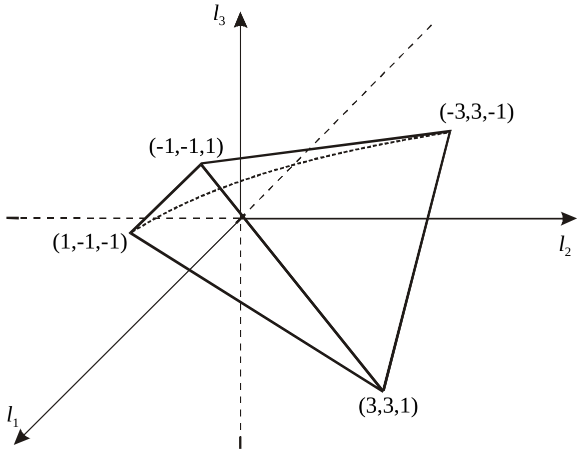

Fig.2. The stability area of the third order discrete system, S_3

The robustness is determined by:

$$P = \iiint_{S_3} p(l_1, l_2, l_3)\, dl_1 dl_2 dl_3 \tag{18}$$

For the third order discrete system the Kharitonov's four polynomials are given:

$$\begin{aligned} R_1(z) &= z^3 + \bar{l}_1 z^2 + \underline{l_2} z + \underline{l_3} \\ R_2(z) &= z^3 + \bar{l}_1 z^2 + \bar{l}_2 z + \underline{l_3} \\ R_3(z) &= z^3 + \underline{l_1} z^2 + \bar{l}_2 z + \bar{l}_3 \\ R_4(z) &= z^3 + \underline{l_1} z^2 + \underline{l_2} z + \bar{l}_3 \end{aligned} \tag{19}$$

and the appropriate robustness is given by:

$$P_1 = \iiint_{S_3^1} p\left(\bar{l}_1, \underline{l}_2, \underline{l}_3\right) d\bar{l}_1 d\underline{l}_2 d\underline{l}_3 \tag{20}$$

The total robustness for the third order discrete system is given by (15).
In the next tables robustness is calculated for the second and the third order system for the uniform, exponential and Poisson distribution.

Table 1. Robustness for the second and the third order system with uniform distribution of parameters

$\underline{l}_1$	$\bar{l}_1$	$\underline{l}_2$	$\bar{l}_2$	P_i	P	$\underline{l}_1$	$\bar{l}_1$	$\underline{l}_2$	$\bar{l}_2$	$\underline{l}_3$	$\bar{l}_3$	P_i	P
1	1.5	0.5	0.6	1	0.188	4	5	1	2	-0.5	0.5	0.015	0.0003
0.5	2.5	0.5	1.5	0.375		-5	-2	-4	-2	0.5	2	0.056	
-1	-1.5	-0.5	1.5	0.75		2	5	1	2	-0.5	0.5	0.333	
1	2.5	-0.5	-0.9	0.667		1	2	1	2	0	0.5	1	

Table 2. Robustness for the second and the third order system with exponential distribution of parameters

l_1	l_2	P_i	P	l_1	l_2	l_3	P_i	P
8	7	0.998	0.283	5	6	7	0.987	0.017
5	3.5	0.967		2	3	4	0.802	
2	1	0.589		0.9	0.8	0.77	0.172	
1	1.1	0.498		0.8	0.7	0.6	0.124	

Table 3. Robustness for the second and the third order system with Poisson distribution of parameters

l_1	l_2	k_1	k_2	P_i	P	l_1	l_2	l_3	k_1	k_2	k_3	P_i	P
6	9	1	1	0.992	0.317	10	12	13	1	1	1	0.999	0.033
6	7	1	2	0.967		5	6	7	0.3	0.4	0.5	0.975	
4	5	2	3	0.695		1	1.5	2	0.1	0.2	0.3	0.334	
2	2.5	1	1.5	0.475		0.7	0.8	0.9	0.1	0.2	0.3	0.101	

Based on the results in the tables, such parameter values can be selected for which the system has the highest robustness. Analyzing the results, the following can be concluded.
With the exponential distribution of parameters, the robustness of the system increases, if the values of all parameters l_i, $i = 1,\dots,n$, increase simultaneously. If the value of one parameter decreases, the robustness of the system decreases.
With the Poisson distribution of parameters, when the value of the parameter k_i decreases, the robustness of the system increases, and when the values of the parameters l_i decrease, the robustness, also, decreases.
In systems with a uniform distribution of parameters, robustness depends on the extent to which the values of ($\underline{l}_i$, $\bar{l}_i$) are within the limits of the stability region.

CONCLUSION

The method presented in this paper enables the robustness estimation of discrete system with uncertain parameters. This method represents the generalization of Kharitonov's method when system

parameters are random variables and it is based on the probability of stability estimation method. For its simplicity, this method can be used in practice.
The results are illustrated on the examples of the second and the third order discrete systems with different probability distribution of parameters: uniform, exponential and Poisson distribution.
Based on the results in the tables, such parameter values can be selected for which the system has the highest robustness.

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SENSITIVITY OF MIMO CASCADE NONLINEAR SYSTEMS TO PARAMETER VARIATIONS

Bojana M. Zlatković[1], Biljana Samardžić[2]
[1]University of Niš, The Faculty of Occupational Safety, Nis, Serbia
e-mail: bojana.zlatkovic@outlook.com
[2]University of Niš, The Faculty of Science and Mathematics, Nis, Serbia
e-mail: biljana@pmf.ni.ac.rs

Abstract: The sensitivity of MIMO cascade nonlinear systems to parameter variations is analyzed in this paper. Sensitivity is an very important indicator of how much the output varying in relation to variation of system parameters. For MIMO systems sensitivity is very important property because small changes of parameters values can make the system unstable and chaos may appear. The analysis results are illustrated by example of MIMO2 cascade nonlinear system and confirmed with simulations.
Key words: sensitivity, MIMO2 cascade nonlinear system, chaos, bifurcation diagram, phase portraits

INTRODUCTION

Changes in system parameter values always occurred because of environmental effects and other perturbations and disturbances. These changes and affections are called parameter variations. Parameters are naturally changing and may lead to an undesirable response of the system. Parameter may vary in time due to age, wear, environmental conditions, etc., which can lead the system to instability and chaos. That is why it is very important to examine the sensitivity of the system to changes in parameters. A way to minimize system sensitivity is discussed in this paper.
Sensitivity is defined as how much the output varying with respective to variation of system parameters, [1].
One of the basic criteria for control systems is to minimize the sensitivity of the response to uncertainties and parameter variations. For control systems the sensitivity must be low as possible because if the system parameters are changed the system output must be stable.
Sensitivity of MIMO cascade systems to parameter variations is analyzed in this paper. These systems show great sensitivity to parameter changes. By adequate selection of parameter values, the sensitivity can be reduced which is very important for the system stability and its correct work.
MIMO (Multiple Input Multiple Output) cascade nonlinear systems can be found in tyre industry for rubber strip transportation, [2, 3], and in cascade connected nonlinear electrical circuits, [4 - 6]. These systems consist of large number of MIMO nonlinear subsystems of the same structure.

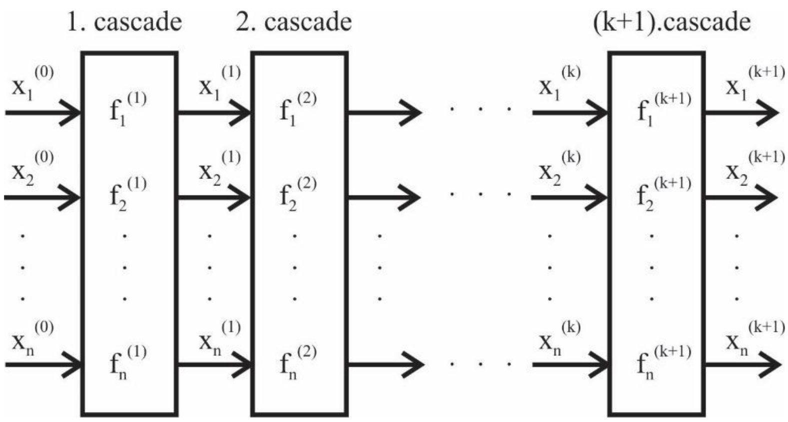

Fig. 1. MIMO cascade nonlinear system with *n* inputs and *n* outputs.

Each cascade in Fig. 1 is defined by the following set of equations:

$$\begin{aligned} x_1^{(i+1)} &= f_1^{(i+1)}\left(x_1^{(i)},\dots,x_n^{(i)}\right) = x_2^{(i)} \\ x_2^{(i+1)} &= f_2^{(i+1)}\left(x_1^{(i)},\dots,x_n^{(i)}\right) = x_3^{(i)} \\ &\vdots \\ x_{n-1}^{(i+1)} &= f_{n-1}^{(i+1)}\left(x_1^{(i)},\dots,x_n^{(i)}\right) = x_n^{(i)} \end{aligned} \tag{1}$$

$$x_n^{(i+1)} = f_n^{(i+1)}\left(x_1^{(i)},\dots,x_n^{(i)}\right) = -l_1x_n^{(i)} - l_2x_{n-1}^{(i)} - \dots - l_nx_1^{(i)}, i = \overline{0,k}$$

where parameters $l_j = l_j(\mathbf{x}^{(i)}), j = \overline{1,n}, i = \overline{0,k}$ are either the constants or functions (linear or nonlinear), whose argument is the input vector of each cascade $\mathbf{x}^{(i)} = \left[x_1^{(i)},\dots,x_n^{(i)}\right], i = \overline{0,k}$. Because the system (1) is nonlinear, at least one parameter l_j must be nonlinear function.

This cascade system has in total $k+1$ cascades. Each cascade has *n* inputs and *n* outputs. The output vector of the $(i+1)$th cascade $\mathbf{x}^{(i+1)} = \left[x_1^{(i+1)},\dots,x_n^{(i+1)}\right]$ measures $1 \times n$ and it is at the same time the input vector of the $(i+2)$th cascade. The number $i+1$ in brackets is the ordinal of the cascade. The set of functions $f_m^{(i+1)}\left(x_1^{(i)},\dots,x_n^{(i)}\right), m = \overline{1,n}, i = \overline{0,k}$ is the same for each cascade. Functions $f_m^{(i+1)}\left(x_1^{(i)},\dots,x_n^{(i)}\right), m = \overline{1,n-1}, i = \overline{0,k}$ are linear, only function $f_n^{(i+1)}\left(x_1^{(i)},\dots,x_n^{(i)}\right), i = \overline{0,k}$ is nonlinear. Thus, each cascade represents one nonlinear subsystem.

One of the characteristics of MIMO cascade systems is the possibility of chaos appearance. In higher order MIMO nonlinear cascade systems, MIMO*n*, ($n > 3$), spatial hyperchaos can occure, [7].

Chaos is a very interesting nonlinear phenomenon whose analysis is very beneficial to practical applications in many scientific fields: engineering, physics, mathematics, etc., [8, 9]. Chaos leads system to unpredictability and instability, [10 - 12], and exibits extreme sensitivity to initial conditions.

Thus, in order to provide a desired spatial dynamics of MIMO systems, it is necessary to select adequate parameters of these systems including initial conditions and nonlinear functions. This way the system sensitivity to parameter variations can be reduced.

MIMO cascade nonlinear systems show complex chaotical behaviours over a wide range of system parameters. Control of the chaos in MIMO cascade nonlinear systems can be accomplished choosing the appropriate parameters values.

For specific example of MIMO cascade nonlinear systems (MIMO2) for 5000 cascades, a detailed analysis of sensitivity to parameter changes is done. The results are presented using a bifurcation diagram and phase portraits.

Depending on given parameters values of MIMO2 cascade nonlinear system its dynamic can vary from spatial stable focus to the spatial limit set and chaos phase portraits.

MIMO2 CASCADE NONLINEAR SYSTEM

The MIMO2 system consisting of $k+1 = 5000$ cascades is given in Fig.2. Each cascade is described by the next set of equations:

$$\begin{aligned} x_1^{(i+1)} &= f_1^{(i+1)}\left(x_1^{(i)}, x_2^{(i)}\right) = x_2^{(i)} \\ x_2^{(i+1)} &= f_2^{(i+1)}\left(x_1^{(i)}, x_2^{(i)}\right) = -l_1x_2^{(i)} - l_2x_1^{(i)} \\ l_1 &= \left(x_1^{(i)}\right)^3 - 1, i = 0,\cdots,4999 \end{aligned} \tag{2}$$

where l_2 is random parameter, and l_1 is nonlinear function. The inputs into the first cascade are $x_1^{(0)} = 0$ and $x_2^{(0)} = 1.1$.

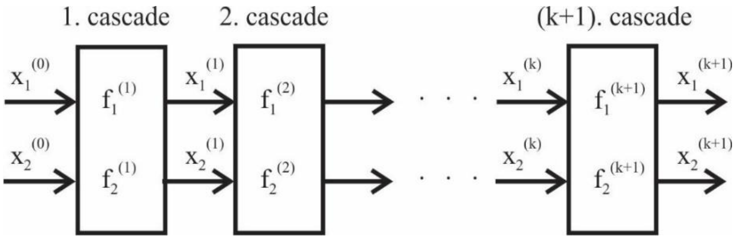

Fig.2. MIMO2 cascade nonlinear system.

Monitoring the dynamics of the whole MIMO2 system (1), using bifurcation diagram, is based on monitoring the two outputs of the last cascade $x_1^{(5000)}$ and $x_2^{(5000)}$ as a function of control parameter l_2. It can be noticed from Fig. 3, that for $l_2 = 0.1$ bifurcation appears and for $l_2 \in [-0.6, 0.1]$ appearance of spatial limit sets (spatial oscillatory dynamics) and spatial chaos in system (2) is possible.

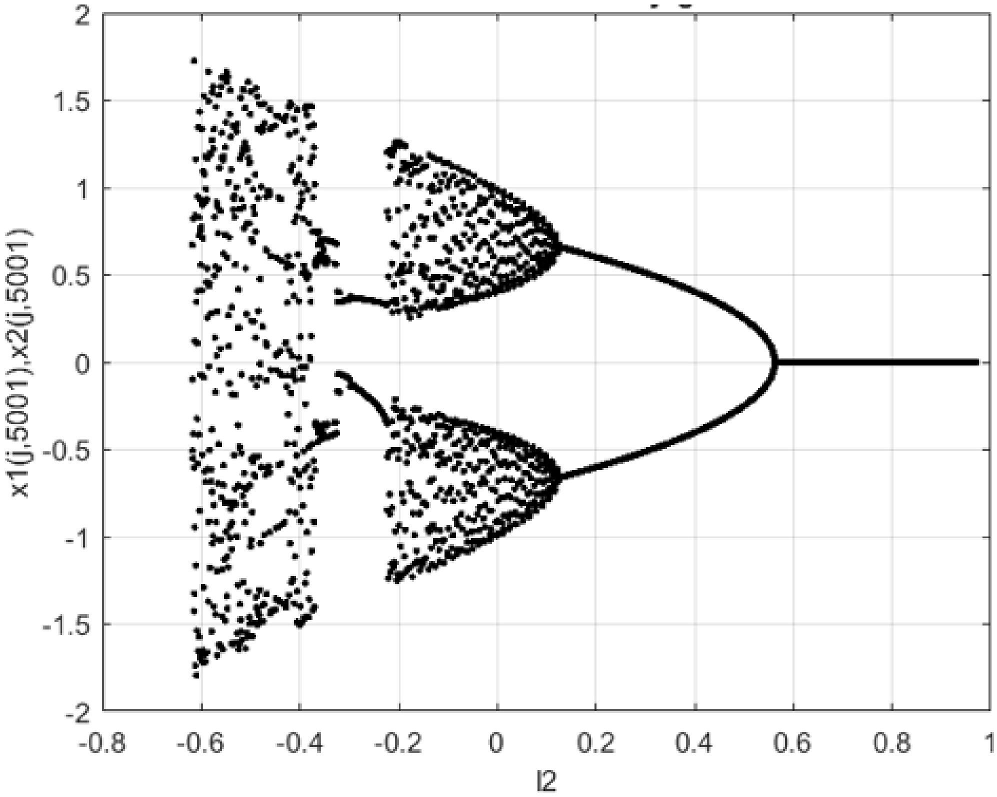

Fig.3. MIMO2 cascade nonlinear system bifurcation diagram

In the case of MIMO2 system, spatial phase portraits are shown in the phase plane $(\mathbf{x_1}, \mathbf{x_2})$, where $\mathbf{x_1}$ is the vector of the all cascades first outputs, and $\mathbf{x_2}$ is the vector of all cascades second outputs.

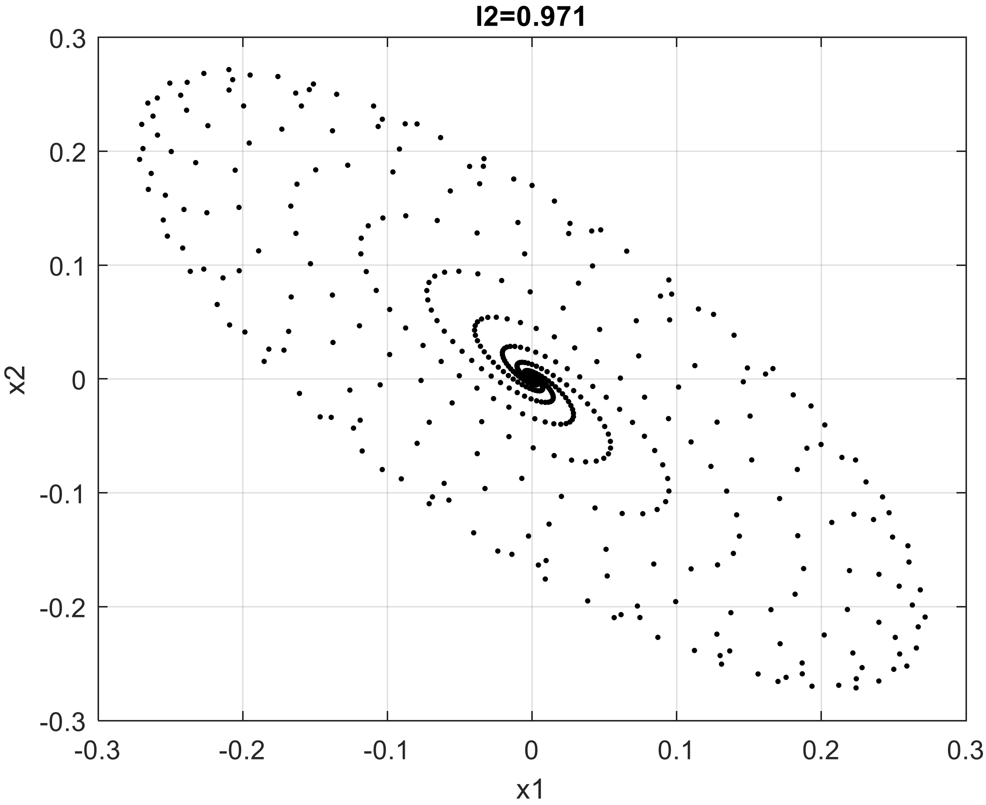

Fig.4. MIMO2 cascade nonlinear system phase portrait – stable focus

In Fig.4. stable focus is presented for l_2=0.971. It can be concluded by compering with bifurcation diagram that MIMO2 system is stable for that value of parameter l_2.

In the cascade system (2) spatial oscillations can appear. Namely, after a certain series of cascades the dynamics of the system is repeated. Under the large amplifications, these spatial oscillations become complex motions, which can be described as spatial chaos.

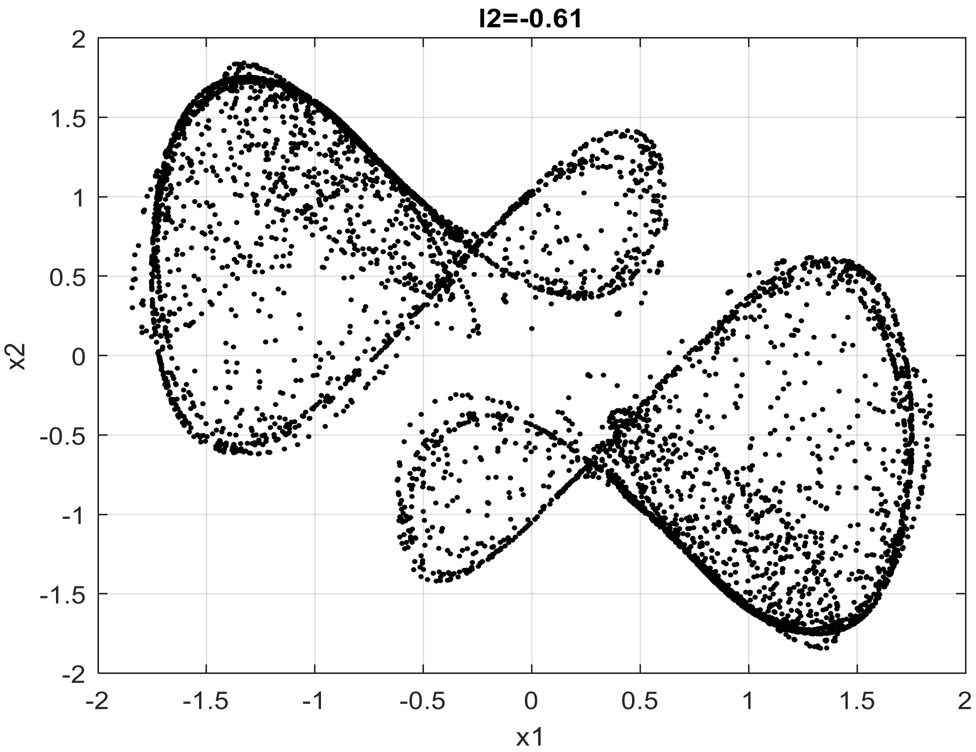

Fig.5. MIMO2 cascade nonlinear system phase portrait – spatial chaos

In Fig.5. spatial chaos is shown and it is obtained for l_2=-0.61. System is unstable for that parameter value.

Spatial limit set is a set of mutually separated points in the phase space, which are distributed in such way that approximately form a closed curve.

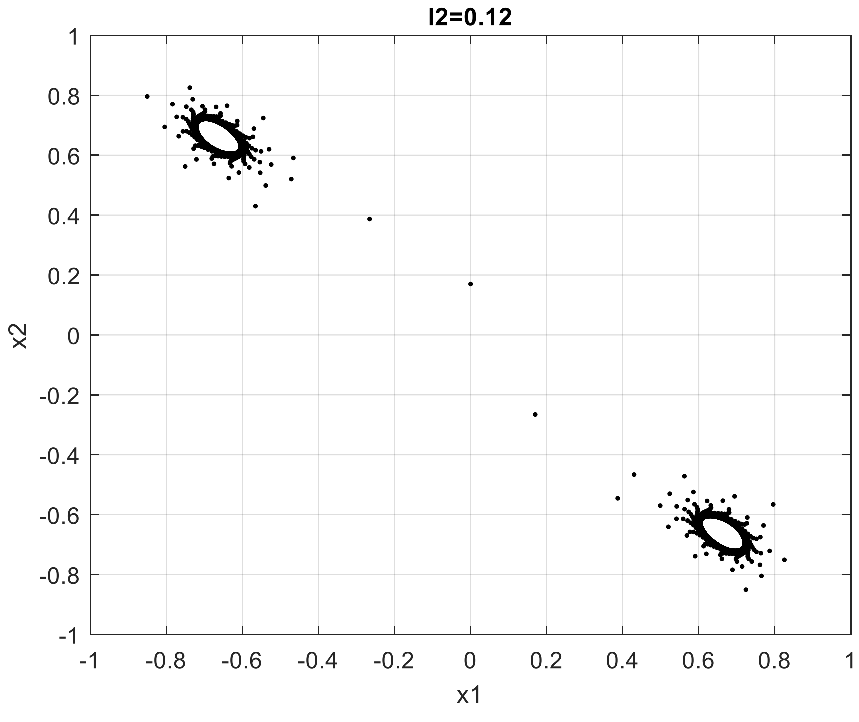

Fig.6. MIMO2 cascade nonlinear system phase portrait – two spatial limit sets

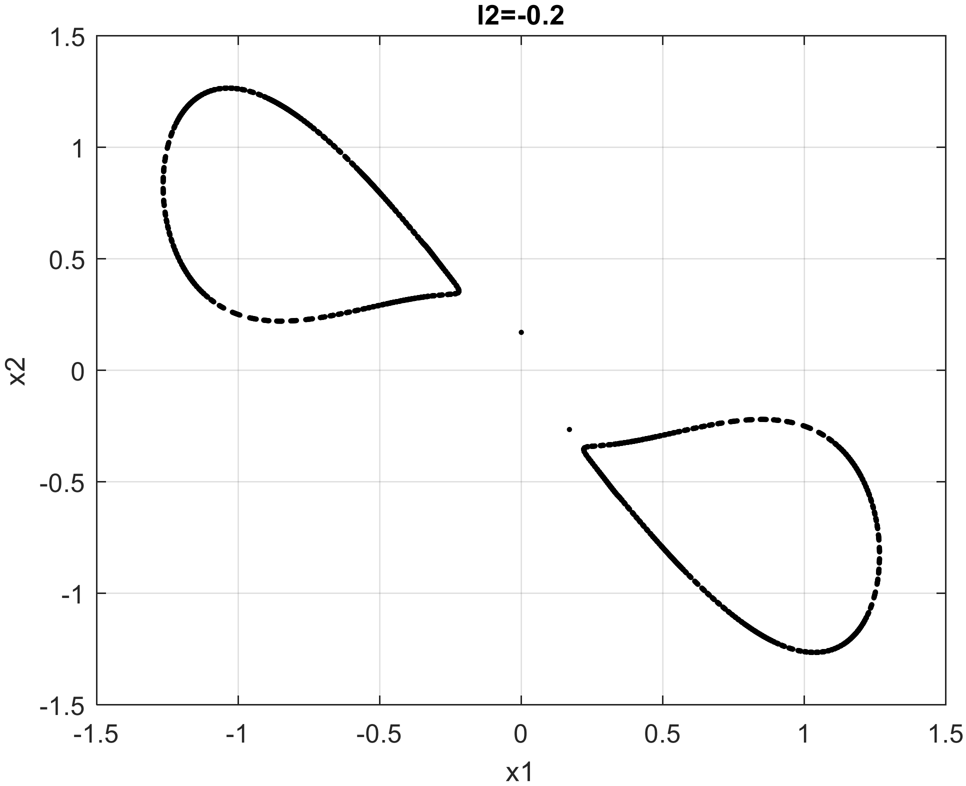

Fig.7. MIMO2 cascade nonlinear system phase portrait – two spatial limit sets

For l_2=0.12 and l_2=-0.2 phase portraits with two spatial limit sets are presented. For these values of parameter l_2 system is unstable, also.
From the phase portraits, Figs. 4-7 it can be seen how sensitive the system is to small changes in parameter l_2. Phase portraits follow the dynamics represented by bifurcation diagram, Fig. 3.

CONCLUSION

Sensitivity is an very important indicator of how much the output varying in relation to variation of system parameters. For MIMO systems sensitivity is very important property because small changes of parameters values can make the system unstable and chaos may appear.
For specific examples of MIMO cascade nonlinear systems (MIMO2) for 5000 cascades, a detailed analysis of the sensitivity to parameter variations is done. By adequate selection of parameter values, the system sensitivity to parameter variations can be reduced which is very important for the system stability and its correct work.

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Session 6

Engineering Management

COMPARATIVE RESEARCH OF THE APPLICATION OF THE INDUSTRY 4.0 CONCEPT IN THE WORLD AND SERBIA'S ECONOMY

Dragan D. Milanovic[1], Svetlana Dabic Miletic[2], Ljiljana Pecic[3],
[1]University of Belgrade, Faculty of Mechanical Engineering, [2]University of Belgrade, Faculty of Traffic, [3]Academy of Technical and Art Applied Studies Belgrade, Serbia,
e-mail: ddmilanovic@mas.bg.ac.rs

Abstract. The question arises to what extent certain changes are manifested in our environment and where is the position of Serbia on the map of global technological changes. The research will be dedicated to examining and analysis of phenomena of Industry 4.0 in the economy of Serbia, with a focus on the Smart Factory concept. In order to know how to behave, it is necessary to find out where we are in relation to the developed countries of the world and to answer the following questions: what does it mean, who is affected by it, at what speed, how intensively and what is actually changing? There are many questions. In this paper, we will try to answer some of them.
Key words: industry 4.0, smart factory, economy of Serbia, comparison

INTRODUCTION

In these researches, the central question is to what extent Industry 4.0 is present in the global economy of Serbia, which countries have gone the furthest when it comes to technological progress and where is the position of Serbia in relation to the rest of the world. The analysis of previous researches, and then the design of the new research, as well as the analysis of the obtained results for the territory of Serbia, will be presented. By studying the literature, a research methodology which can be carried out in Serbia was formed, similar to researches in the world. Based on everything mentioned so far, it is clear that the concept of Industry 4.0 is extremely complex and that it can be approached as a phenomenon from various aspects.
However, the format of the Paper somewhat limits the breadth that authors can cover with a new research. This leads us to try to examine only those factors that have proven to be fundamental. Seen from mechanical engineering perspective, the center of focus naturally goes to the Smart Factory, which is presented throughout this paper as a central component of the concept and something to which the most attention and detail are given.

PREVIOUS RESEARCH

The term Industry 4.0 was introduced to the public for the first time,11 years ago, more precisely in 2011, at the trade fair in Hanover, as the name for a joint initiative to strengthen the competitiveness of German industry by representatives from the field of business, politics and science. You could say that since then, this concept has become a trend in companies and scientific institutions worldwide. There are other terms that can also be found in the literature, from the concept of the Industrial Internet promoted by the American company General Electric, to Integrated Industry, Smart Industry or Smart Manufacturing. The essence remained mostly the same, to integrate the latest technologies into the business model of your company with the aim of better positioning on the market. Also, the most developed countries of the world have started their development strategies and projects on a higher level in order to adapt to exponential technological changes. So, in addition to Germany (Industrie 4.0), the most concrete in investing in this type of development are France (the Nouvelle France Industrielle), Sweden (Produktion 2030), Italy (Fabbrica Intelligente), Belgium/Netherlands (Made Different), Spain (Industria Conectada 4.0), Austria (Produktion der Zukunft) as well as, of course, the USA (Industry Connected 4.0) and manufacturing sectors throughout China [8].
A Smart Factory can be defined as a system that has the ability to independently optimize the performance, independent learning and adapting to new conditions in real time. Also, it has the ability to connect with similar production systems via a global network and that means the possibility of continuous cooperation and even synchronized work of two or more Smart Factories [2].

In order for the system defined in this way to function, it is necessary to meet multiple factors. First of all, provide the appropriate basic technological infrastructure. The basis of that infrastructure is huge amounts of data in digital form. It is natural that this should be the first thing to examine in a certain environment. To what extent are data collected [2]? Data sources can be diverse (production lines, smart products, social networks, digital images and videos, purchase transactions, GPS location data of mobile devices, etc.) In this business setting, data become a new kind of resource that is expected to be available in real time [6].

Also, the term used in the literature, when it comes to the initial stage of the environment's readiness to integrate the Industry 4.0 concept, is the so-called degrees of digitization [3]. Digitization represents the process of data transformation from analog to digital form, i.e. means changing analog information (in written form) into digital form so that a computer can store, process and send it on. Only after the data needed are in digital form, it is possible to start the digitalization process, i.e. the process of using digital technologies with the aim of optimizing and automating processes within the company. Digitalization is a continuous process that must be regularly updated in line with the technological progress [4].

Since in this part of the Paper we are dealing with the application of Industry 4.0 in practice at the global level, it is necessary to present certain status parameters for the world's top in terms of technological development. The ideal cross-section and optimal solution of the previous two requirements is the example of the United States of America. During 2021, a survey that covered over 150 American manufacturers was conducted is shown in Table 1 [5].

Table 1. Phenomena of Industry 4.0 in the United States of America [5]

Technology	Active use	Plan to use	Do not plan to use
Data analytics	71%	25%	4%
Cloud computing	64%	35%	1%
ERP software	58%	34%	8%
RPA (robotic process automation)	43%	43%	14%
Internet of Things	40%	47%	13%
Artificial intelligence (Machine learning)	38%	51%	11%
Additive manufacturing (3D print)	34%	43%	26%
Virtual/Augmented reality	31%	43%	32%
Blockchain	31%	43%	26%

As you can see from the table above, Data Analytics (which includes the concept of Big Data) and Cloud Computing are dominant with 71% and 64% of active use, respectively. On the other hand, the least present technologies are Blockchain and Virtual/Augmented reality, which are used by slightly less than a third of companies [6]. In order for there to be a progress in any field, it is necessary to identify the elements that hinder and slow down that same progress, and which need to be overcome.

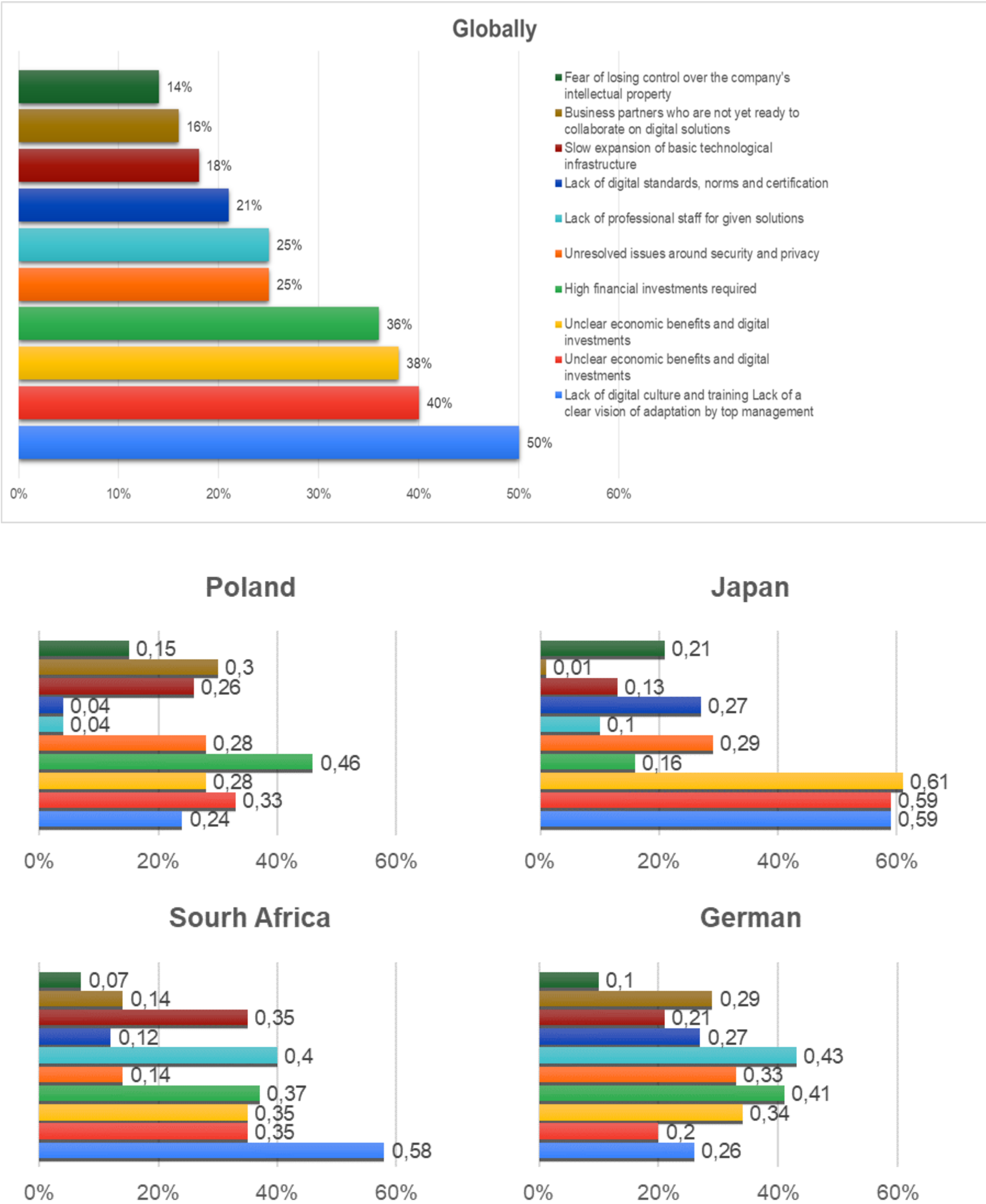

Fig. 1. Main barriers in adopting modern/digital technologies [8]

Based on Fig. 1, the general impression is that the main barrier in the adoption of digital technologies, in addition to money, which is almost always a crucial factor, is the lack of knowledge. Employees around the world, both managers and those at lower hierarchical levels, lack digital culture and training.

More precisely, managers must, first of all, get to know the new trends that the concept of Industry 4.0 brings, when it comes to strategy, management and organization. When it comes to modern technologies, they must not be unknown to almost anyone in the company [8].

RESEARCH METHODOLOGY

Under the phenomena of Industry 4.0, we mean its manifestations, characteristics and technologies that are closely related to the concept. More precisely, the idea is to examine the extent to which modern/digital technologies are used in Serbian industry, and then to determine the presence of smart production in practice based on multiple examined factors.
The survey was formed according to the model of already conducted researches [3], [4], [6], [8], and it contains 20 questions, 6 general and 14 on the given topic. The order of the questions in the survey did not follow the process by which the literature was interpreted in previous researches, but the goal was rather to arrange the questions so that the most important ones were among the first ones, as this is where the examinee's attention is at the highest level (of course, this only applies to 14 questions on a given topic). Also, the order was guided by the principle of general to specific questions.

RESULTS ANALYSIS AND DISCUSSION

In order to draw conclusions about the properties of any population, i.e. the basic set, it is necessary that the sample is large enough. When the sample is greater than or equal to the number 30, its distribution of arithmetic means can be satisfactorily approximated by the normal distribution model and it is considered representative [1].
The survey was conducted in May 2022. 105 companies that own a factory/plant were contacted, and 31 responses were received. The sample of n = 31 meets the initial requirement, which means that it is possible to start the analysis.
As with the interpretation of the literature, in the results analysis and discussion, the approach is inductive. In order to be able to consider the use of modern technologies, first it is necessary to have the appropriate basic technological infrastructure. Its condition, as in the literature, is measured by the degree of digitization and data collection. This paper presents only some of the questions included in the survey.
Table 2 shows the comparative results of the survey on the same questions as Table 1. In the economy of Serbia, the most applied technology is data analytics, which is used by 55% of companies, while 39% of companies plan to use it. They are immediately followed by ERP software (55%), mobile devices (52%) and the concept of the Internet of Things (48%). Definitely in the last place is VI with the use of only 3%, while more than a half of the companies do not even plan to start using it. Apart from the difference in the degree of use, the order of the application of technologies is quite similar to that in the USA.

Table 2. Phenomena of Industry 4.0 in Serbia

Technology	Active use	Plan to use	Do not plan to use
Data analytics	55%	39%	6%
ERP software	55%	26%	19%
Mobile devices	52%	35%	13%
Internet of Things	48%	29%	23%
Sensor technology	45%	35%	19%
Cloud computing	45%	35%	19%
RPA (Robotic process automation)	42%	29%	29%
Real-time systems	35%	32%	32%

RFID	26%	32%	42%
Virtual/Augmented reality	16%	23%	61%
Additive manufacturing (3D print)	13%	23%	65%
Blockchain	13%	13%	74%
Artificial intelligence (Machine learning)	3%	45%	52%

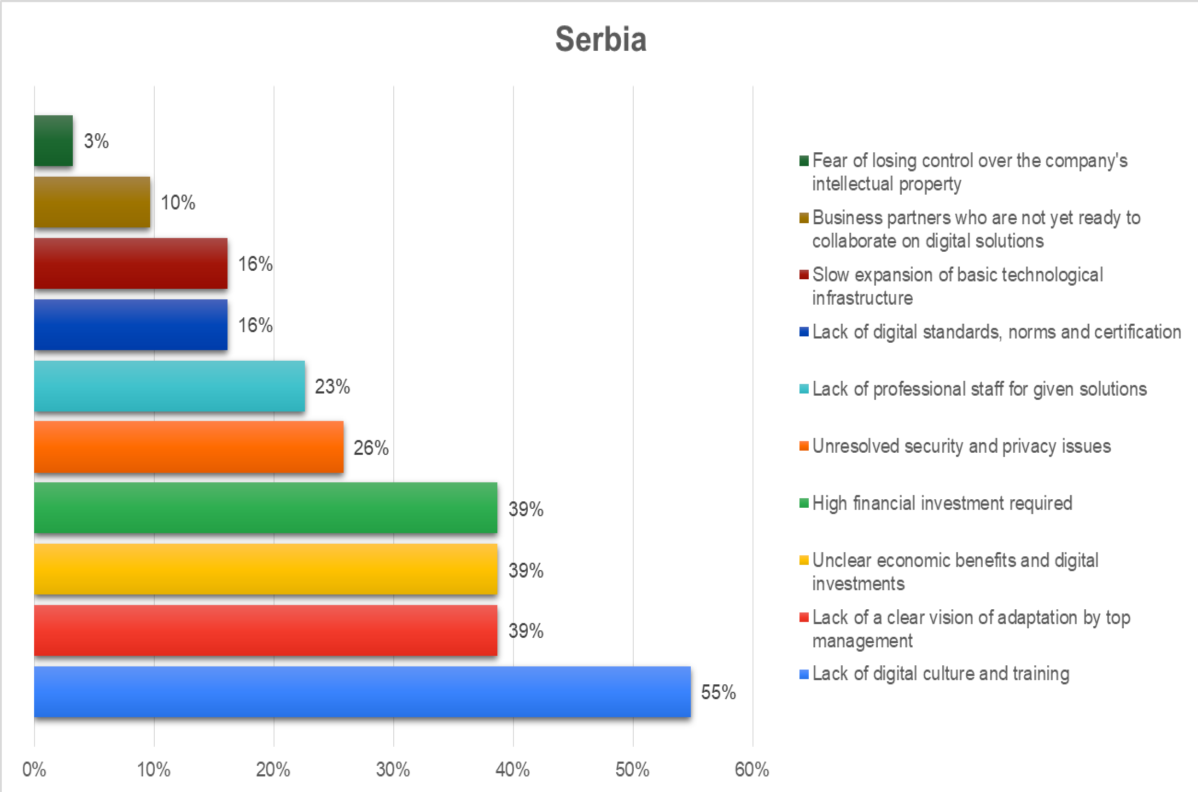

Fig. 2. Main barriers in adopting modern technologies in the industry of Serbia

In addition to technologies, an indispensable element is the shortcomings that hinder their adoption. The examinees were offered answers like those in Figure 1 in order to highlight, from a strategic perspective, the main obstacles on the way to digital technologies and the new business models that accompany them. Fig. 2 shows the layout of responses, and what is interesting is that an almost identical layout was obtained to the one regarding the responses at the global level. Again, one of the main problems is of a financial nature, but what turned out to be an even greater barrier is the lack of expertise and knowledge. Therefore, over 60% of companies in Serbia identify the lack of digital culture and training as the main obstacle.

CONCLUSION

Based on the obtained results, the general impression is that the use of modern technologies in the industry of Serbia is at a surprisingly enviable level in relation to expectations, especially when compared with reference researches. The latest technologies require large financial investments. Therefore, the arrival of large foreign companies on the Serbian market in recent years undeniably affects the overall statistics.

If we want our industry to progress, apart from the inevitable condition in the form of strengthening the state economy, it is necessary to work on improving and familiarizing ourselves with the concept of Industry 4.0, as well as everything that goes with it. This paper has only covered the basics of the concept from a mechanical engineering perspective. However, the environment will certainly need numerous analyses and papers where the focus will be placed on some other elements, such as

organization, economy, safety, sociological and psychological influences, etc. Although the topic has been quite popular in the world for years, until recently, relatively few papers could be found in Serbian language. Today, the situation is somewhat better, but domestic authors must deal with the given topic to an even greater extent. Also, the education of employees in the economy must be at a higher level if we want to keep pace with the world.
When it comes to the concept of Industry 4.0 as a global phenomenon, we can say that the world is facing big challenges in the future. That's why we need to develop by introducing new technologies and we need people who in the first place understand themselves and their environment. We can be such people too, the only question is what we want... The decision is up to us. Because if we point ourselves in the right direction, the scope of our potential has no limits.

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MODELING OF MASHHAD HEALTH TOURISM USING ISM

Ali Reza Afshari[1], Ahmad Baghi[1], Sanja Stanisavljev[2]
[1]Department of Management, Shirvan Branch, Islamic Azad University, Shirvan, Iran.

[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia.
e-mail: afshari@mshdiau.ac.ir

Abstract: Nowadays, health tourism is the most visible part of a generalized growth in the globalization of health, which essentially comes down to international trade in health services. Most people prefer to receive healthcare close to home. But under certain circumstances it can make more sense for a patient to receive healthcare abroad. In this context, this study aimed to identify factors affecting to health tourism in Mashhad, Iran, the second largest city in Iran. We have identified various factors affecting health tourism through a systematic literature review of publications on health tourism. Later, twenty-five experts from the health tourism industry and academia took up ISM. Experts were chosen based on their experience (more than 20 years) and available. An introductory brainstorming session and interview process were conducted to explain the research objectives to the experts. Then all the factors were discussed and collected the responses from the experts to apply the ISM technique. Then factors were placed in a hierarchy, formed the contextual relationships and framed the final relationship matrix.
Key words: Health tourism, Interpretive Structural Modeling (ISM), Tourism Management.

INTRODUCTION

Cross-border health care' denotes a broad social phenomenon involving the movement of patients, providers, or services across national boundaries for health care reasons [1, 2]. It encompasses various concepts, such as medical tourism, inbound and outbound, or incoming and outgoing medical travelers [2]. It may be sanctioned by the government or initiated by the patient as medical tourism. Government-sanctioned outbound care usually involves insured procedures that create a delay that may pose catastrophic risks to the patient's health. Medical tourism, however, is often planned and coordinated by the patients without the inclusion of a public health insurance system [1-3]. It excludes emergency and unplanned care for illnesses or complementary and alternative medicine [4]. It also refers to medical professionals traveling internationally to provide medical services [2]. Although not a new concept, medical tourism has emerged as a flourishing industry for medical treatment [3]. In this study, the definition is confined to international visitors who consider going abroad to receive medical services. For many years, it has been common for people from under-developed or developing nations to travel to developed countries to benefit from advanced and innovative medical services. Medical tourism has now changed this approach and incorporates bidirectional flows when people from all countries frequently travel across their international frontier to obtain certain health care, which is either too delayed, inaccessible, unaffordable, unavailable, of poor quality, or legally banned at their home country [5-7].
Available estimates show that the number of tourists traveling abroad for health care will reach 11 million tourists each year, with a projected annual growth of up to 25% for the next decade [4, 8-10]. The global medical tourism market is also expected to rise to $28 billion by the year 2024 [11]. Asian, Middle East, and South American countries have played a major role in the growth of the medical tourism industry worldwide [9, 12]. Iran has also experienced the growth of medical tourism in recent years, even though it has been practiced in the country for decades [13]. In 2012, Iran hosted 3.3 million tourists [14], most of whom sought medical treatment [15]. Likewise, in the first seven months of 2018, over 4.7 million visitors arrived in Iran, of whom around 300,000, largely from Central Asian and Arab countries, were possibly attracted to the country's health care system [16, 17]. Given the above, it is reasonable to believe that Iran has an extremely large scope for medical tourism to grow. While features such as geographic proximity, low service cost, quality care, cultural similarities, or the commonality of religion may have played a key role in attracting medical tourists to Iran [18], Iran's potential contribution to medical tourism has been challenged by several factors, such as Internet

connectivity, information and communication technology (ICT) infrastructure, and international relations due to the re-imposition of US-led sanctions on trade [19]. In particular, access to well-designed and comprehensive online platforms has been recognized as the obvious prerequisite for building up a successful medical tourism industry [20-22]. However, it is unclear what proportion of ICT development contributes to the Iranian medical tourism industry. Existing research argues that Iran faces an absence of well-established media and appropriate website contents to provide medical tourists with essential facilities and services [17, 22, 23]. Yet, few studies have examined the structure, data elements, and performance of Iranian medical tourism. Little is known as to whether those are sufficiently established to attract medical tourists from other countries.

MATERIAL AND METHODS

As a new form of tourism and industry, medical tourism has substantially grown over recent years. Medical tourism may be defined as an economic activity based on integrated services provided by two sectors, medical and tourism. Because of the potentials it offers, the market for medical tourism is rapidly expanding, making it intensely competitive on an international scale [24]. Further, medical tourism gives patients access to high quality healthcare at lower costs and with shorter waiting times for treatments. Accordingly, patients seeking medical care are willing to travel from developed countries such as Australia, United Kingdom and USA to developing countries such as Costa Rica, India and Thailand for medical treatment [25]. It is reported that Thailand, Singapore and India have the highest share of medical tourism market in Asia. Also, Latin America is an important destination for medical tourism including countries such as Colombia, Brazil and Mexico as well as the Central Asian (Middle Eastern) countries like Jordan, Turkey and the UAE. Accordingly, each of the abovementioned countries is trying to fix its problems and promote global medical tourism [26]. The annual global income of medical tourism has grown about 20 percent [27]. In 2014, the income from medical tourism approximated $55 billion in America where about 11 million patients were referred to other countries for treatment, and every patient spent an equivalent of $3500 to $5000 on each visit [28]. Statistics on people traveling to other countries to receive medical services are unreliable and as figures presented by different studies they vary from country to country. However, the number of patients traveling to other countries is increasing annually and this increase is expected to rise even more sharply in years to come. According to the global income of this industry, Iran has taken a number of measures to increase its share of the market for medical tourism; nevertheless, there is still a series of barriers including international and infrastructural prerequisites for the country's participation in the global market.

Barriers to the development of medical tourism

Previous studies on medical tourism have mostly emphasized challenges, barriers and development potential. In a study, Singh (2014) [29], examined the development potential and barriers of medical tourism in India. The results highlighted India's strengths in the field of medical tourism including low cost, strong reputation in surgical procedures such as cardiovascular surgery, organ transplantation, eye surgery and the country's unique tourist attractions. According to the study, the obstacles faced by the industry in India include a lack of government initiative in the field of medical tourism, a lack of concerted effort to promote the industry and a lack of uniform pricing policy and standards among hospitals. In another study, Jeremy Snyder et al. (2015) [30] suggested that changes in healthcare policy were required to deal with an outflow of Mongolian medical tourists. Reforms expressed in this study include increased funding for health systems in Mongolia and efficient use of such funds to improve education opportunities and incentives for health staff and to eliminate corruption and favoritism in the health system. In the same vein, Han and Hyun (2015) [31] developed a model explaining the intentions of medical tourism by considering impacts of quality, trust, satisfaction, and reasonable pricing. The results proved quality, satisfaction, and trust in clinics to be the factors that strongly affected intention to revisit a clinic in the destination country. Their results also showed that satisfaction and trust were significant mediators. In general, the moderating impact of reasonable pricing was evident in the proposed theoretical model. The most important barriers to the development of medical tourism in Hong Kong, reported by Vincent C.S. Heung et al. (2011) [32], included cost, infrastructure, policies, government support and promotion of medical tourism. Finally, strategies such as promotional activities, investment, communication skills with medical tourists, were considered to help remove barriers.

Medical tourism in Iran

Like many countries, Iran has also decided to invest in medical tourism. Iran consists of 31 provinces and has a population of about 80 million. The country is located in central Asia and borders many countries such as Pakistan and Afghanistan to the east, Turkey and Iraq to the west and Turkmenistan to the north, as well as Azerbaijan and Armenia and Arabic countries the south. The majority of Iran's population are Shi'a Muslim [33]. In terms of economy, Iran's exchange revenues are dependent on crude oil exports to other countries. However, in order to reduce dependence on the oil industry, Iran is trying to capitalize on tourism as a source of income. Medical tourism represents one such plan [34]. Iran has very attractive potential that includes low-cost health care, internationally renowned doctors, successful performance of surgical procedures at the global level and low waiting times for treatments. However, Iran's medical tourism industry has some obstacles including: lack of a comprehensive information management system specific to medical tourists, inadequate marketing, insufficient infrastructure, lack of skilled professionals in the field, and shortage of relevant training programs [35]. According to Iran document 1404 (2025), It is predicted that, 1,400,000 people will be attracted to medical tourism. Hence, Iran has the potential to gain top ranking in medical tourism in the Middle East [36]. Paradoxically, Iran ranks tenth in the world for tourist attractions while its rank in attracting tourists is 52. Unfortunately, statistics regarding the number of medical tourists entering Iran are unavailable and only statistics relating to 2004 and 2005 are accessible.

Interpretive structural modelling (ISM)

Interpretive Structural Modeling (ISM) is a methodology used to identify relationship among specific items, which define a problem or issue; it was firstly developed in 1970’s [37]. ISM is interpretive as judgment of the selected group for the study decides whether and how the variables are related. ISM is a well-established methodology for identifying relationships among specific items, which define a problem or an issue. This approach has been increasingly used by various researchers to represent the interrelationships among various elements related to the issue. ISM approach starts with an identification of variables, which are relevant to the problem or issue. Then a contextually relevant subordinate relation is chosen. Having decided the contextual relation, a structural self-interaction matrix (SSIM) is developed based on pairwise comparison of variables. After this, SSIM is converted into a reachability matrix (RM) and its transitivity is checked. Once transitivity embedding is complete, a matrix model is obtained. Then, the partitioning of the elements and an extraction of the structural model called ISM is derived. In this section, key concept of ISM approach is discussed in detail.

ISM is a well-established methodology for identifying relationships among specific items, which define a problem or an issue. For any complex problem under consideration, a number of factors may be related to an issue or problem. However, the direct and indirect relationships between the factors describe the situation far more accurately than the individual factor taken into isolation. Therefore, ISM develops insights into collective understandings of these relationships. ISM starts with an identification of variables, which are relevant to the problem or issue, and then extends with a group problem solving technique. Then a contextually relevant subordinate relation is chosen. Having decided on the element set and the contextual relation, a structural self-interaction matrix (SSIM) is developed based on pairwise comparison of variables. In the next step, the SSIM is converted into a reachability matrix (RM) and its transitivity is checked. Once transitivity embedding is complete, a matrix model is obtained. Then, the partitioning of the elements and an extraction of the structural model called ISM is derived. In this approach, a systematic application of some elementary notions of graph theory is used in such a way that theoretical, conceptual and computational leverage are exploited to explain the complex pattern of contextual relationship among a set of variables. ISM is intended for use when desired to utilize systematic and logical thinking to approach a complex issue under consideration. ISM is a computer-aided method for developing graphical representations of system composition and structure. ISM methodology is interpretive as the judgment of the group decides whether and how the different elements are related. It is structural on the basis of mutual relationship; an overall structure is extracted from the complex set of elements. It is a modeling technique, as the specific relationships and overall structure are portrayed in a digraph model. It helps to impose order and direction on the complexity of relationships among various elements of a system. It is primarily intended as a group learning process, but individuals can also use it [38].

RESULTS AND DISCUSSION

The researcher finds the growth factors of Mashhad health tourism through a systematic literature review of publications on health tourism. Later, twenty-five experts from the health tourism industry and academia took up ISM. Experts were chosen based on their experience (more than 20 years) and available. An introductory brainstorming session and interview process were conducted to explain the research objectives to the experts. Then all the factors were discussed and collected the responses from the experts to apply the ISM technique. Then factors were placed in a hierarchy, formed the contextual relationships and framed the final relationship matrix.
The ISM model presented in Fig. 1. shows that the policy rules and regulations factor is at the bottom. This factor influences other factors like transport Infrastructure directly and most other factors indirectly while it cannot be influenced by another factor. The “policy rules and regulations” is an important factor that merits attention right at the beginning. It could also be understood that a successful “policy rules and regulations” will certainly improve the Mashhad health tourism industry. The next factor is “Transport Infrastructure”. This factor influences other factors, but it is influenced by “policy rules and regulations”. “Price” is the next level factor. It is influenced by transport Infrastructure and policy rules and regulations. At the same time, it directly affects “Health Tourism infrastructure” and indirectly affects other factors. Next level factors are the ICT and Human Resource, which act as a hub of the system. It indirectly influences a large number of factors and is amenable to be influenced by other factors. Hence, it can be understood that “ICT and Human Resource” are two extremely important factors requiring the major management involvement. The next level factor is Safety and Security. Environment is the level II factor. Health and hygiene, Natural and cultural resources are the level I factor.

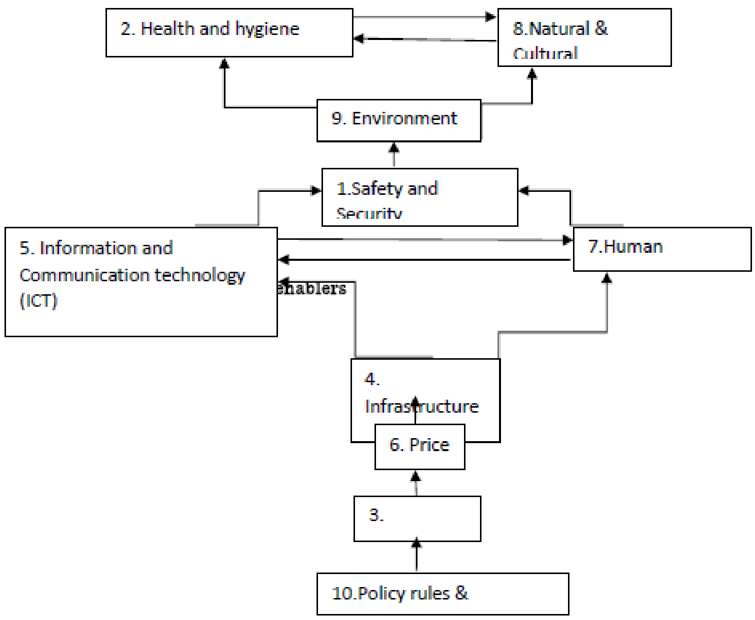

Fig. 1. Mashhad ISM Model

CONCLUSION

Some of the potential factors have been highlighted in this study and put into an ISM model, to analyze the interaction between them. These factors need to be addressed for the improvement in health tourism. This study can give better insights to the top and middle level management as they can tackle these factors effectively. The fully developed ISM is useful for identifying and summarizing relationships among specific factors that define an issue or problem. Finally, by integrating Decision Making Trial and Evaluation Laboratory (DEMATEL) method and Analytic Hierarchy Approach (AHP), the future researchers can understand the functional differences of the ISM and DEMATEL methods in terms of explaining and visualizing the interactions of the barriers of telecom services.

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ENTREPRENEURIAL BEHAVIOR AS A PREREQUISITE FOR THE DEVELOPMENT OF MODERN BUSINESS

Mihalj Bakator[1], Dejan Đorđević[1], Dragan Ćoćkalo[1], Sanja Stanisavljev[1], Dragana Kovač[1], Edit Terek Stojanović[1]

[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: mihalj.bakator@uns.ac.rs

Abstract:
Entrepreneurial activity has been known to positively affect economic development and economic growth. This is important especially in the modern business environment and for business development as the global economic and geopolitical crisis, where job security is low, and competitiveness of enterprises is at risk. In this paper entrepreneurial behavior, and entrepreneurial activities for modern business development are analyzed. The main goal is to present suggestions and guidelines for entrepreneurship and the domestic economy.

Key words: entrepreneurship, trends, business, entrepreneurial behavior, Serbia

INTRODUCTION

The modern economy is the economy of entrepreneurship. Entrepreneurship has been the ideal of the capitalist economy since the end of the eighteenth century. Business management is an entrepreneurial activity. Entrepreneurial behavior is a way of thinking, determined by a creative and innovative approach to business, which is increasingly taking the form of corporate entrepreneurship [1]. According to Drucker [2], the driving force behind changes in attitudes, measures, and behaviors is "technology." What enabled the emergence of the entrepreneurial economy in the US economy are new areas of application of management: in new companies, in small companies, in non-economic activities, in small businesses (cafes, restaurants), in the field of systemic innovation.
The development of entrepreneurship and entrepreneurial behavior became especially important in the early 1990s with the economic transformation of the socialist planned economies of Eastern Europe, as well as with the economic transformation of China. According to Mahajan [3], the so-called economic miracles (the author refers to national economies that have transformed from sluggish and uncompetitive economies to competitive and flexible economies) are the product of enlightened politics and entrepreneurial energy that unleashes the nation's potential. The greatest chance for economic development is the development of entrepreneurship.
The changes that have taken place in the global economy in the last two years have affected psalms. On the other hand [4], the field of entrepreneurship is always changing. Entrepreneurial activity has become even more important in developed economies as well as in the newly industrialized economies of the world. Innovation and creativity have imposed themselves as the basic postulates of modern business. In the domestic market, entrepreneurship as a concept and as a way of doing business is not sufficiently developed, especially when observing modern trends in the field of entrepreneurship in the world [5].
In this paper, trends in entrepreneurship development and its importance for the domestic economy are overviewed. The paper consists of three main sections (excluding the Introduction and Conclusion sections). The first section addresses trends in entrepreneurship development as an important part of economic growth. The next section addresses discusses the application of entrepreneurial behavior in the domestic market. Finally, in the third section suggestions and guidelines regarding entrepreneurship development are noted.

TRENDS IN ENTREPRENEURSHIP DEVELOPMENT

Entrepreneurial behavior is ubiquitous today in all forms of business and social life. We have already mentioned that the establishment of the entrepreneurial economy has enabled new areas of application of management - in new companies, in small companies, in non-economic activities, in small businesses, in the field of systemic innovations [6]. Enterprises, including a large number of non-enterprise organizations (universities, institutes, etc.). In the economy of entrepreneurship, all individuals should behave entrepreneurially, regardless of whether they are self-employed, owners, or employees of the company, but all organizations, regardless of the nature of the activity, should also behave entrepreneurially [7].

In the modern economy, based on knowledge and in the conditions of global competition, all organizations and their employees must behave entrepreneurially. Entrepreneurship is no longer a characteristic of individuals, as owners of capital or self-employed individuals, but also of all employees in all business organizations. Entrepreneurial behavior is a way of thinking, determined by a creative approach to business [8]. Corporate entrepreneurship means that all individuals who are employed in a modern business organization apply the basic principles of entrepreneurship and act as if they are entrepreneurs [9].

According to some considerations [10], businesses are becoming smaller, regions are becoming drivers of business and entrepreneurial activity, and agility is encouraged through smaller hierarchies. Although global business has undergone significant changes due to the COVID-19 pandemic, entrepreneurial optimism is extremely high. Rao [11] believes that entrepreneurship must evolve, that the application of science in entrepreneurship is extremely important today, creativity is expected from all participants in the economic process, as well as the exchange of information as a prerequisite for entering the next phase of global communication.

The main areas of business for new entrepreneurial ventures are [4] - business services, food production and distribution, catering, health and cosmetics, retail and home services. As trends in the development of entrepreneurship can be observed and:

- • Work from home, and globally observed work at a distance,
- • Mobile business and trade,
- • Growth of subscriptions in various services,
- • Application of destructive technologies,
- • Growth of social responsibility,
- • Diversification,
- • Business education,
- • Involving young people in the world of entrepreneurship.

Remote work from home is not new as such, but it gained momentum during the pandemic crisis. Some groups of individuals, such as IT professionals involved in system maintenance, or customer service, have moved from region to region during the crisis to be closer to their customers. This trend will be more and more significant in the years to come, due to the fact that due to the increase in employment costs, employers are accepting this form of work because it significantly reduces costs. It is the same with the business that is coming through mobile applications - the pandemic crisis has blown the wind in their backs and today they have become an integral part of everyday life and performing certain business transactions of both individuals and organizations.

According to Kotler et al. [12], one of the critical topics in modern business is the application of advanced technologies, such as artificial intelligence (AI), NLP sensors, robotics, augmented reality (AP), virtual reality (VR), etc. The combination of these technologies enables the functioning of 5.0 marketing in business.

There is a growing insistence on the application of good practice in the field of social responsibility due to the fact that the pandemic crisis has pointed to the weak sides of liberal capitalism, as well as the global economy - vulnerability of certain groups, inflexibility of certain occupations or even regions, etc. The help of corporations through social initiatives in the field of corporate social responsibility has a positive effect not only on the market, but also on the image of business organizations themselves.

The business must be diversified so that the business organization can monitor changes and repair possible shocks and turbulence in the business itself. This has been best shown in the last two years by Chinese corporations, which have adapted to the demands of the global market in a short period of time. New business conditions require new knowledge and skills, and this has been shown in the past two years. Critical thinking and solving business problems, creativity and adequate human resource management are certainly important elements of management that will be important in the future. The application of modern management methods and techniques is certainly necessary, but a completely new way of thinking about the essence of business is also needed. Outdated business methods and techniques must be discarded, and knowledge must be a pillar of modern business.

Faced with the economic crisis caused by the global pandemic, more and more young people are turning to entrepreneurship and starting their own business. This trend is noticeable during the last two decades, especially after the economic crisis of 2008. Maldives are turning to the development and application of modern technologies, especially in the field of ICT.

APPLICATION OF ENTREPRENEURIAL BEHAVIOR IN THE DOMESTIC MARKET

Entrepreneurial behavior is not twofold in domestic enterprises. Domestic companies, especially those that are state-owned, have inherited an outdated way of doing business. Domestic private companies are mostly burdened by a chronic lack of capital, so they do not deal too much with the application of modern techniques of entrepreneurial activity. Also, the level of innovation in domestic private companies is extremely low.

What has always been dominant in the domestic economy since the very beginning of the economic transition is the phenomenon that entrepreneurship is tied to real private capital, which is invested in the small and medium enterprises sector, and thus limited to lower financial investments. Entrepreneurship has not been comprehensively treated as an opportunity for an entrepreneurial initiative of an individual to enable the emergence of large corporations, which will eventually become market leaders. In the domestic market, entrepreneurship was positively viewed only in the context of the development of small and medium enterprises and the ability of these companies to be shock absorbers for the transition recession - primarily viewed from the aspect of creating new jobs and employment. Such an observation of entrepreneurship by the state could not provide significant results. The essence of serious observation of entrepreneurship is that private property is inviolable and that an individual who accepts risk and creates innovations can become a large corporation owner and market leader in a short period of time.

Industry 4.0 was created through the application of innovative action, creativity and flexible behavior. The most important technologies and products of Industry 4.0 were created as a result of entrepreneurial activity, in the group of small and medium enterprises. Modern business requires that the business organization be smaller, flexible and innovative, as well as agile. According to Kotler et al. [12], agility is needed to provide an adequate real-time response to market changes.

The transformation of domestic companies must be based on the application of management techniques that support competitiveness, innovation and flexibility, as well as on the interventional improvement of the knowledge of their employees, and especially the executive management. The inclusion of as many young people as possible in entrepreneurial activity is especially important for the development of entrepreneurial behavior at the level of the national economy [13].

Every small business or self-employment does not necessarily have to be an entrepreneurial activity, just as not every employer is an entrepreneur. Domestic public companies, although large employers, are not business organizations that are significantly entrepreneurially oriented. The essence of entrepreneurial behavior is in accepting risks and changes based on innovative action, which creates conditions for the development of business entities and the economy as a whole. Domestic companies must be transformed in accordance with the needs of the global economy and socio-economic trends and technical-technological trends in modern education. The most important directions of action in the function of the development of the entrepreneurial economy should be:

1. limiting the operation of the bureaucratic apparatus,
2. creating equal business conditions for all,
3. establishing an entrepreneurial climate at the level of the economy,
4. Faster response of state institutions to the problems of entrepreneurs, especially groups of small and medium enterprises, (in terms of taking an active role in the development of entrepreneurship in the domestic market.

SUGGESTIONS AND GUIDELINES

Based on the analyzed literature and the current global and domestic market, the following suggestions and guidelines for improving entrepreneurship and the domestic economy are noted:

- Entrepreneurship education should be present in bigger capacity on all levels of education.
- The government has to minimize the bureaucratic procedures required to start a business and simultaneously increase data security of founder information.
- Problem solving on the market due to monopolies unfair competition and other unlawful market disruptions have to be sanctioned in an effective way. This would create equal conditions for all entrepreneurs and their activities.
- Entrepreneurship has to be viewed as an opportunity to create economic value, and as a foundation of the value economy.
- Enterprises should consider entrepreneurial activities as driver of innovation and new product and service development.
- Market research is a valuable part of entrepreneurial activities, thus individuals and enterprises have to address changes on the market in a timely manner.
- Technological advancement should be viewed as an opportunity for improving and scaling business.
- Enterprises should not wait for technology to bring new challenges and issues, but rather move towards technological change and embrace it. More precisely, enterprises should apply and implement modern technologies before the same technologies become the “weapon” that is used by their competitors.

In sum, entrepreneurial behavior and entrepreneurial activities present a strong driver of business development. Entrepreneurship positively affects economic development and national competitiveness. It creates new jobs and it can utilize resources of little value to create value on a larger scale. The government should consider incentive means, and to establish an environment where the risk aspect of entrepreneurship is reduced to acceptable levels.

CONCLUSION

The greatest success in the last thirty years has been achieved by those companies that come from countries where entrepreneurial behavior has been strongly emphasized - China, South Korea, Taiwan. The greatest chance for economic development is the development of entrepreneurship. The implementation of the entrepreneurial concept in all organizations, regardless of size and activity, is essential for strengthening the competitiveness of the organization.

The main limitation of this paper is the lack of empirical data from potential new, existing and non-entrepreneurs, as well as from enterprises that encourage, consider or are not at all considering entrepreneurship activities, nor promoting entrepreneurial behavior. This way a more in-depth analysis can be conducted. This current paper provides a roadmap for future research, which should include unemployed people, employees, enterprises, and entrepreneurs.

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SUSTAINABLE BUSINESS IN THE CONDITIONS OF GLOBAL CHANGE

Dejan Đorđević[1], Dragan Ćoćkalo[1], Cariša Bešić[2], Mihalj Bakator* [1], Ljiljana Đorđević[3]

[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: mihalj.bakator@uns.ac.rs
[2]University of Kragujevac, Faculty of Technical Sciences Čačak, Serbia
[3]Environmental Protection Agency, Serbia

Abstract: In this paper, the authors analyze the need to adapt business organizations in line with new trends in the global market, especially observed from the aspect of the impact of the pandemic on sustainability. Developments in the global economy over the past two years have highlighted the need to improve business philosophy and practice in all segments. Companies coming from countries in transition could not adequately respond to the negative effects of this crisis. The paper discusses suggestions and guidelines for improving sustainability and sustainable business of domestic enterprises.

Key words: sustainability, polls, global market, change, crisis

INTRODUCTION

The global COVID-19 pandemic had the most significant impact on doing business, as well as on the global business environment in 2021 [1]. Most of the efforts in the last two years have been focused on improving the health situation, as well as maintaining the business. During 2021, there was a slight recovery compared to 2020, but there was also an increase in the cost of swearing and inflation [2]. Global supply chains are not fully established, which further affects the costs of doing business at the global level, as well as increasing the price of industrial products [3]. This trend will continue during the first half of 2022. These global tendencies in business will also have an impact on the sustainability of jobs, especially in the developed countries of the world, which may deepen the economic crisis. Regardless of these facts, the business world, primarily corporations, should focus on achieving sustainable development goals. Sustainable development goals include not only the business and economics, but also the standard of living of humans in all social aspects (healthcare, social security, job security, fair wages, affordable housing etc.). Sustainable business strategies should include these noted aspects. Social and economic aspects are both important for long-term success in the modern business world [4]. The post-pandemic period, and the current war in Europe brought a pending energy crisis that significantly affects small, medium-sized, and large enterprises. In some cases, large enterprises are affected in a more severe manner compared to SMEs, as they lack flexibility. In such conditions, it is important analyze, and discuss potential solutions and outcomes regarding social and economic sustainability of domestic enterprises. Domestic enterprises already face challenges as they lack productivity, appropriate quality control, and the lack of application of modern management tools and techniques [5].

The main goal of the paper is to overview current business trends from the aspect of sustainability and challenges of achieving sustainable business strategies. The paper analyzes notes the situation in the domestic market regarding sustainable business. The paper discuses suggestions and guidelines for improving competitiveness of domestic enterprises regarding sustainable business strategies. The paper consists of three main sections (excluding the Introduction and Conclusion sections). The first section addresses current business trends and the challenges of sustainability. The second section analyzes the domestic market and sustainable business strategies.

BUSINESS TRENDS AND SUSTAINABILITY ISSUES

The global economy declined in 2020 due to the negative effects of the pandemic. The crisis that has arisen as a result of the pandemic has shown how economically interconnected and interdependent the world is. The result was an almost instantaneous reduction in world trade, a drop in production and a reduction in employment. During 2021, there was a recovery from the negative economic effects of the pandemic, but also the recovery was not uniform, which affects the increase of economic tension in the global level. Pandemic supply chain pressures have increased pressure on supplies. The growth of demand with the opening of economies has led to an increase in the prices of key global products, such as oil, gas and metals. The growth of prices of industrial products will be noticeable during the first half of 2022.
All companies that plow in the global market are facing rising plowing costs, as well as problems in supply chains. The beginning of 2022 indicated that the producers of products of higher stages of finalization will raise the prices of their products (auto industry). In this way, companies are trying to amortize the negative consequences of the crisis caused by the pandemic, but they are also passing on the growth of costs to final consumers.
According to some understandings [6], some of the key trends that will shape modern business in the coming years are:

- Integration,
- Valuation of human capital,
- Responding to change,
- Improving the environment,
- Establishment of sustainable supply chains,
- Establishing sustainable consumption and production,
- Application of new technologies in the function of sustainability,
- Protection of fundamental rights,
- Creating realistic policies, regulations and norms,
- Improving stakeholder capitalism.

The world must be reintegrated, and the key factors of integration will be advanced technologies. Technological progress, which will continue in the near future, will only further affect the connection between countries and their economies [7]. Technological progress and the changes caused by it have influenced the development of the world and humanity in a way that has not been seen until today.
According to some understandings [8], the fight for talents, for the best people and managers, has been the cornerstone of the world's fiercest market players for many years. Investing in the development of employees, building their capacities, and especially managerial skills, makes an essential difference between dynamic companies, as opposed to those that are quickly overcome. People are key in the fight to improve the productivity of modern organizations.
The crisis caused by the COVID-19 pandemic during 2020 and 2021 pointed to the need to change and improve the business philosophy of modern business organizations. Changes are becoming more frequent and more intense, and the business environment is turbulent. New business conditions, determined by the reality of economic crises, require a new approach in the management process of a modern organization. A business system committed to change must be based on knowledge, leadership, creativity and innovative action. The new business philosophy implies the creation of creative teams of highly educated professionals, who act as leaders and entrepreneurs.
Economic development, environmental protection and community development are interrelated. A modern business organization that wants to achieve long-term business success must harmonize its business development with the requirements for protection and improvement of the environment, based on the production of environmentally friendly products, integrated waste management and protection of natural resources (land, water, air, etc.) [9]. The issue of the environment, social and economic development must be considered together in terms of forming a single agenda for action.
Sustainable supply chains are a prerequisite for improving business at the global level, primarily from the aspect of reducing business costs. They directly influence the establishment of sustainable production and sustainable consumption.

Technology is the most dynamic factor in economic development, as well as the competitiveness of companies. Technology enables not only the creation of new technical solutions and new products, but also new markets. Rapid technological development has resulted in the emergence of new industries, new groups, new companies, and new competitors. The essence of new technologies is in increasing business productivity, which improves the competitiveness of companies. The application of a new technological solution increases the production capacity of the company, reduces the use of human labor and, in the long run, reduces the cost of doing business per unit of product.
The 2030 Development Platform, launched at the annual meeting of the World Economic Forum 2020 [10], focuses on building a motivated private-public partnership and civil society aimed at improving ecosystems, in order to seize future opportunities.
During the last two years, we have witnessed the restriction of certain rights and freedoms as individuals everywhere in the world. The future social framework should be based on respect for fundamental rights. This includes the coexistence of realistic, achievable policies and regulations, which will take into account all the possibilities that may occur, such as the global pandemic. The essence of a successful policy is that it is achievable and that it can be realized in practice.
The modern economic system should take into account the need for social responsibility and the realization of the goals of all stakeholders. The public interest is the primary interest of every business organization. The public interest should be incorporated into the business policy of the organization, which should be realized in business practice. The implementation of initiatives in the field of corporate social responsibility should be expanded, and global market leaders should take even greater part in the implementation of good business practice based on the principles of social responsibility.
According to the agenda of the World Economic Forum in the field of sustainable development [11], it is necessary to establish new economic thinking, which primarily implies the establishment of funds for financing sustainable development and improving action in the field of climate change. From the aspect of society, one should strive for the establishment of an inclusive society and equality. In the area of invasions, one should strive for responsibility, and the market must undergo certain forms of transformation. These principles are long-term.

DOMESTIC MARKET AND SUSTAINABLE BUSINESS

According to analysts at the European Bank for Reconstruction and Development (2021), in countries affected by the challenging economic circumstances of the impending pandemic, the COVID-19 pandemic has only exacerbated existing problems - this primarily refers to the consequences of the transitional recession. The domestic economy has been in a transitional recession for many years, which has only intensified the effects of the global pandemic crisis.
The main problem of domestic companies is non-competitiveness, which occurs as a consequence of poor business productivity and lack of application of new technologies and knowledge. The low level of technological equipment of domestic companies, high business costs, as well as the inefficiency of business systems are just some of the problems faced by domestic companies [12]. On the other hand, we should not ignore the chronic lack of financial resources, which makes it impossible for domestic companies to focus on policies and strategies that enable the improvement of global business. In that sense, domestic companies are unable to act innovatively and increase their productivity based on the application of modern technological solutions and modern equipment.
The domestic market faces multiple possible outcomes. These potential outcomes depend on multiple factors including, but not limited to, global economic recession, severity of energy crisis, competition intensity, market share dynamics, globalization acceleration and the development of monopolies, reduced exports of national products and services, reduction or stagnation in product and service quality, lack of sustainable business strategies, lack of regulation regarding environmental and social protection and resource overexploitation. The potential scenarios are presented on Figure 1.

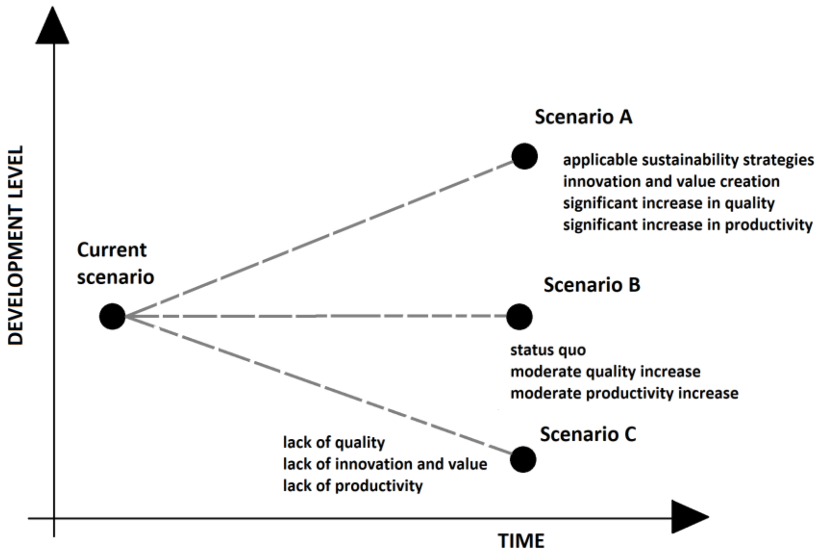

Fig. 1. Potential development scenarios

The worst case scenario – scenario C includes the further decline of productivity, product and service quality, lack of innovation and value creation, lack of modern management initiatives, and the lack of a long-term systematic sustainability strategy on a national level. This scenario has low probability compared to the next, moderate scenario.

The next case scenario – scenario B, has a larger probability compared to the previous one. This scenario can be viewed as a status quo situation, where limited positive development is expected in the domain of productivity increase, moderate increase of product and service quality, drafts of potential sustainability strategies on a national level, increased flexibility of business models, and preparedness of domestic enterprises for various crises that may occur due to the current global economic and political environment.

The best case scenario – scenario A, has a lower probability compared to scenarios C and B. This scenario would require significant and crucial changes in the domain of productivity, new manufacturing equipment, quality excellence of products and services. It would also include applicable and implementable sustainable development plans and sustainable business-oriented culture in the domestic business environment. If the current global economic situation is taken into consideration, then it is difficult to predict, which scenario will most likely come to realization.

SUGGESTIONS AND GUIDELINES

Based on the analyzed literature and the potential development scenarios, the following key suggestions and guidelines for improving domestic business sustainability are proposed:

- SMEs have to adapt to the dynamic changes on the market. This includes readiness for supply chain disruption and market share disruption.
- Sustainability has to be an organic goal and not a pro-form short-term solution. More precisely, enterprises should address all aspects of their business process and based on this to adjust their strategy and business model.
- Advanced technologies should be considered as main tools and drivers of sustainable development. These technologies can significantly improve business effectiveness and process efficiency.
- National sustainable strategies have to be developed and promoted. Incentive programs for sustainable business models should be considered.
- Enterprises have to implement modern and flexible management tools and techniques in order to increase key sectors of their business.

Overall, enterprises have to consider and focus on innovation and value creation. Creating value to the customer is an important aspect of survivability on the modern globalized market. Enterprises have to constantly track and analyze the current situation on the global business scene, as these major changes can significantly affect competitiveness and the future survival on the market.

CONCLUSION

It can be concluded that in the future, it is necessary to achieve sustainable productive economic growth, which is key to improving the lives of individuals. Creating real economic and social value is an important aspect of sustainable development and sustainable business. In the context of domestic enterprises, sustainability should not be only in the domain of profits, but also in the domain of social security, employee wellbeing, and improvement of local communities.

The main limitation of this paper is the lack of empirical data from enterprises. However, the paper provides adequate insight into the main challenges of sustainable business of domestic enterprises and invites future research. For these future studies it is recommended to address sustainable business factors on a micro-level (enterprises), and macro-level (national, international). The influence of these factors could be further investigated via survey, robust data collection, and advanced statistics analysis.

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BUILDING MANAGEMENT - MODERN TENDENCIES

Stanko P. Stankov[1]
[1]University of Niš, Faculty of Electronic Engineering, Niš, Serbia
e-mail: stanko.stankov@elfak.ni.ac.rs

Abstract: Modern buildings are equipped with various technical systems and devices in order to achieve the greatest possible safety, comfort and convenience. Very important components in these facilities are heating, ventilation, cooling and lighting. Fulfilling the set requirements means ensuring the compliance of these components, while considering changing external conditions, which act as disturbances on the space in which a certain object is located. Buildings are permanently exposed to constant changes in influences such as the temperature of the external environment, the amount of solar radiation, moisture content in the air, wind strength, etc., so these factors must be taken into account when designing control systems. In order to realize the set tasks, the construction of the central system for supervision and control (CSSC) using PLC (programmable logic controllers) and SCADA systems (supervisory control and data acquisitio). The advantages of introducing such a management configuration are: monitoring the status of all installed devices and equipment, the possibility of management from one place, synchronization of integrated subsystems, implementation of cntrol algorithms in order to achieve greater savings, prevention and reduction of the consequences of potential accidents.
Key words: building, control, supervision, SCADA, HVAC

INTRODUCTION

The goal of every construction is to provide conditions for living and working in comfortable and economically acceptable conditions, with complete harmony with nature. The environment in which we live with its climatic conditions, the culture of housing and living, as well as the construction and cultural traditions, imposed high demands on the builders. The requirements become greater if we take into account the growing awareness of the need for sustainable development and environmental protection. Despite the strict requirements, the intensive development of science, technique and technology enables the application of modern materials and new solutions in the construction of buildings, while designers and contractors have exceptional opportunities for creative work and professional affirmation [1]. Recently, along with the increasing construction of buildings, the question of managing those buildings, improving the comfort and preserving the value of both newly built buildings and old ones that have been restored or will be work on them for the purpose of revitalization inevitably arises. Management of facilities such as large business centers, hotel facilities, sports facilities, etc. is not at all a simple and easy task for designers and contractors as well as for the owners themselves. Facility management plays a strategic role in meeting the set goals, a term that is increasingly popular in our country and which is a starting point for a successful business, for preserving the value of buildings, using energy-efficient technologies, modern materials, advanced communications and intelligent control. [1 - 3]. Modern buildings must meet the following criteria: use of alternative sources of energy, enabling maximum personal comfort, minimization of exploitation expenses, the highest degree of automation, high level of security, integration of all subsystems. Technological and technical progress is the basis of the construction of modern buildings, especially when it comes to the so-called "green" and "passive" buildings. For the first ones, the emphasis is on preserving the environment and the beneficial effect on people's life and work, and when it comes to second ones, the emphasis is on the application of energy-efficient technologies. Today, the so-called are experiencing great development BAU (Building automation) systems, i.e. building management systems. They have become indispensable in the design and construction of various types of facilities such as business facilities, industrial, sports, shopping centers, hotels, and even individual facilities. Before investing and building a certain object, an extensive analysis is carried out, whose aim is to look in detail at the possibility of achieving maximum profit with minimum expenditure. It should be noted that the industry of shopping centers and retail general, in recent years has become one of the most important drivers of development in all countries, especially in developed ones [1, 4].

ARCHITECTURE OF THE CONTROL AND SUPERVISION SYSTEM

Building management is multidisciplinary in nature and requires from the designer of the management system solid knowledge of thermotechnics, mechanical installations, devices and equipment related to those installations, new materials used in modern construction and modern control systems. Adequate technical equipment is also needed to achieve the required quality. For the successful implementation of the mentioned buildings, constant mutual coordination between designers of all professions, contractors and users of the facility is necessary. Facility management can be divided into three functional units, which are interconnected: commercial building management, infrastructural building management and technical building control. Commercial management has a role in creating the conditions for maximum use of the facility's capacity, renting of the facility and the realization of related financial transactions. Infrastructural management includes the organization and control of all services required for the normal functioning of the facility, such as cleaning service, maintenance service, etc. Control of technical systems installed in facilities ensures the constant functionality of those systems with adequate preventive, current and investment maintenance of them. The three aforementioned elements form a unique unit of the building's management system and they are interconnected and dependent [1]. The configuration of the BAU system is shown in fig. 1.

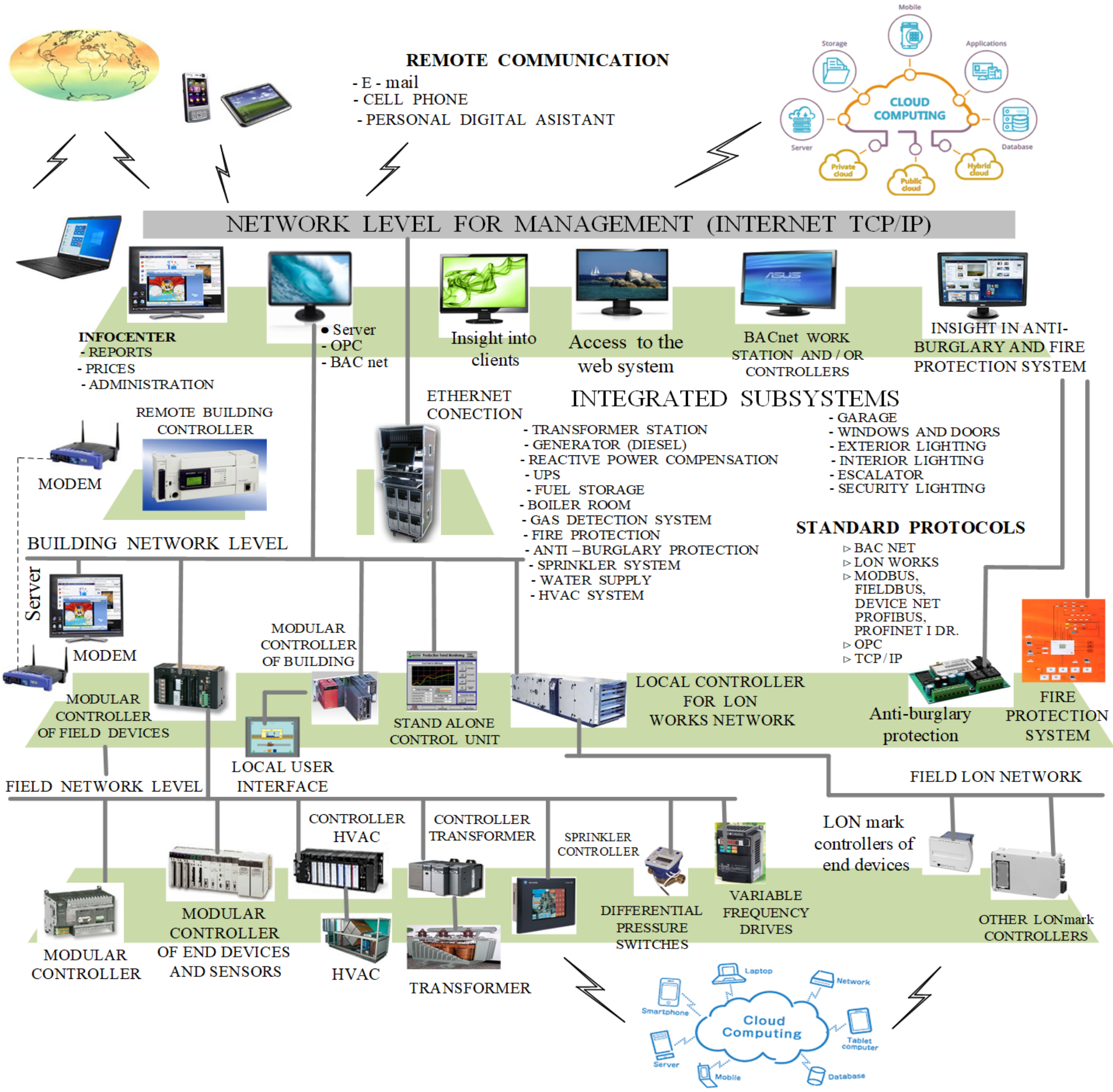

Fig. 1. Configuration of the building control system

The structure of these systems has three levels: the highest level of management (Management level), device and equipment controller level (Automation Stations level), device level in the field (Field level). On the highest level are dispatch computers, connected by fiber optic cables. For security reasons, a double connection (Hyper ring) is performed. The communication protocol at this level and at the device and equipment controller level is Ethernet TCP/IP or BACnet TCP/IP. At the level of devices and equipment in the field, standard protocols such as Modbus, Fieldbus, Devicenet, Profibus, Profinet, etc. are used. The basis of the management system of the modern facility is the Central System for Supervision and Control (CSSC). It is a SCADA computer on which the operator sees the entire facility and monitors all relevant parameters related to the facility's functionality and defined criteria [5]. When it comes to large and complex facility, there are several such computers, on the one hand due to data security, and on the other hand due to the need for a larger number of operators, at various locations in the facility, to access the system. Control and supervision of the facility ensures: visualization of the drive status and measurement of important parameters in the facility; reception, processing and display of process measurements; measurement trend display; chronology of events and analysis; monitoring and processing of warning and alarm signals; the possibility of remote automatic and remote manual control of the facility; generation and presentation of daily and periodical reports; lists of prerequisites by individual functional units; additional functions at the user's request. The supervisory control system consists of a PLCs with appropriate analog and digital input and output modules and SCADA systems. Some manufacturers have developed specialized PLC devices and SCADA intended for BAU systems. The PXC family of compact and modular control units with the DESIGO SCADA system, a product of the Siemens company is an example of that. Realization of the supervision and control system is a relatively complex task, especially when it comes to a complex object where there are various measuring - acquisition and control devices and signals, which should be connected into a functional unit. The designer of this system should have insight into all technical and technological requirements, into the functionality of all equipment and devices, as well as insight into all technical installations and technical systems, which will be managed from one center. At the beginning of the project, the designer must, in a clear and concise way, review all analog and digital inputs and outputs, so that he can have an overview and more easily design the supervisory control system. Fig. 2 shows the organizational structure of the building management of the renowned DESIGO system. Desigo owns complete suite of cloud applications, building management systems, building automation controls for primary and room and field devices to improve the operations of building at all levels [6].

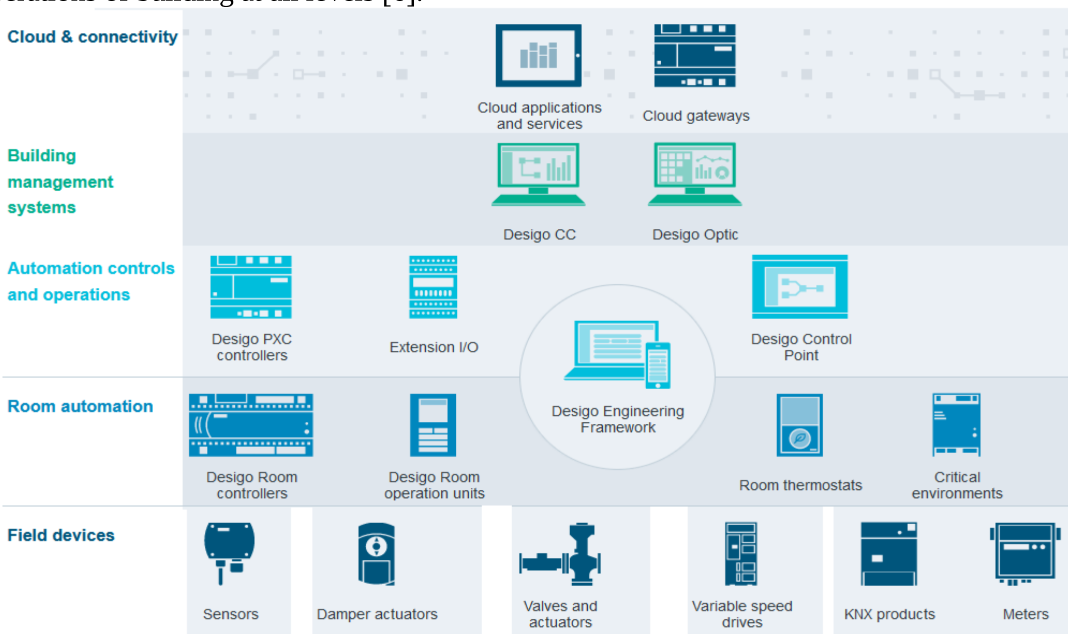

Fig. 2. Desigo building automation system - Desigo system at a glance [6]

A SCADA review

The SCADA review is a very important option that provides the operator with information about what is happening in the facilities being monitored. This representation depends on the type of object it refers to and its complexity. Those options that are not available for a specific object are gray and their activation is disabled. The options are sorted from the most frequently used to the least frequently used. When opening applications from the menu, Windows access is supported for each of the selected options. Each application opens in a new window, with the ability to zoom in or out and move them around on the screen, and drag them down to the line. SCADA software is simultaneously required, on the one hand, to enable simple specification of functional units of system and individual elements within them, as well as an optimal operator interface, and on the other hand, to provide a graphic interface, animation of processes, real time and chronological monitoring of relevant values, alarming in case certain values and parameters go beyond the defined limits, acquisition and storage of data and analysis of that data. Along with the development of the SCADA system, there was a need to protect the data that is transmitted, both acquisition and control information. When looking at building monitoring and control systems, several relatively complex objects are encountered. These are: boiler room, air conditioning chambers, chiller, heat pump, fire extinguishing system (sprinkler), transformer station, diesel generator, distribution cabinets, then connectors, external, internal and security lighting, escalators and elevators, doors, blinds on the windows etc. [2 - 4].

Communication protocols

When designing a building management system, the question of choosing a communication protocol arises. The dilemma is whether to choose an open protocol or a protocol with limited access. Previous experience shows that the advantage is on the side of the open protocol. Here again the question arises: what to choose: LonWorks (Local Operating Network) or BACnet (A Data Communication Protocol for Building Automation and Control Networks). Leading world companies, which, among other things, are involved in the production of building management systems, such as Siemens, Honeywell, Invensys, Johnson and TAC, are the biggest sponsors of LonWorks. On the other hand, BACnet is supported by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers - an association of engineers in America, who deal with problems related to HVAC systems). BACnet is now the globally accepted standard in building management systems [1].

BUILDING INTERNET of THINGS

With the increase of Internet of Things (IoT) applications in the field of building automation and the mass integration of IoT solutions in the public, commercial and residential sectors, more and more is being talked about a new or rather expanded concept - Building Internet of Things (BIoT). It is based on the idea of connecting to the network all components of the housing that can provide Internet connection, with an overall increase in the efficiency of the upgraded systems and installations, reduction of energy consumption and improvement of comfort for the residents. One of the most current technological trends in the building sector is precisely the transition from Building Automation Systems (BAS) to building IoT platforms, in which devices and services are interconnected in a single IP platform with an open communication protocol. The establishment of partnerships between manufacturers of building automation systems and providers of IoT solutions creates conditions for the formation of research consortia that further accelerate the development of technologies in this area. The new BIoT products are based on the latest innovations in the field of building automation, including devices with IoT connectivity capabilities and specialized software platforms. Collaboration between companies developing IoT and profiled BIoT products is key to creating advanced smart building solutions with integrated cloud-based analytics capabilities and based on the full potential of the Internet of Things [6]. The advantages of remote monitoring and management capabilities of BIoT technologies for building automation are increased physical security of locations through remote monitoring of installed video cameras and security systems, activation of alarms, notification of security companies, etc. IoT technologies in buildings enable complete and efficient management of the building, simplifying the user's life and eliminating the need to visit all available rooms in a huge hotel, for example, to check if there is a light that is not turned off or an HVAC unit that is not turned off. The large volume of data (big data) collected and processed in the virtual environment, as well as the integration of control commands and functions in the cloud system, further increase the potential consequences of a targeted hacker attack and make the security of modern smart buildings vulnerable. Unfortunately, in our time such scenarios are quite possible. Therefore, developers of IoT and BIoT solutions should seriously focus on cyber security to convince consumers that their products are safe enough and do not carry risk [7]. In fact, the smarter a building system becomes, the more complex and multi-layered security technology it needs. Security expectations are especially high for Building Internet of Things platforms, which cover literally all aspects of daily activity in buildings.

CONTROL OF THE HVAC SYSTEMS

HVAC (Heating, ventilation and air conditioning systems) have an important place in the equipment and devices, which are integral elements of modern buildings. Control of these systems is one of the most important aspects of building management, because the energy "waste" in these systems is high. The task of the BAU system is the optimal use of installed devices and equipment, saving energy, protecting and preserving the living space and the environment, providing maximum comfort and a pleasant feeling to the people who live in these buildings [2].

Boiler room

The boiler room is intended for the preparation of hot water, which serves primarily for room heating. Various technological processes often require hot water heating. Within the boiler house there are boilers, burners, storage and daily fuel tanks, gas supply, transfer points, boiler pumps, transport and circulation pumps, electromagnetic and electric valves, expansion vessels, measuring elements for level, pressure, temperature of supply and return water, calorymeters, encoders, etc. With the SCADA display of the boiler room, the monitoring of thermal, electrical and hydraulic parameters is of interest. One SCADA screen of the boiler room is shown in fig. 3 [1].

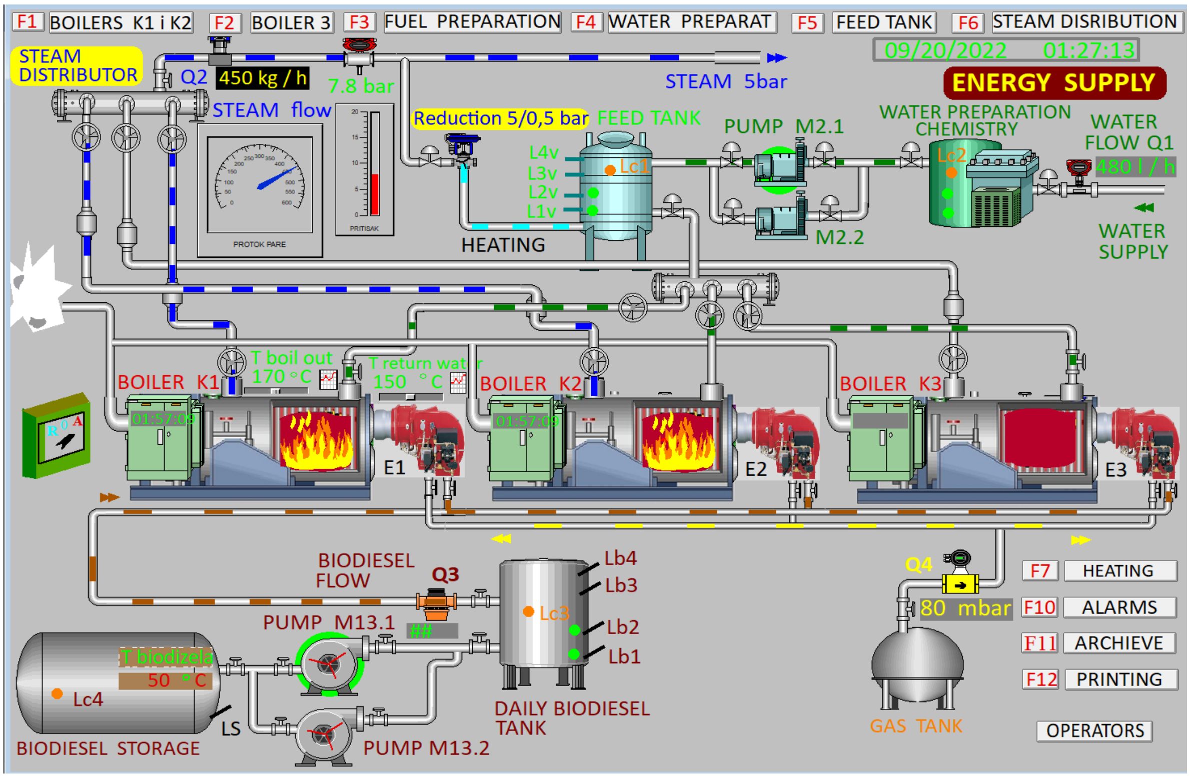

Fig. 3. Display of one SCADA screen of boiler room

In this sense, the SCADA application has three parts, one with electrical, the second with hydraulic, and the third with thermal parameters. They can be displayed side by side on a third of the screen, or individually. The parameters that are measured or recalculated are displayed on the SCADA images (but only the basic ones that are sufficient for the dispatcher so as not to overload him with unnecessary data). Of the parameters that are displayed on the electrical diagram, the following stand out: pump motor parameters (current-order value of phase currents), active (sum of phase powers), reactive (sum of phase powers) and apparent power, cos φ. Among the hydraulic parameters, the following are displayed: water levels in the expansion vessels, water pressure, fuel levels in the storage tanks and the day tank (fuel oil or light heating oil), gas pressure, fuel temperature, outgoing and return water temperature, water pressure. Depending on which probes are submerged, the current fuel level in the tanks is displayed. The display of thermal parameters gives a picture of the temperature of the fuel in the storage tanks and in the daily tank, the temperature of the water in the boilers, the temperature of the water in the discharge and return lines, the room temperature and the outside temperature. Certain data are also given in tabular form.

Chamber air conditioning

Air chamber is one of the key elements of the HVAC system. This complex device provides: temperature and humidity regulation of the air – conditioned space with limitation of maximum and minimum temperature (temperature and humidity sensors – spatial type and channel type); damper control (fresh and recirculation air with the damper actuator) with options “free cooling” and “free heating”; exhaust and pressure ventilator with a two – speed motor, or with frequency regulation of the number of revolutions; water heater or electric heater with pre – heating control; regulation of the valves of coolers, heaters and recuperators; regulation of the pump of cooler, heater and recuperator. Figure 4. shows the SCADA screen of the air conditioning chamber is provided, where the set and current values of characteristic values and parameters (heating and cooling temperature, fresh and dirty air temperature, statuses of the variable frequency drives that regulate the operation of the intake and exhaust fan) and the operating mode can be monitored (summer/winter) [1, 2].

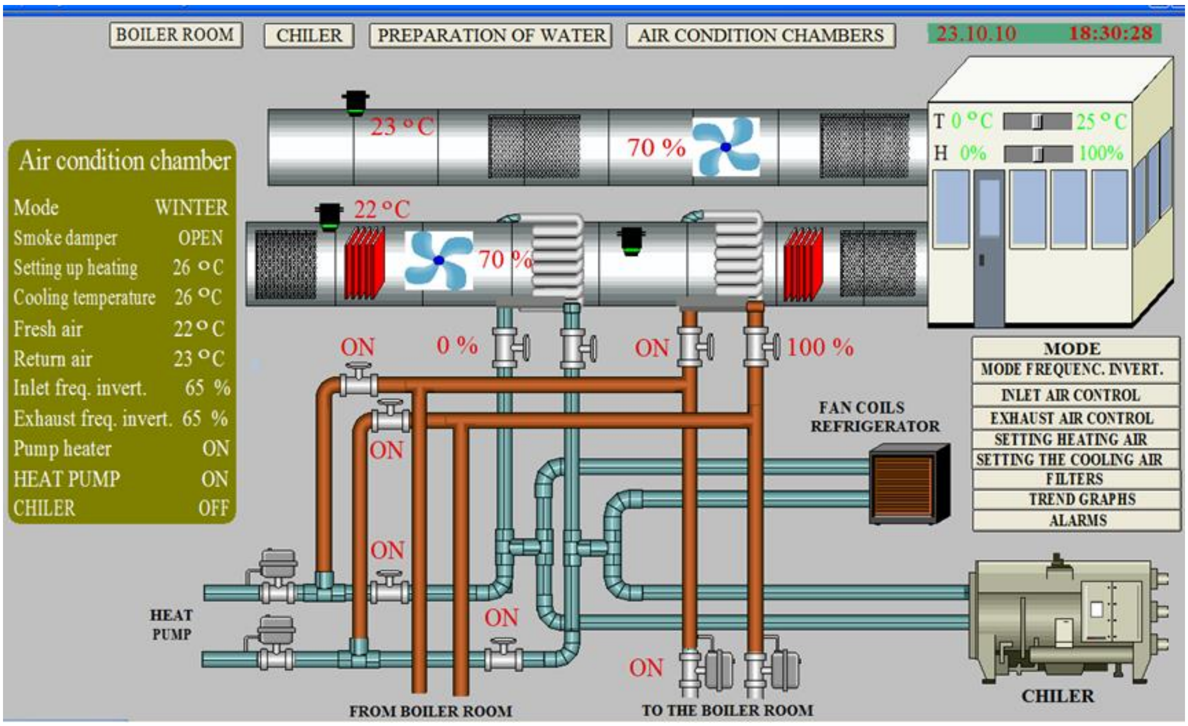

Fig. 4. The one SCADA screen of Air conditioning chamber

Chiller

Chillers are devices of exceptional performance in terms of efficiency, especially the new series, which can use low ambient temperatures throughout the year. They provide high reliability in residential, technological and industrial applications. Although the level of maximum energy savings is achieved in continuous operation, chillers allow significant energy savings during short periods of operation, while also guaranteeing a longer lifespan and reduced need for maintenance compared to conventional chillers. The SCADA screen of the chiller is given in fig. 5. on which the compressor and pump statuses, inlet and outlet temperature are displayed. It is possible to adjust the cooling temperature [2].

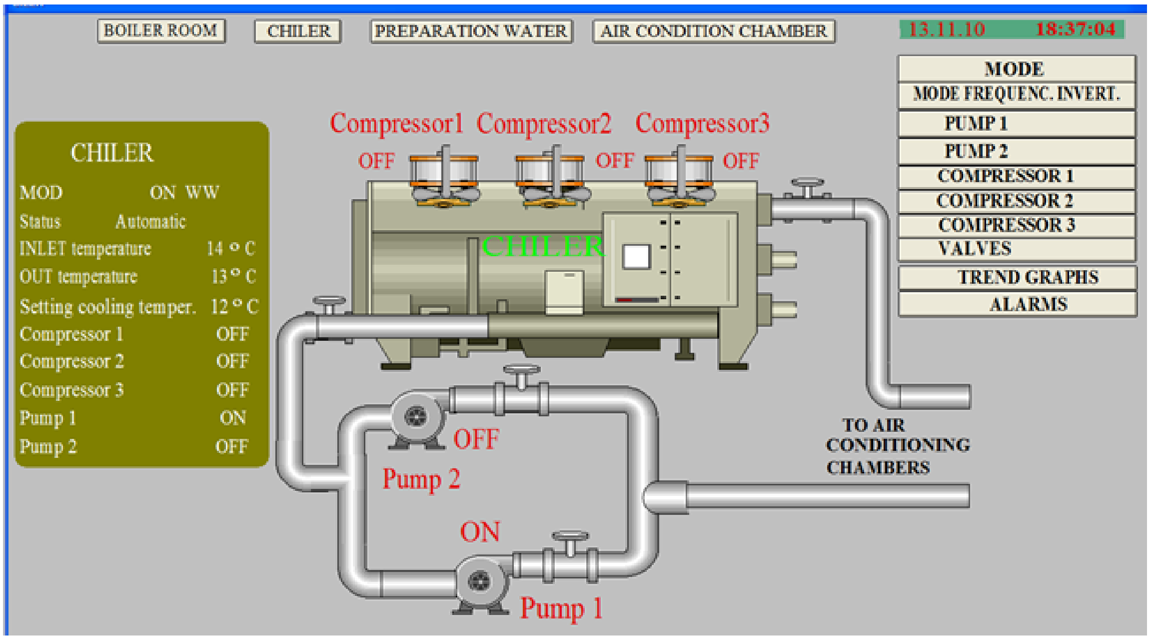

Fig. 5. The SCADA screen of the Chiller

SAFETY SYSTEMS

Security systems, intended to ensure the safety of people and the facility itself, through constant monitoring and supervision of parameters that indicate excessive events and immediate alarming and notification of responsible persons for certain segments are of great importance for the functioning of the facillity. In addition to physical security, security systems include: fire protection, burglary protection, video surveillance, access control [1].

A fire protection

Since in a short period of time a fire can take away the material resources invested over the years, maximum attention fire protection (FP) must be paid during the construction of buildings, and in addition, it is also a legal obligation, whereby the buildings are divided into categories and based on the degree of danger, fire protection system is designed. Mobile fire extinguishers, fire early detection and alarm systems and automatic fire extinguishing systems are foreseen for these purposes. On the basis of the elaboration on fire protection, a suitable FP switchboard with a certain number of zones is selected, to which detectors for early fire detection are connected. CSSC is in constant communication with the FP central, to which the HVAC system is also connected. The electric motor drives of the FP flaps, certain electrical sockets and the smoke extraction system are also related to the conditions of the FP control unit [1].

Video surveillance

The video surveillance system, together with the alarm system, enables the facility's physical security service to work more efficiently, thanks to the fact that it can have insight into critical points of the facility from one place. This system also performs continuous recording, which makes it possible to review the recorded material and use it as evidence in case of extreme situations. At the same time, the control of physical security is carried out. The video surveillance system includes the following elements [1, 8]:

- Cameras (fixed and mobile) that are placed outside and inside the building.
- Computer system used for displaying images from cameras on appropriate monitors, selecting images to be displayed, recording and reviewing the recorded material, which is stored on the hard disk, for a certain period of time.
- Monitors that enable physical security to continuously monitor protected zones. On a larger monitor, multiple cameras can be seen, and on a smaller monitor, images from all or selected cameras can be displayed sequentially, or an image from only one camera can be selected. In the event of an alarm, an image of the zone where unauthorized access has been detected can be displayed on the smaller screen.
- Camera control keyboard.

Access control

This system provides control of access to vital parts of the facility, detection of movement through the facility and records of working hours. Access control is controlled by a computer with appropriate software, which is usually installed in the video surveillance room. The software can support a large number of cards (typically several thousand) and a large number of controllers (several dozen). Access control is usually carried out through identification cards, the holder of which, based on the possession of the card, has access to certain parts of the facility. In addition to the computer, the access control system includes a corresponding number of other elements: controllers, expansion modules, magnetic readers and cards.

Biometric Readers

This technology leverages physiological characteristics unique to each individual to enable identification. It’s both more convenient for users and a more secure way for organizations to authenticate individuals to permit access. Fingerprint recognition is the most widely used biometric control today, but it is by its nature a touch technology. Iris scans are a popular alternative: a camera captures the iris - the eye’s colored part - and compares the photograph with an authentication database.

Facial Recognition

Facial recognition is a touchless technology that examines the subject’s face and compares it to profiles stored in a database. It looks at different characteristics like the 3D profile of the face (size, shape, and position of the eyes, jaw, and cheekbones), skin texture, and vascular and heat patterns that in combination are unique for each person. The system then converts the data into a composite and compares it to a database of known faces to find a match. Facial recognition contributes to a frictionless and touchless user experience. Users only need to show their face at a scanner and no longer need to keep track of access cards, key fobs or other physical devices.

Cloud-Based Access Control

Advantageous security tech developments for businesses is cloud based access control systems (fig. 6) [8]. From a business perspective, they reduce the need to manage on-site servers, and help convert capital costs into more manageable (and predictable) operating costs. But the big advantage is in your physical security. They offer greater flexibility to expand or change features in response to an increasingly dynamic environment, and make it possible to manage system users and access privileges from anywhere at any time. Protection against data lose is increased, because are stored in multiple locations to mitigate the risk of natural disasters, fire, etc.

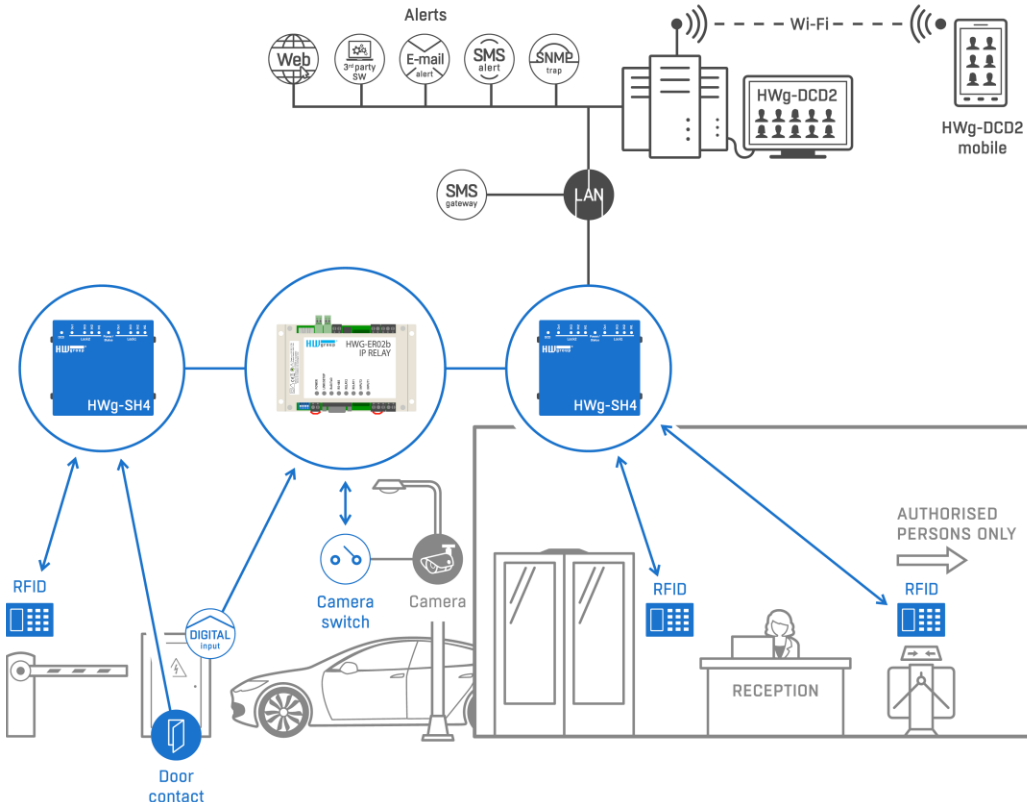

Fig. 6. Building security and access control [8]

Alarms

Alarm protection is a function of the physical security of the building and is usually realized in several segments: protection of the outer circle of the building, indication of the opening of the front door of the building, protection of certain parts of the building (energy part, warehouses, administrative part, etc.). The alarm protection system includes: microwave barriers with a certain range, magnets or microswitches on the entrance door, coders, addressable sensors and an addressable alarm control panel to which the aforementioned elements are connected. The control panel is connected to the CSSC. With the help of the control panel, access to the door is controlled (via magnets or microswitches), alarming or acknowledgment of alarms using a code, motion detection in protected zones (via sensors and barriers). The switchboard is controlled using codes. It is usually sufficient to install two coders: one in the reception unit (doorman) and the other in the video surveillance room. The perimeter of the facility is protected by microwave barriers. In addition to the light alarm (LED) and sound alarm (siren), there are displays with messages that are printed according to the specific situation, with automatic display of images of the protected zone of interest on the alarm monitor. The following systems are connected with alarm protection: gas detection, evacuation system, automatic control systems, control of air conditioning, heating and cooling systems, contol of rooms, control of systems for powering the building with electricity [1].

CONCLUSION

The central system for monitoring and control has become a standard in the construction of facilities of various purposes, but not only as an obligation but also a sound economic logic, whereby the effect of reducing costs is achieved, from energy consumption to efficient maintenance and extending the life cycle of equipment, preserving the environment and increasing the safety and comfort of living in the space. Fulfillment of the requirements regarding the high level of comfort and safety of these facilities is provided by complex technical systems. The effects of installing cheap energy and control systems are short-lived. Problems in maintenance and manual monitoring appear very quickly, along with user dissatisfaction. The integration of all systems (thermal energy, electrical energy, telecommunications, water supply, safety equipment, etc.) that are part of the building and the introduction of central management and supervision are recognizable features of modern buildings. Although such systems do not yet have a place in all buildings, the depletion of conservative sources of energy and drinking water, the constant rise in energy prices and world trends and efforts to preserve nature oblige investors and designers to accept a modern approach to building management. In fact, the smarter a building system becomes, the more complex and multi-layered security technology it needs. Security expectations are particularly high for Building Internet of Things platforms, which cover virtually all aspects of daily activities in buildings. Among the benefits that BIoT technologies provide is the improved efficiency of corporate, office and commercial facilities. It is related to optimal management of the energy consumption of the largest consumers - HVAC systems, lighting, computer and server rooms, by means of intelligent controllers, thermosensors, sensors for presence, movement, daylight, etc.

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Session 7

Students session

THE ROLE OF ORGANIZATIONAL BEHAVIOR IN THE DEVELOPMENT OF QUALITY AND RESPONSIBLE BUSINESS

Biljana Maljugić[1], Srđana Taboroši[1]
[1]University of NoviSad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: biljanamaljugic28@gmail.com

Abstract: The paper presents the role of organizational behavior, observing the field from the point of view of the initial factor for business improvement and the long-term survival of a business organization. The adoption of Quality Management System - QMS and the action of the business organization in Corporate Social Responsibility - CSR initiatives are indicators of quality and responsible business. The possibilities and benefits of implementing QMS and CSR and their impact on leadership, employees, work performance, and company performance were discussed. The implementation of international standards significantly contributes to organizational behavior through guidelines for recruitment and selection of personnel, as well as the necessary procedures for the implementation of social responsibility activities. Based on examples confirmed in business practice, recommendations and guidelines for business improvement are given.
Keywords: Organizational Behaviour, QMS, CSR, Socially Responsible Business

INTRODUCTION

Organizational behavior (OB) according to Robbins and Judge (2009) [1, ch. 1, p. 7] studies and investigates the influence of individuals, groups, and structures on behavior within the organization to aquire knowledge and its application to improve the effectiveness of the organization. It is a special field of expertise that contains common knowledge in the study of the behavior of these three categories in the organization to achieve better work results through its application. Considering the conditions of the environment in which the organization is located and operates, certain factors also affect the work of the organization. The relationship between the organization and the environment must be well balanced for the business effects to be satisfactory. It is of great importance for the organization to recognize and respond to challenges and changes that could disrupt these relationships. This is essentially the task of management, but also all employees. Satisfied clients, consumers, compliance with legal regulations, political and economic conditions in the environment as well as technological changes affect the organizational behavior and performance of the organization. Therefore, the behavior of managers and employees in an organization will generally determine the performance of the entire organization.
In interaction with consumers, clients, and stakeholders, the organization creates an image in the environment by its behavior, and how dominant its reputation will be in the increasingly competitive market depends on the quality of the business it conducts. The quality of products/services, processes, and the entire business in modern society requires the implementation of a Quality Management System - QMS. Gal et al. [2], see QMS as a management and control tool for the implementation of all business activities that include the appropriate organizational structure, planning, business processes, necessary resources, and quality documents in meeting the needs of all business parties [2], [3]. Effective application of QMS in a business organization manifests it self in business success factors [4]. Bhatia and Awasthi point out that QMS implements changes and increases organizational performance achieved through quality information, better operational performance, environmental, design performance, P/U quality, effective external performance in supplier and customer relationships, and competitive priorities [4], [3].
Given that Corporate Social Responsibility - CSR is one of the factors of QMS, it is linked to organizational behavior, that is, it can be observed how responsible behavior is represented in the organization, depending on the level of CSR procedures and policies adopted. The international standard ISO 26000 provides recommendations, guidelines, and explanations to understand social responsibility. ISO 26000 supports and assists companies in guiding principles and implementing social responsibility activities on the example of best business practices in a global environment. ISO 26000:2010 contains a communication protocol that describes appropriate wording to assist

organizations in communicating the use of this standard. ISO 26000 documents are in line with the OECD for multinational companies and the United Nations Agenda 2030 Sustainable Development Goals [5], [6].

ORGANIZATIONAL BEHAVIOR AND QMS

Quality Management Systems

Quality management systems are increasingly represented in the strategy of organizations [9] as well as in service activities because they bring significant improvements [7]. In their research, To, Yu and Lee [7] confirmed that leadership, i.e. top management in its supportive behavior towards quality management significantly contributes to the components of quality management. Specifically, it affects the process approach, affects human resources in relationship management, and makes better decisions supported by facts. User orientation in this case of quality improvement has shown significant effects on business improvement.

By applying normative documents of QMS, system approach, methods of organization theory and organizational behavior, Yakovlev and Glukhov [8] showed that the development of economic goods requires an inseparable connection between production and consumption. In this study, the role of the product as an element of the connection between the producer and the consumer was confirmed in the created model of the interaction process, suitable for all activities, by including the most important features of the product, the applicability of quality and price concerning value.

Leadership committed to a quality culture and QMS implementation showed according to research by Maina and Awuor [9] that there is a significant relationship between leadership and QMS performance. If the leadership is determined and operates following these intentions, which imply responsibility, maintaining quality in the organization, will result in the improvement of QMS performance. This further implies the planning and establishment of the quality policy in the organization by the leadership. Investment in necessary resources for quality implementation as well as responsibility for performance, quality monitoring and control, quality maintenance, and audit of results. Purwanto [10] showed in his study a significant relationship by which leadership and organizational culture influence the implementation of ISO 9001:2015 in a company. Organizational culture has a significant impact on service quality [11], [14], which has effects on user satisfaction and improves organizational performance.

In research conducted in higher education institutions, it was determined, based on the responses of lecturers, that knowledge management has a mediating role between leadership and the performance of organizational tasks [12]. Through the mediation of knowledge management, the elements of leadership and organizational tasks of lecturers were strengthened. Through data analysis, in addition to leadership, knowledge management, and performance of organizational tasks, the variables information technology support, quality management system, and work motivation also showed good results in this study.

For quality management in current socio-economic conditions, Lyskova [13] emphasizes the importance of the approach to the development of human resources management and the necessity of establishing a quality management system of human resources in the organization. Lyskova suggests applying the Japanese business model, which would serve most organizations. Human resource development and knowledge management bring benefits to individuals and the entire organization. At the individual, group, or organizational level, qualitative changes in business processes are recognized in the recommended model, for the improvement of management, the development of innovation and creativity, the realization of the economy of knowledge, employee satisfaction, and well-being in society.

Standardization of Human Resource Management

In the context of business organization and organizational behavior, human resources are the most important essential factor in achieving organizational goals. According to Holt [14], human resources are the first strategic resource of any organization, a force for development and initiation of change.

The standardization of human resources management significantly contributes to the selection of quality personnel and better business operations through the improvement of human resources, which results in a greater performance of the entire organization, and company. The set of ISO international standards for human resource management provides guidelines and helps organizations, i.e. human resources departments, to perform their work well.
The ISO 30408 Human Resource Management standard provides guidelines on human resource management in the direction of the structure of an efficient system for managing employees following organizational and operational needs and encouraging cooperation towards all interested parties, predicting and managing human resource risks, and developing company culture [15], [14].
The ISO 30405 Human Resource Management standard provides guidelines for employment, on effective recruitment processes and procedures [15], [14].
The ISO 30409 Human Resource Management standard provides guidelines for manpower planning and helps organizations respond to projected demands for the required personnel [15], [14].
The ISO 30400 Human Resource Management standard contains a glossary that provides an understanding of the basic terms used in these standards [15], [14].
The latest version of the Standard ISO 30414:2018 Human resource management is a document that provides guidance on internal and external reporting on human capital [16]. The ISO 30414:2018 standard contributes to the sustainability of human capital. It can be applied in all types of organizations. By applying ISO 30414:2018, improvements in the organization's performance can be achieved. The standard covers and provides guidelines for reporting on human capital in the following areas [16]: compliance and ethics; costs; diversity; leadership; organizational culture; organizational health, safety, and welfare; productivity; employment, mobility, and turnover; skills and abilities; succession planning; labor availability.

ORGANIZATIONAL BEHAVIOR AND CSR

Voluntary activities of companies and initiatives within the concept of social responsibility are realized in such a way as to satisfy the needs of consumers and customers, and to provide convenience and protection for stakeholders, employees, and the ecological environment in which they operate. For this purpose, social and cultural projects are implemented for the benefit of society and the community, as well as ecological, so-called green projects in the preservation of the environment and natural resources. To maintain its economic interests and ensure survival in the market, corporate social responsibility is included in the company's strategy. Değirmenci [17] confirmed in his study that corporate social responsibility has a positive effect on the organizational behavior of employees. By establishing a socially responsible corporate policy, employees are more loyal to the company and more motivated, which results in higher productivity and work performance [17].
Ali, Islam, Mahmood, Ali, and Raza found a significant relationship between corporate social responsibility and employee engagement. Socially responsible business through the mediation of compassion at work and psychological ownership contributed to an increase in the work engagement of employees [18].
The performance of employees, according to the results of research by Fadlan [19], is significantly influenced by the work environment and organizational culture, but the most significant of all variables was motivation as the highest value.
Although CSR is represented in company strategies for the benefit of society and investments with a specific goal, on the one hand, it essentially brings the expected reputation of the company. Organizational legitimacy, image, and reputation of the company favor the motivation of employees. Employees feel safe and proud, they have a positive attitude towards ethical behavior. Companies that contribute to better CSR have a higher level of behavior and ethics. In some organizations, this is not the case. But it was established that by applying social cognitive theory CSR can prevent unethical and pro-organizational behavior of employees. By increasing the level of moral identity, CSR can reduce the unethical pro-organizational behavior of employees in the organization [20].
Magalhães [21] points out that socially responsible business derives from the culture (national, organizational) of the business organization. The author suggests that in the future it is necessary to pay more attention to culture to improve the implementation of CSR in business practice.

Looking at research work in the field of corporate social responsibility at the micro level, Levine, Presbitero, Ramya, and Willness [22] noted that it is increasingly penetrating the domains of organizational behavior and human resources. Employees understand and participate in CSR initiatives in different ways. CSR is in favor of the organization and employees to benefit the users, however, recently there have been opposing opinions that need to be considered.
Taking into account the cooperation of several actors in economic processes, production, industry, and other activities, then socially responsible business implies the coverage of all necessary activities for the realization of those processes. Dorstewitz and Lal [23] proposed a new model for the practical application of CSR based on actor-network theory, systems thinking, and complex process pragmatism. Given that the actor-network theory, which refers to organizational behavior including technology, people, and micro-processes, underpins the socially responsible business approach, one can expect the realization of interactive systems of agents of interested parties that will provide new solutions to CSR problems through cooperation and association. The authors propose an examination of the model, through the mentioned CSR approaches and actor-network theory in different industry sectors. It is significant to single out the need for the transformation of the energy sector towards the decentralization of production, storage, and trade of energy from renewable resources, from systemic observation and monitoring of applied technologies at the micro-grid level.

RECOMMENDATIONS AND GUIDELINES FOR IMPROVEMENT

With the need to satisfy customers with a service in the service industry organizations, the necessity of employee creativity is inevitable, on which leadership has a significant influence. In achieving organizational goals, a transformational leadership style is recommended that would fully affirm employees. To make quality business decisions, transformational leadership applies a process approach in which priority is given to users, and quality seekers, while also adopting feedback from employees to improve services [7].
Ali, Islam, Mahmood, Ali and Raza [18] point out that by applying CSR, managers can establish strategies for attracting and retaining the quality and talented personnel in the organization, which will contribute to greater work engagement. In this way, work performance will increase and the performance of the organization will be improved. In addition, the socially responsible business enables the sustainability of the company not only in the economic sense but sustainability as a benefit to society and in the ecological contribution to the environment. According to the same authors, CSR initiatives should also be implemented within the organization through communication and the development of employees' awareness of socially responsible business [18].
According to the opinion of Zonghu, Junyun, Yulang, Ming, and Xu [20], for the long-term sustainability of the organization, the need for profit should not be emphasized too much, but company management should focus more attention on Socially Responsible Business - SRB as an opportunity to reduce the unethical pro-organizational behavior of employees. The construction of CSR programs in which employees would participate, which would include the creation of better working conditions, employee rewards, transparent procedures, commercial practices, and environmental protection, would distinguish ethical behavior. Furthermore, moral identity is equated with an important criterion for the selection of staff during employment. If companies advocate a CSR culture to preserve a moral working climate, employees will also contribute. The effects of ethical business are visible in satisfied users, in the delivery of quality and safe products/services, as well as in cases of resolving complaints from dissatisfied customers [20].

CONCLUSION

The long-term survival of a business organization is conditioned by the quality performance of business activities, but also by responsible business towards the community, society, and environment in which they operate. Quality management in the creation of quality products or services according to consumer needs, and performance of quality processes for clients and interested parties is supported by international standards. The readiness of the organization to comply with the requirements of standardization or accept the guidelines depends on the leadership and the perception of the employees, that is, their behavior. Organizational behavior says a lot about the organization. Whether that behavior is conditioned by quality leadership or culture of quality, in any case, shows to what level the organization can present all the requirements for socially responsible business. Examples from business practice show that increasing work performance can be achieved through several variables. From quality management and implementation of international standards, motivation, and ethical behavior of employees, to contribute to the community through CSR initiatives and environmental protection.

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AUTOMOTIVE ERGONOMIC, THERMAL ANALYSIS OF DIFFERENT DRIVING POSITIONS

Alexandru Dumitru Antonie[1], Adrian Eugen Cioablă[1], Luisa Izabel Dungan[1]
[1]University Politehnica Timisoara, Faculty of Mechanical Engineering, Timisoara, Romania
e-mail: adria.cioabla@upt.ro

Abstract: Ergonomics represents a multidisciplinary science involving the best possible combinations of factors in regards to user (driver) position and equipment (vehicle) involved in the process. This aspect involves elements of passenger safety, prevention measures, in direct content with the vehicle actuality in terms of existent technology, comfort, performance and efficiency. This aspect is related to the best possible position of the driver / passengers, without uncomfortable body positions for vehicle exploitation. In this regard, the process of designing the vehicle involves good knowledge on human anatomy, driver / passenger specifications, vehicle and existent environment. The present paper represents a short study on the driver position impact in different scenarios, on muscle effort, by using a thermal vision camera.
Key words: automotive ergonomics, thermal analysis, driver position.

INTRODUCTION

Ergonomics is a multidisciplinary science involving fields that have information about people. The basic goal of ergonomics is to design equipment that will achieve the best possible fit between the users (drivers) and the equipment (vehicle) such that the user's safety (freedom from harm, injury, and loss), comfort, convenience, performance, and efficiency (productivity or increasing output/input) are improved [1]. Ergonomics involves "fitting the equipment to the people (or users)." This means that equipment should be designed such that people (population of users) can fit comfortably (naturally) within the equipment and they can use the equipment without any awkward body postures, movements, or errors. Another important consideration involves "humans as a systems component." This means that the designer must treat the human to be a component of the system that is being designed. The process for designing a vehicle should thus involve the considerations of the following major components: the driver/user, the vehicle, and the environment [2]. After taking in consideration the ergonomic side of the driver position another important aspect that need to be take in consideration is the capability of multiple adjustment for the position seat and the steering wheel. For example, the seat should be able to have the possibility to be adjust for the height, distance to steering wheel, recline etc. and the steering wheel to have the possibility to be adjust for reach and height, all this feature are needed to create a good driving position and let the driver to have a comfortable experience [3-6].
As stated ergonomics is related to all aspects inside of vehicle, according to internal factors like thermal or noise comfort, chair position, driver assistance and so on. Relative to ergonomics awareness, this involves the aspect that the employees have not proactively measured ergonomics risk in early product development stage [7]. Traditionally in the automotive design process most of the ergonomics risk inputs was provided at the end of the styling process [8]. Previous research highlighted the importance of integrating ergonomics as general concept into a total quality management system [9, 10]. This aspect, due to its studied impact, is taken in consideration during all the steps involving manufacturing process. Relative to driver seat, it can be mentioned that in the sitting state, the main structure of supporting the human body is spine pelvis, legs and feet [11]. Some measurements indicate that the most comfortable sitting posture is moving the hips forward slightly from seat back, making the upper body tilt slightly upward and keeping the angle between the upper body and thigh in 90 ° ~ 115 °. At the same time, the angle between thigh and calf, and the angle between calf and feet should reach a certain range when legs extend forward. At this time, lumbar spine, sacrum, lumbar intervertebral disc and soft tissue bear the most of loading from the upper body. In addition, the driver needs to realize waist bent, torsion and other actions. Therefore, the two aspects are most important for the design [12]. Currently there are developments in many aspects involving driving, one of them, by example, being the replacement of real mirrors with digital ones, in order to

improve the driver's field of vision [13]. The issues and potential drawbacks are currently investigated, due to lack of information and reduced use for this type of equipment.
But all this feature are useless if the driver is forced or decide to use an incorrect driving position, that can make the experience of driving a car one that create a lot of discomfort.
To be able to see what happen and what is the effect of this type of driving position we will analyze what is the effect to human body in terms of thermal output for muscular mass.

MATERIAL AND METHODS

To be able to see what effect a bad driving position has to the driver we will make a comparison between three driving position:

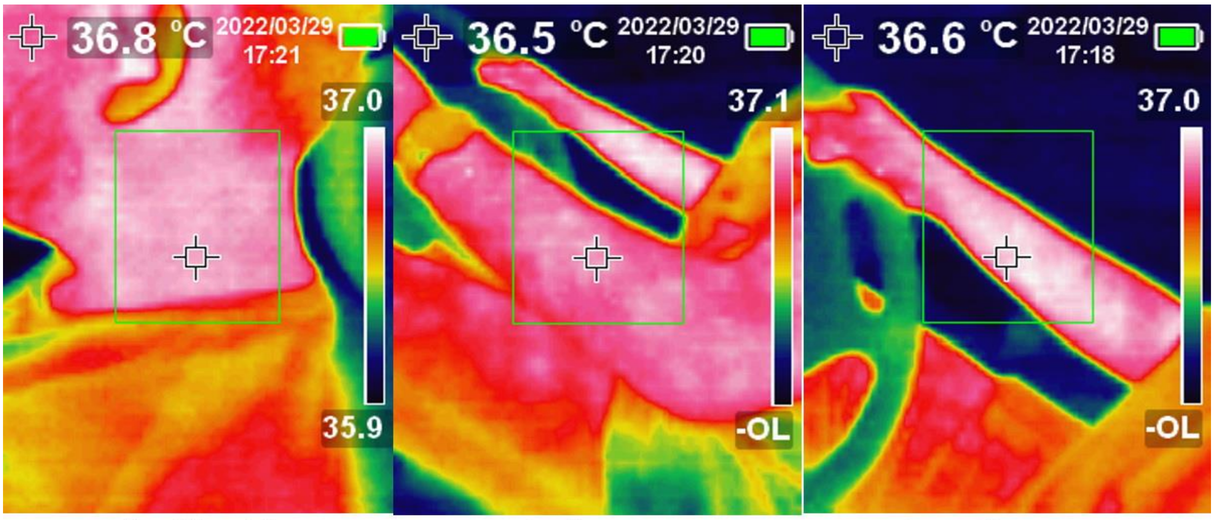
- When the driver is position very close to the steering wheel, but the driver is still able to drive in a safety way and use all the feature that the automobile has;
- When the driver is position far from the steering wheel, but the driver is still able to drive in a safety way and use all the feature that the automobile has;
- When the drive is position in his ideal driving position, a position that allow him to drive for a lot of time.

For this experiment we will use the scenario when the automobile is driven on highway. In this scenario the driver will not move too much in the seat, he will not be forced to make any move, like take a sharp corner.
To be able to see how a bad driving position will affect the driver with the help of a thermovision camera we will see how the temperature of the body of the driver is influences, if we see that the temperature of the driver body is start rising we can tell that the muscle is contracted and that will let to an increase of driver fatigue. We will measure the temperature of the drive in three points, inner forearm, outer forearm and neck of the driver, to see how the driving position will affect the driver. The driver will keep his position for about 10 minutes and after that the measurement will start, every record will be made from minute to minute.
To be able to do this experiment following instruments have been used:

- Thermovision camera from the UNI-T, model of the camera is UTi85H+. That have the capacity to registered temperature between 30ºC and 40ºC,
- Car, the care that was used for this experiment is a BMW 318i compact. The important thing regarding the car is represented by the possibility to adjust the driving seat (multiple adjustments available).

RESULTS AND DISCUSIONS

Driving seat is put close to the steering wheel, in this situation the driver is required to adjust the seat to be close to the steering wheel, but to have the possibility to operate all the function of the car. In the picture bellow we can see example of the picture that where taken by the thermovision camera. In the first picture we can see the temperature of the neck area of the driver, in the picture we can see that the temperature is 36.8 ºC. In the second picture we can see the picture of the outer forearm and we can see a temperature of 36.5 ºC. In the last picture we can see the temperature of the outer forearm and we can see a temperature of 36.6 ºC.



neck of the driver   outer forearm   inner forearm

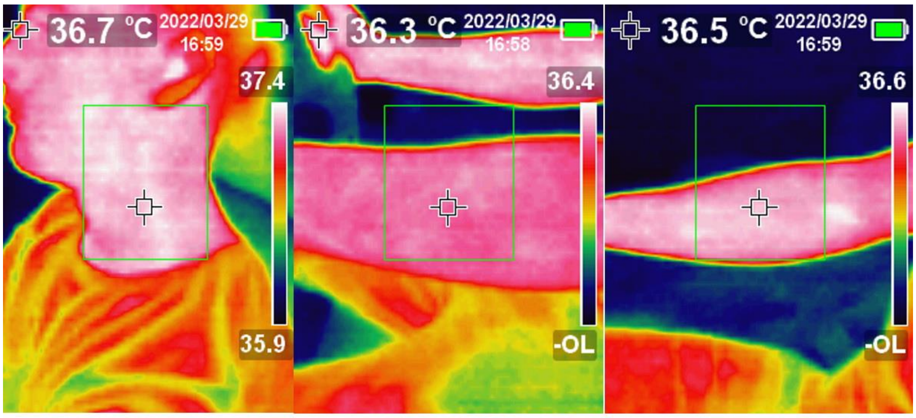
Fig. 1. Heat distribution with driver seat close to steering wheel.

Table 1. Temperature distribution, steering wheel proximity.

No.	Inner forearm [°C]	Outer forearm [°C]	Driver neck [°C]
1	36.6	36.5	36.8
2	36.6	36.4	36.8
3	36.7	36.5	37.1
4	36.6	36.5	37.1
5	36.8	36.5	37.1
6	36.8	36.5	37.7
Average	36.7	36.5	37.1

In the table 1 we can see the date of the first position, we can observe that for the inner forearm we have an average temperature of 36.6 ºC, for the outer forearm we have an average temperature of 36.4 ºC and for the neck area we have an average temperature of 37.1 ºC.

Driving seat is position far from the steering wheel, in this situation the driver is required to position the seat far from the steering wheel, but to have the possibility to operate all the function of the car. In the picture bellow we can see example of the picture that where taken by the thermovision camera. In the first picture we can see the temperature of the neck area of the driver, in the picture we can see that the temperature is 36.7 ºC. In the second picture we can see the picture of the outer forearm and we can see a temperature of 36.3 ºC. In the last picture we can see the temperature of the outer forearm and we can see a temperature of 36.5 ºC.



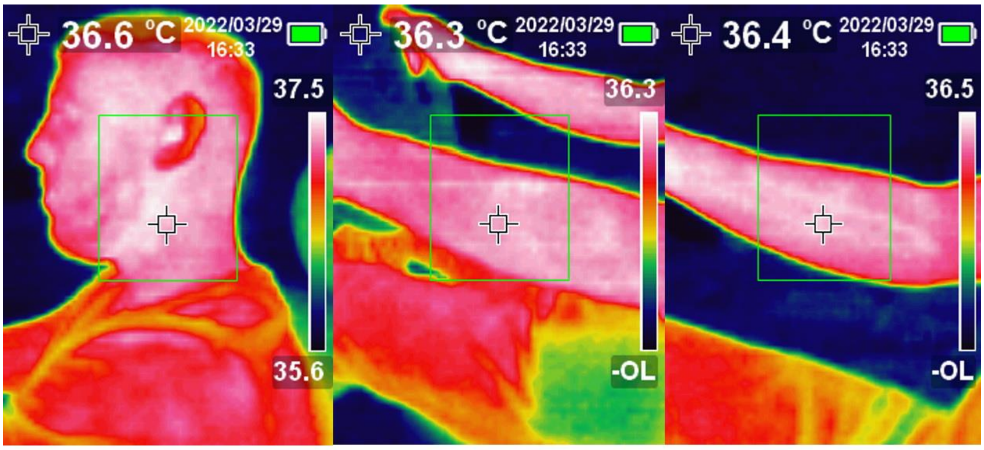
neck of the driver   outer forearm   inner forearm

Fig. 2. Heat distribution with driver seat far to steering wheel

Table 2. Temperature distribution, subject far from steering wheel.

No.	Inner forearm [°C]	Outer forearm [°C]	Driver neck [°C]
1	36.4	36.3	36.6
2	36.5	36.3	36.7
3	36.5	36.3	36.7
4	36.6	36.4	36.9
5	36.6	36.4	37.1
6	36.6	36.5	37.3
Average	36.6	36.4	36.9

In the table 2 it can be seen the date of the first position, we can observe that for the inner forearm we have an average temperature of 36.5 ºC, for the outer forearm we have an average temperature of 36.3 ºC and for the neck area we have an average temperature of 36.8 ºC.
Driving seat is position in the most comfortable position for the driver, this position will permit to the driver to have the possibility to drive for a lot of time without the effect of fatigue appear. In the picture bellow we can see example of the picture that where taken by the thermovision camera. In the first picture we can see the temperature of the neck area of the driver, in the picture we can see that the temperature is 36.6 ºC. In the second picture we can see the picture of the outer forearm and we can see a temperature of 36.3 ºC. In the last picture we can see the temperature of the outer forearm and we can see a temperature of 36.4 ºC.



neck of the driver outer forearm inner forearm

Fig. 3. Heat distribution with driver seat in comfortable position.

Table 3. Temperature distribution, subject in comfortable position at steering wheel.

No.	Inner forearm [°C]	Outer forearm [°C]	Driver neck [°C]
1	36.3	36.3	36.6
2	36.4	36.3	36.6
3	36.4	36.3	36.6
4	36.4	36.4	36.7
5	36.5	36.4	36.9
6	36.7	36.5	36.9
Average	36.5	36.4	36.7

In the table 3 one can observe the date of the first position, we can observe that for the inner forearm we have an average temperature of 36.4 ºC, for the outer forearm we have an average temperature of 36.3 ºC and for the neck area we have an average temperature of 36.7 ºC.

CONCLUSION

After the measurements we can observe that in the case of the ideal driving position the average temperature of the driver body in the three zone that were analyzed have a lower value that the other two positions. In this case we can tell that the driving position have an impact to the fatigue of the driver.

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THE IMPORTANCE OF ENVIRONMENTAL MANAGEMENT AND PROTECTION IN THE FOOD INDUSTRY WITH THE APPLICATION OF INDUSTRY 5.0

Aleksandra Kovačević[1]
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: aleksandra.unija@gmail.com

Abstract: The development of the industrial revolution conditioned the development of the industrial economy itself, the most dynamic and extensive change of all major changes, which explosively changed all aspects of the previous model on the basis of which the entire social community is developing. In this way, a completely new form of social behavior and industrial culture is established, including the national and organizational culture of the company. The industrial cultural matrix was so different, that it is simply incomparable to what existed before the appearance of the first factories, steam and machine tools. Contemporary social business is based on modern technology, knowledge and new management theories. The application of new technologies has helped to a great extent to improve the quality of human action in many areas, both business and social. Companies increasingly attach importance to quality.
Keywords: circular economy, industry 5.0, food industry, economy, knowledge, environmental protection

INTRODUCTION

The emergence of new ways of creating products caused the entire industry to function as a natural eco-system and waste from one industry becomes raw material in another, i.e. to mimic circulation. Taking into account the predictions about the growth of the population on Earth, an increase in production is expected from the food industry, which inevitably brings with it an increase in the amount of generated waste. Organic components of waste of plant origin are interesting for further utilization, because they contain large amounts of highly valuable molecules. The goal of the work was to show how waste from the food industry is not waste but a raw material that can be included in other processes, the basic principles of the circular economy - regeneration and circulation. The wine industry, as the main industry when it comes to grapes as a raw material, generates large amounts of this kind of waste. As production grew, so did the amount of waste, which is why people began to see the negative aspect of improving production processes [1].
The paper will present a theoretical presentation of the importance of applying knowledge management and environmental protection in the food industry, specifically related to Industry 5.0 and modern industry models.
Industry 5.0 is the full integration between man and technology. Before entering that phase, a period of transition needs to pass, which some evaluate as very dark, and others as the liberation of man. The positive side is less physical effort because robot assistants can optimize production and do difficult and dangerous jobs. The combination of machines and new technology increases productivity, which brings down prices. In developing countries, structural changes in processing industries from traditional to technologically complex ones, with greater productivity and competitiveness and greater created added value, are a condition for increasing the intensity of industrialization. It is a prerequisite for the creation of new jobs and sustainable economic development. As the main drivers of more intensive development of industry and structural changes in it, the following are considered: knowledge, skills, innovations, technologies, demand, resource efficiency, investments, company size, value chain activities, agglomerations and industrial policy [13].
Food loss and waste is a major global problem: every year, a third of the world's food production is lost or wasted on its way from the farm to the consumer's plate, corresponding to a staggering 1.3 billion tons of perfectly good and edible food, or 216 kg food for of each of us [14]. Moreover, resources for food production are inadequately used. Only 5% of fertilizers actually end up in nutrients for human consumption, and some of them do not improve human health and well-being. Only 40% of irrigation water reaches plants, and soil degradation affects 30–85% of agricultural land in Europe.

Finally, the average European consumes 40% more calories than recommended, while more than 50% of the European population is obese [15].

THE TERM AND SIGNIFICANCE OF THE CIRCULAR ECONOMY

The concept of circular economy is based on the assumption of the use of resources in production and use in a way that maximizes the duration of the value of the produced product or service, reduces in the process of production and use to a minimum level waste material that cannot be reused, maximizes the utilization of resources, and ultimately cycle the product or service is returned to the production process to create new value. Innovations in the field of communications, material use technology, production processes, etc., only in the last few years have created space for a strategic turn towards the concept of a circular economy. The greatest progress in this turn was achieved by the People's Republic of China and the European Union, and it is precisely the regulation aimed at implementing the concept at the national and supranational level that encourages the further development of innovations that enable and facilitate its application, define its potential and future development. In what way the two technological advances that are currently most expected, the Internet of Things and Blockchain, will affect the implementation and development of the circular economy concept, we will see through the example of regulation at the EU level and the potential impact of these two technologies. [17].

CIRCULAR ECONOMY IN INDUSTRY 5.0

The circular economy has another great advantage - it is not reserved only for rich countries. China was the first country in the world to adopt a circular economy implementation law in 2008, followed by others [2]. The European Union has created a circular economy package by expanding earlier directives on waste management. The ten-year development strategy (2010-2020) of Europe 2020, which was adopted after the global economic crisis in 2008, mentions the transition from a linear to a circular economy as one of development of EU priorities. The production of food waste and by-products follows the entire life cycle of food, from agriculture through industrial production, food processing and sale, all the way to household consumption. In developed countries, 42% of food waste is generated in households, 39% is lost in industrial food production, 14% is generated in the food service sector and 5% is generated in retail chains and during distribution [10]. Waste and by-products have great potential for reuse in various production systems. Considering the limitations in the industry, there is a great tendency towards the possibility of using by-products and the use of essential food ingredients, because they can be an important source of compounds that can partially or completely replace certain raw materials. The goal is to reduce the amount of waste through an adequately developed production strategy.

Then it is necessary to define the principle according to which any generated waste and by-products can be used in the production of other food or non-food products [3]. However, in order for this "zero waste" practice to be properly implemented, the principle of waste management hierarchies is very important [4].

The goal of applying modern production methods is to reduce the amount of waste through an adequately developed production strategy, and then to define the principle according to which any generated waste and by-products can be used in the production of other food or non-food products. Waste in the food industry is generated in various sectors along the production chain, from farms, packaging/processing, transport/distribution, retail, services and households, with around 18% of waste estimated to come from food processing and packaging as a result of necessary operations. such as washing, peeling, deseeding, separating [5].

The recommendations of the European Commission on the circular economy were accepted, and amendments to the law in the area of environmental protection were adopted, including amendments to the Law on Waste. The National Strategy for Sustainable Development for the Republic of Serbia was adopted in 2008 and was valid until 2017. further action in the area here are given sustainable development. It is important that such strategies do not remain just a dead letter on paper, because, as a consequence of the industry based only on linear economy, Serbia today has 3,500 wild landfills and only 8 sanitary regional landfills. Only 5-7% of waste is recycled, while on an annual level, material worth 50 million euros is disposed of in over 150 unsanitary landfills [6].

APPLICATION OF MANAGEMENT SYSTEMS IN INDUSTRY 5.0

The largest number of jobs are created in companies that are growing and expanding rapidly. They are the bearers of innovation and strengthen the economy in that way. In Serbia, work must be done to increase the number of dynamic small and medium-sized enterprises that will permanently employ, contribute to economic growth and be the driving force behind the process of innovation. For these purposes, it is necessary to establish a state institution that will enable them to obtain capital and create a favorable business environment in which they have the opportunity to innovate and grow. It is necessary to include local self-governments that will connect qualified persons, technological centers and organizations in their region and beyond. In the last couple of years, positive developments have been made, which resulted in an increase in the growth of products of medium high technological complexity. However, it is still an unfavorable export structure. In order to improve the situation, it is necessary to encourage industrial sectors that realize significant exports, as well as those with a large export potential, to increase the share of newly added, primarily domestic value in their exports (use of domestic inputs, engagement of highly educated domestic workforce, use of domestic patents and innovations with special emphasis on raising the technological level [12]. Modern society is based on modern technology, knowledge as well as new theories of management. The application of new technologies has helped to a great extent to improve the quality of human action in many areas. Companies are increasingly giving importance quality. In order to fully realize the quality system, it is necessary to clearly and precisely define the goals and strategies by which the company is run. The acquisition of new knowledge, skills, as well as the use of new ideas, are a pillar of modern economic trends.

The importance of management comes to the fore when looking at a certain market with an increase in the rate of innovation; the need to replace informal knowledge with formal methods and ways of saving and retaining knowledge within the collective memory of the company, all because of the ever-present trend of permanent reduction of the workforce, the possibility of losing human potential as a result of workforce mobility, workforce reduction or changes in strategic business directions. Knowledge management is a chance for a company to undertake certain activities based on knowledge, intellectual capital and thus achieve efficiency and quality in business processes, thereby creating employee satisfaction.

THE TERM AND SIGNIFICANCE OF BIOTECHNOLOGY IN MODERN INDUSTRY MODELS

Biotechnology has begun to realize products that, together with classic breeding methods, increase the production of food to meet the needs of the growing human population. More than 70 agriculturally grown plant species were transformed, about 60 into which genes for 10 traits were introduced were tested under field conditions, and 48 products were commercialized by the end of 1997. Two non-governmental institutions from Sweden and Canada have published studies with interesting results. Studies predict how in the future three great forces will shape nature and society: erosion, technological transformation and concentration of corporations [16]. Erosion brings with it cultural and social diversity, a kind of cultural hegemony of a new unifying culture that very quickly and efficiently imposes standards and a new "culture" of behavior. On the other hand, the technological transformation has struck right at the foundations of nature. What should and has been developed for billions of years is now being attempted, claims prof. Marijan Jošt, changing and re-creating through one night. The only question that remains is how the human race and nature manage in such an accelerated situation and how to adapt to the changes. The power that biotechnological science takes into its hands is unimaginable, therefore, for example, prof. Still compare the hydrogen bomb and the anthrax bomb. It is the knowledge that selectively approaches the study and interfering in life, and life always finds a way to surprise. But in addition to technical application, we must focus our attention on the topic of technological progress

IMPORTANCE OF BIOTECHNOLOGY IN INDUSTRY 5.0

Due to the high content of cellulose, grape pomace is an excellent raw material for obtaining bioethanol and biogas, and at the same time, the issue of waste from the wine industry is solved, which is very important from an ecological point of view. Also, there are no ethical disagreements in the use of industrial waste, as in the use of conventional crops, where the primary purpose is human and animal nutrition [7]. Bioactive components of the oil, such as phytosterols, tocopherols, tocotrienols, flavonoids, phenolic acids and carotenoids, enable the wide use of the oil in both the pharmaceutical and food industries, especially considering the trend of replacing animal ingredients with plant ones [8]. Taking into account the predictions about the increase in the population on Earth, the food industry was expected to increase production enormously, which inevitably entails an increase in the amount of generated waste. Unlike some other industries, this is a potential raw material that contains invaluable amounts of bioactive substances, which would be a shame not to use [9].
The concept of cleaner production, as well as the concept of zero emissions, implies a developed network between industries, their grouping and close mutual cooperation. The industries themselves are expected to modify their processes to make the most of their resources, alone or in cooperation with a network of industries, since waste can be a resource if put in the right place [10]. Serbia's industry after 2000, in conditions of late and unsuccessful transition, is characterized by resource-intensive exports, high imports, unfavorable production structure, technological and economic lagging of most capacities, insufficient inflow of foreign capital. Although certain positive developments were made after 2015, the growth of industry is still insufficient. Although in the entire post-war period our country was characterized by extremely dynamic industrialization, that process was not accompanied by an appropriate industrial policy.

CONCLUSION

The modern business environment requires companies to adapt to the novelties emerging on the market. In order for the company to achieve a market advantage, it is necessary to present all its products and services on the market in a unique and recognizable way that will differentiate it from the competition. Employee development is critical to overall market success. Without improving human resources, the products themselves will not be innovative and different. It is necessary to monitor the competition but also potential external collaborators. By implementing a strategy based on the use of human resources, the company significantly improves its ranking. The global market requires constant training of employees, following new trends in personnel education. Education encourages an innovative way of doing business, which is of great importance for every individual in society. Constant improvement implies the introduction of radical changes in all business processes, which is also part of a strategy based on the application of human resources management. Hiring human resources and using them in the right way and at the right time will reduce the company's overall operating costs. In this way, there will be an increase in business efficiency with the achievement of positive results. The possibilities of using different branches of the food industry are diverse, which is confirmed through the mentioned references, it is necessary to apply it in practice and use this possibility in the best way. The goal is to use resources in the best possible way. This will be achieved by connecting management, quality systems, circular economy and the application of ISO standards related to environmental protection.

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RISK MANAGEMENT IN CRISIS TIMES

Biljana Maljugić[1], Marija Matotek Anđelić PhD[2]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
[2]Technical College of Applied Studies in Zrenjanin, Republic of Serbia
e-mail: biljanamaljugic28@gmail.com

Abstract: Times of uncertainty and times of crisis, as well as post-crisis periods, significantly affect the organization's operations. The paper considers the possibilities for risk management according to the proposal of integrated models and key stages of the enterprise risk management process (Enterprise Risk Management - ERM) in accordance with ISO 31000. Enterprise Risk Management Academy - ERMA ISO 31000 RM3 provides better solutions in the form of five levels of risk management maturity in the organization. In order to determine the presented levels, it is necessary to evaluate six attributes. The post-crisis period of risk management requires improving the resilience of business systems for continuous operation.
Key words: Risk Management, QMS, ISO, ERM, crisis times

INTRODUCTION

In the case of the current Covid crisis, due to the pandemic and the maintenance of business in the post-pandemic period, the authors Bitan, Olaru, Hassany and Costache [1], [2] proposed an integrated model that contains a plan to ensure the implementation of continuous activities in the organization. The plan was conceived on the *"high-level structure"*, High-Level Structure - HLS promoted by the International Organization for Standardization - ISO [1, p. 3/25]. In the acquired circumstances of the crisis, the most important role belongs to innovations. It primarily refers to the introduction and implementation of safety measures in the work environment. Necessary measures include protective equipment for employees, provision of backup copies of equipment and installations, data protection tools for working from home, access to internal network and applications [1], [2].
The aforementioned activities require logistical support, which has proven to be a necessary element in the survival system due to disruptions and pressures of the crisis even during previous crises. Logistics companies maintained their competitiveness through the implementation of the Quality Management System - QMS, which had a positive effect even during the Covid pandemic. The number of these companies increased significantly during the previous crisis, and it must be emphasized that the requirements for certified logistics have also increased, as evidenced by the sample of 277 companies in the conducted research. The competitiveness of these companies in the period of the current macroeconomic instability of COVID, was supported by new guidelines for logistics service providers on the formulation of their QMS policies and the identification of the appropriate target customer segment [3].
Organizations face many forms and different types of risk. For these reasons, the ISO 31000:2018 [4] standard provides guidelines for risk management. ISO 31000:2018 is not specified for specific industries or sectors so that the proposed risk management approach can be applied in all organizations and in decision-making at all levels.
IEC 31010:2019 is the guideline document with the most significant description of techniques for implementing risk management. It provides information about specific risks and helps in making decisions in uncertain situations [5].
For effective risk management in times of pandemics, natural disasters, cybercrime, faced by organizations today, Clare Naden [6] recommends ISO 31000:2018. The standard is supported by the United Nations Industrial Development Organization - UNIDO.
Alijoyo and Norimarna [7] define the ISO 31000 Standard as a risk management process that includes related activities for directing and controlling the risks faced by the organization. In addition, it also defines a risk management framework with the necessary elements for integration, design, implementation and assessment to improve risk management in the organization.

ENTERPRISE RISK MANAGEMENT

One of the disciplines that is still developing is Enterprise Risk Management - ERM. According to Pagach and Wieczorek-Kosmala [8, p. 323/1 of 10] the COVID-19 pandemic showed that the comprehensiveness of the risk as well as its dimensions were insufficiently considered in this situation, which led to reduced values. It can be said that the impact of this crisis on ERM is evident. The role of ERM is to assess and define risks that may affect the organization's success in achieving its strategic goals. ERM helps the board and managers to understand the level of risk in the organization, to identify the risks, assess the impacts of the risks, develop a response to the risk and finally communicate and monitor the risks. ERM has the responsibility of helping management to create, preserve and realize value. COVID-19 has shown that it is difficult to reliably assess the consequences of a pandemic and persistence is difficult to define. Pandemic risk, according to the same authors, should be seen as a possibility of seriously threatening the organization's strategic goals, and in that case they suggest a review.

Describing the ERM process, the authors state interrelated phases that begin with risk identification, which is aimed at considering threats and opportunities that could affect the organization's performance, risk assessment, with an assessment of probability (frequency of occurrence) and severity (consequences, such as possible damage that is caused) of previously identified risks. The results of the risk assessment are essential for the next stage of the process, i.e. the decision. Deciding on the best risk treatment methods to use is largely a compilation of methods. The variety of possible treatments can be adopted by the suggestion of Hopkins [9] who distinguished between four decisions: *"1. tolerate (accept/retain), 2. treat (control/reduce), 3. transfer (insurance/contract) or 4. terminate (avoid/eliminate) "* according to Pagach and Wieczorek-Kosmala [8, p. 5 of 10]. The activities of the ERM process should be constantly monitored and reviewed. The stages of the ERM process framework proposed by ISO 31000:2018 are shown in Fig. 1 according to Pagach and Wieczorek-Kosmala [8, p. 5 of 10].

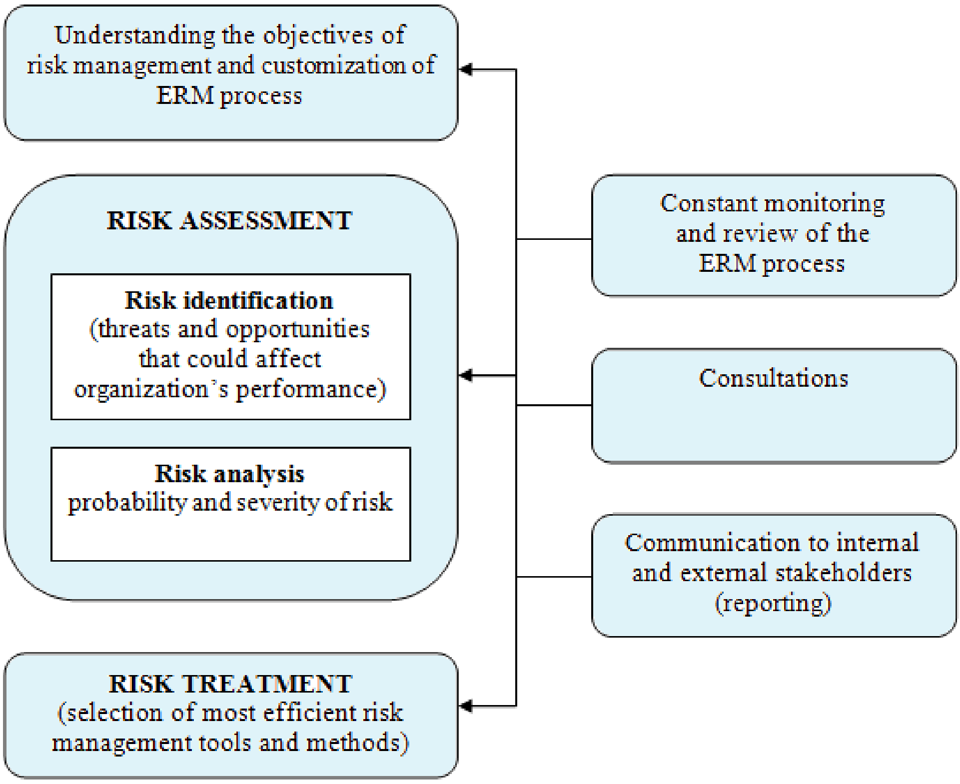

Fig. 1. The key stages of the enterprise risk management (ERM) process in accordance with ISO 31000

Source: Pagach, D., Wieczorek-Kosmala, M., The Challenges and Opportunities for ERM Post-COVID-19: Agendas for Future Research, Journal of Risk and Financial Management, Vol. 13, No. 12, p. 323, 2020., [4], [8, p. 5 of 10], [7, pp. 129-130].

Fig. 1 graphically presents the stages, links and flow of activities of the comprehensive ERM process. The three basic phases of ERM are as follows:

- First phase - understanding the objectives of risk management and adapting the ERM process,
- The second phase - risk assessment, which includes risk identification (threats and opportunities that may affect the organization's performance) and risk analysis probability and risk severity,
- Third phase - risk treatment (choice of the most effective tools and methods for risk management) [8].

It is noted that this is a cyclical process that is repeated, with constant monitoring and review of the ERM process, with consultations, and communication with internal and external actors in reporting on the results of the implemented activities.

The specific and unique characteristics of the Covid crisis are the risk, which according to Pagach and Wieczorek-Kosmala [8, p. 6 of 10] *"materialized"*, with such energy and possibilities of a very strong impact on ERM systems that had not been noticed until then. Many global organizations, in order to confront the emerging unknown of the COVID-19 crisis, have examined their risk identification, analysis and assessment processes to better respond to continuing and emerging risks. During this process, communication with interested parties and better linking of risk management with strategy is necessary. ERM gained a lot of importance in this crisis and as a necessary regulatory requirement. Also as part of a strategic process that creates and adds an advantage to the organization on the value it possesses.

How well business organizations were strategically prepared for turbulent situations in the global environment is shown by the very few examples of those that managed to confront the sudden Covid pandemic. Unfortunately, many companies have not adapted to the new situation. In order to avoid surprises and minimize the consequences of the mentioned crisis, some companies made significant efforts to get over the crisis as easily as possible, with as few losses as possible, and to shorten the post-pandemic recovery. These findings support the fact that the basis of modern business is the QMS and the ISO 31000 standard.

A HIGHER LEVEL OF RISK MANAGEMENT

Business transformation towards building resilience and sustainability of organizations is based on mature risk management using ISO 31000 [7]. Alijoyo and Norimarna's research in Indonesia, conducted in one of the largest social enterprises dealing with energy, established that the previous generic model of risk management should be improved towards a higher level of risk management maturity with stronger foundations of resilience and sustainability due to the impact of the Covid-19 crisis. Organizations that have adopted ISO 31000, predict and warn of risks according to that standard, can very easily upgrade and improve it with the ERMA ISO 31000 RM3 model. Given that it was observed that the previous ERM is not sufficient in the Covid-19 crisis and post-pandemic period, ERMA ISO 31000 RM3 [10] provides better solutions with five levels of maturity according to Alijoyo and Norimarna [7, p. 131-132]:

1. **Level - The initial level** of maturity in which risk management is ad-hoc, individual initiatives or only on a certain aspect of risk, to manage only certain risks and relies on corrective measures.
2. **Level - Repeatable**, systematically applied, but risk management is not integrated with organizational management, where competence, leadership and commitment to risk management are not evenly distributed.
3. **Level - Defined**, systematically implemented risk management and implemented according to the instructions and the ISO 31000 standard. It is integrated with organizational management, competence, leadership and commitment to risk are represented, management is evenly distributed, but positive behavior in risk management is still limited.

4. **Level - Managed**, risk management is integrated with organizational management. Systematically and consistently implemented according to ISO 31000. Fits with a culture that includes strong competency support, leadership and commitment to risk management. Positive risk management behavior prevails throughout the organization and is consistently supported by reviews, corrective actions and required improvements.
5. **Level - Optimized**, risk management is an integral part of the management organization and organizational management, systematically and consistently applied according to the instructions and standard ISO 31000. Starting from the leadership, the commitment to risk management is identified with the organizational culture of the company. Risk management is represented at all levels of the organization. It includes all the necessary activities in the review, risk correction and improvement measures, which constitute the essence of the survival and sustainability of the business organization.

ERMA ISO 31000 RM3 [10] suggests that in order to determine the maturity level of risk management in an organization, it is necessary to evaluate six attributes, which according to Alijoyo and Norimarna [7, p. 133]:

1. **Risk Culture -** refers to the measurement of how corporate values have strengthened the risk management culture, meaning the adequacy of competence optimization to take advantage of risk management and positive behavior in relation to risks;
2. **Risk Management Framework -** measuring how strong leadership and commitment have supported an integrated risk management framework through design, implementation, evaluation and improvements in risk management effectiveness;
3. **Risk Management Process -** to what extent was the risk management process used as a technical approach in implementing the integration of risk management in all organizational processes;
4. **Management Process -** to what extent the strategy based on planning and implementation according to the ISO 31000 standard is supported in the risk management process;
5. **Performance Management -** refers to measuring the extent to which performance management is planned, implemented, reviewed, improved and what are the improvements based on risk;
6. **Resilience and Sustainability -** measuring the degree to which the organization was resilient and sustainable, planned, implemented, controlled, reviewed, improved and what improvements are based on risk.

In the tabular overview, it is possible to recognize the levels of fulfillment that include the participation of these six attributes of the level of maturity, which are evaluated through 22 indicators, 52 parameters and 168 test factors. The process of this assessment achieves the value of achievements, i.e. improvements that give maturity levels of risk management in a matrix representation, fulfillment [7, p. 133].

Table 1. The Achievement Value and Maturity Level

	Initial	**Repeatable**	**Defined**	**Managed**	**Optimized**
Risk Management Framework					
Risk Management Process					
Management Process					
Performance Management					
Risk Culture					
Resilience and					

Sustainability					

	Completely Fulfilled
	Partially Fulfilled
	Not Fulfilled

Source: Alijoyo, F.A., Norimarna, S., Risk Management Maturity Assessment based on ISO 31000-A pathway toward the Organization's Resilience and Sustainability Post COVID-19: The Case Study of SOE Company in Indonesia, 3rd International Conference on Management, Economics & Finance, 26-28 February, 2021., [7, p. 133], Enterprise Risk Management Academy, ISO 31000 Risk Management Maturity Model, Singapore: Enterprise Risk Management Academy, 2020., [10].
Note: Authors Alijoyo and Norimarna [7, pp. 133-134] point out that the details of the evaluation criteria including taxonomy, weight and method are presented by ERMA ISO 31000 RM3 [10].

From the matrix representation, it is observed that organizations need to fulfill all six attributes in an optimized maturity manner. This is achieved by defining: Risk Management Framework and Risk Management Process, with adequate management, so that the improvements, i.e. the value of achievements, are fully fulfilled. Starting from management structures to implementation, risk management must encompass all business processes.
In practice, it is very important that risk management is supported by all employees in the organization. To be incorporated into the culture of the organization. To control, monitor and report on realized activities and achievements in order to timely notice and react to emerging risks in the future. In the background of all of the above, knowledge is hidden. Availability and acquisition of up-to-date and accurate information, knowledge sharing and accountability. Only with such action in time can weak points in the organization be noticed. In this way, preparation and precautions for possible new risks will be ensured, without or with as few surprises as possible for the organization.

ERM IN POST - CRISIS TIMES

The experience gained during the Covid crisis shows the necessity of risk management for acquiring the resilience of business systems in continuous operation. In order to achieve the necessary resilience, it is necessary to invest in new technologies, which include the improvement of digitization, IoT, Big Data, Cloud Computing, Business Intelligence and Cyber Security [11]. In addition, ERM has a significant role in building a communication strategy in crisis conditions [12].

BENEFITS OF ERM IMPLEMENTATION

Given that ERM is designed to combine aspects of corporate and strategic management with risk management, some of the benefits of implementing this type of management can be singled out. Primarily, ERM has proven to be significant in practice for reducing financial risks. After that, a positive connection between ERM implementation and long-term value creation was confirmed in some companies. Performance improvement, better reputation and competitive advantage are achieved through the implementation of ERM [13].
ERM is synonymous with reducing risks and increasing business performance. ERM has characteristics that allow it to be applied regardless of the size and complexity of the company, in the coordination of departments and the exchange of information until managerial decisions are made. Better allocation of resources as well as investor confidence are also significant benefits of ERM implementation [13].

CONCLUSION

Companies and organizations face numerous risks and uncertainties from the environment that affect business. Various economic crises caused risk management to become an imperative of modern business. International ISO standards for business management and risk management, with their guidelines, help the organization to recognize risks in a timely manner, mitigate the impact of risks on the organization and possibly eliminate threatening risks. The ERM method of management has brought certain benefits and can be applied in all companies, regardless of the size of the company and the field of business.
In addition, the development of business organizations, as well as small and medium-sized enterprises, implies the implementation of the latest technologies, digital technologies and the use of digital communication in order to create a base of knowledge and information for faster action in the global competitive market.

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THE ROLE OF CONSULTING ORGANIZATIONS IN THE INTRODUCTION OF QUALITY 5.0

Dijana Tadić Stanić[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
dijana.tadic@tfzr.uns.ac.rs

Abstract: The industrial revolutions that have occurred in recent years are characterized by technological development and superior innovations, which are forever changed the way production processes function. Quality, as an integral part of all industrial revolutions, transformed and improved in accordance with the resulting changes. The gap that has been created between human resources, modern technology and Quality 5.0 can be mitigated by the professional knowledge and experience possessed by consultants. Hiring the services of consulting organizations can contribute to the faster introduction of Quality 5.0, without wasting the energy of employees and material resources.

Key words: Consultants, Quality 5.0, industrial revolutions

INTRODUCTION

The industrial revolutions that have followed in recent years have streamlined and facilitated production processes, creating conditions for better quality. Starting with mechanization, electrification was introduced into industries, then automation, a couple of decades later digitization, and as the last stage of the development of the human mind and technology together, production is characterized by personalization.
Quality 4.0 (in accordance with the name "Fourth Industrial Revolution"), represents digitized quality management, with an emphasis on mass production that takes place with minimal participation of the human factor. Further development of the industry led to the realization of the conditions for Quality 5.0, which focuses on man and his needs. Personalized production with elements of human action emphasizes uniqueness and individuality, which today is considered the highest form of quality.
The introduction of Quality 5.0 in organizations is not possible without experts, who have knowledge, ability, skills and experience in that field. That is why organizations often avoid hiring external help, in the form of consulting firms, whose representatives possess the above-mentioned characteristics.

INDUSTRIAL REVOLUTIONS AND CONCEPTS OF QUALITY IN THEIR FRAMEWORK

The trigger for Industry 1.0 was the steam machine; with the application of electricity, Industry 2.0 appeared; automated machines represent Industry 3.0; Digitized production, remote management, artificial intelligence and many other technologies marked Industry 4.0; after all, we are talking about Industry 5.0. which focuses on man and the quality of his life.
With each adaptation of the industries to the revolutions that followed, the quality also adapted [1]. However, the technological influence on the realization of quality is more pronounced than ever [7].
If we look at the industrial revolutions that happened in the near future, we can see that Industry 4.0 abounds in various types of modern autonomous technologies, which have the ability to independently exchange information, initiate actions and control each other [14]. These are cyber-physical systems, Internet of Things, cloud accounting, cognitive accounting and others.
Then, one of the important features that should be mentioned is that Industry 4.0, among other things, is based on the philosophy of reducing human resources in production facilities to a minimum. Given that the need for a wide range of productivity has not declined, it has represented a major challenge for the global economy [16]. As a solution to this situation, the concept of Industry 5.0 was introduced, which treats the relationship between man and machine in a different way [6]. Accordingly, other authors have concluded [13], that Industry 5.0 is actually an improved version of the previous revolution.

Quality 4.0 was a "leading force" in the Fourth Industrial Revolution [24]. Managing this level of quality required appropriate knowledge and leadership style. Accordingly, of great importance in the introduction of Quality 4.0 was the understanding of the company's top management about the importance of its implementation [9].

With the appearance of Industry 5.0, the aspiration shifts to the formation of the concept of Quality 5.0, which is considered to further improve the essence of quality, thanks to the collaboration of man and machines [18].

However, one of the major challenges faced by today's companies is insufficient training and development of human resources skills, for managing modern technologies and smooth functioning, in changed business processes within Industry 5.0.

THE INFLUENCE OF MODERN TECHNOLOGY ON WORK TASKS OF EMPLOYEES

Some authors pointed out [4], even with the awareness of the Fourth Industrial Revolution, that organizations will face a challenge, that employees will not be fully prepared to face the changes, and that their training and skills development will have to be planned. The reason that contributed to this is the rapid technological progress, which created a gap between technology and employees. Business processes have changed and modernized as much as possible, which initiates that human resources must be prepared for changes and sufficiently trained to be able to cope with changes.

All organizations that modernize their production processes and invest in technology must also actively invest in human resources. Employees must be trained to work with modern technologies, so that they can smoothly perform their work tasks in a better, faster and simpler way. Investing in employees will contribute to the acquisition of new knowledge and the discovery of unrecognized talents. Likewise, for all quality managers, new skills are needed to optimally manage Quality 5.0.

Collaboration with robots, the use of Big Data and its analytics, augmented reality, self-driving vehicles, are just some of the technologies that have changed the approach to performing work tasks. Today, the structure of the workplace must be adapted in accordance with new technological possibilities, and managers must strive to create an atmosphere that will contribute to the growth of job satisfaction, as well as the commitment of the workforce [17]. Therefore, it is desirable to urgently invest and prepare human resources to accept the transformation that is necessary for future survival in the market.

According to one research [10], to successfully implement a quality management program, the attention paid to human resources is essential. Accordingly, the following solutions [4] are possible: training through internal and external training centers, retraining of employees, continuous learning and mental preparation of employees for upcoming changes.

CONSULTING ORGANIZATIONS AND THEIR CHARACTERISTICS

Organizations engaged in professional counseling, strive to identify the causes of problems in companies, and their elimination to improve production and improve quality.

Consultants, as external sources of knowledge, contribute to innovation and input of new energy, from which creative ideas and a wider range of possibilities arise. Consulting services are considered to be one of the fastest growing disciplines in recent years [19]. The reason that contributed to this is the increasing demand for professional knowledge, as a support due to increasingly rapid changes in the market.

Consultancy services represent significant support in meeting the challenges of revolutionary changes [5]. The experience that consultants gain through cooperation with different types of personalities, in numerous, not at all similar industries, through different situations and environments, contributes to a better and faster understanding of the current situation in the company, and a more reliable selection of the best business practice.

By investigating the relationship between the competence of consultants and the quality of services they are able to provide when advising clients, the authors [12] found that the knowledge and attitude possessed by the consultant, the trust that reigns in their team, as well as the trust that is built between the consultants and of employees in the organization, significant for the performance and quality of consulting services. Authors [20], who investigated the impact of consulting performance characteristics on the quality of results achieved within small and medium-sized enterprises, dealt with a similar topic, when using consulting programs supported by the government. They found out that the reliability achieved by the consultants, the acceptance of the proposed changes, as well as their appropriateness, have a positive effect on the quality of the results.

The relationship between the quality of consulting and the capabilities of consultants, among other things, was dealt with by the author [23], who discovered that a high level of quality of consulting and consulting services tends to increase resource capabilities in companies. However, [20] pointed out that hiring consulting services often represents a high bilateral risk. The author also notes that, throughout the entire consultation cycle, trust is a significant success factor as well as the complexity of the project. Also, it points to another important characteristic of the consultant-client relationship, which is the asymmetry of information among the participants in the project.

When it comes to the quality model of consulting services, two authors [22] drew attention to the fact that it has not yet been formed, that is, there is no generally accepted model that would guide all consultants. In support of this issue, the mentioned authors determined four dimensions, which represent a conceptual model of the quality of this type of service. These are: expertise, relationships, involvement and performance.

ENGAGEMENT OF CONSULTING ORGANIZATIONS AS A SOLUTION WHEN IMPLEMENTING QUALITY 5.0

Companies that offer consulting services can build their progress on the foundations of negative factors [15]. This means that the circumstances that force society to change are often the cause of crises, which are considered as something negative, until a solution is found to overcome them and direct them to their own benefit. To manage the mentioned changes, you need people who have the knowledge and who are expert to use the negative factors to their advantage, these people are usually consultants. According to [2], consultants are the most important sources of new management ideas and practices.

The provision of consulting services has been present on the market since ancient times. The frequency of their engagement varied according to the newspapers that appeared. With the changes resulting from the last industrial revolutions, the need for consulting services has increased.

Digitized quality management, i.e. Quality 4.0, was dealt with by one author [11], who presented his model as a result of his work. According to him, the Quality 4.0 model consists of the following axes: data, analytics, connectivity, collaboration, application development, scalability, management systems, compliance, culture, leadership and competence.

Quality 4.0 improves human intelligence and accelerates optimal decision-making, increases transparency and traceability, enables easier auditing, predicts changes and adapts to new circumstances and knowledge faster, removes bias, improves internal communication and helps develop and improve human skills [3].

Quality 5.0, or socially oriented quality, as he called it in his work [3], is considered the most advanced form of quality so far, focusing on man and the quality of his life. Its introduction, in addition to modern technology, requires leadership competencies, expertise, skills, experience and knowledge of how to achieve all conditions for creating sustainable competitiveness of companies in an increasingly demanding market.

With every industrial revolution, progress in quality can be seen [3]. More than two decades ago, the authors of a paper [8] emphasized the importance of consulting firms in quality management, stating that the experience possessed by consultants is often a key factor for the implementation of quality in a company. Also, the same authors stated that quality expertise is increasingly viewed as an extremely valuable resource.

CONCLUSION

Any change causes discomfort that can have two outcomes: it creates an advantage for the one who gets used to it first, or it incites a crisis that deepens until the change disappears or is overcome. We can connect this with the industrial revolutions and the introduction of the modern form of Quality.

In this paper, the role of consulting services during the implementation of Quality 5.0 is highlighted. Consultants are people who professionally deal with the problems of other companies. Throughout their working life, they encounter many challenges faced by other organizations, and based on their experience, knowledge acquired through education and practice, they enable changes to be more easily overcome and the set goals to be achieved.

The concept of Quality 5.0 is new on the market, and there is a lack of knowledge about its introduction and application. Therefore, it can be concluded that the role and engagement of experts will be of great help.

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THE INFLUENCE OF THE FOURTH AND FIFTH INDUSTRIAL REVOLUTIONS ON CONSULTANCY COMPANIES

Dijana Tadić Stanić[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: dijana.tadic@tfzr.rs

Abstract: This paper is based on the impact of the Fourth and Fifth Industrial Revolutions on consulting companies. Consultants are natural persons who, based on their knowledge, expertise and skills, help other companies to overcome the challenges they have encountered. The basis of their successful business is that they are one step ahead of all other market participants. That is, consultants must predict the impacts of industrial revolutions in different domains of business and based on that prediction create strategies, depending on the problems of the company that hired them. Given that two revolutions took place in a short period of time, which completely shook the industry and had a huge impact on the business system, consultants are faced with a great challenge to adapt to the news and acquire new knowledge, to be able to help other companies in a quality way.
Key words: Consulting companies, consultants, Industry 4.0, Industry 5.0

INTRODUCTION

In the last two decades, two industrial revolutions took place, which completely transformed the way production systems function in all areas of work. The changes that followed also affected the organizations engaged in consulting, in terms of their quantity and quality of services [11].
Industry 4.0 and Industry 5.0 have a common feature, which is the use of modern technology. Technological progress that has occurred in recent years has completely transformed the business world. The application of this technology realizes an incredibly large number of possibilities and improvements to existing systems. Therefore, it can be said that the application of modern technologies is a condition first for survival on the market, and then for competitiveness.
Consultants, as external support of companies that hire them, must master the knowledge needed for successful business operation in turbulent conditions, such as today. Based on the commitment to deepen their knowledge and improve their skills, and to improve their abilities, to be able to help other organizations to modernize and improve their operations, consultants will be more in demand in the market.
The need for consultant support has grown in recent years. However, the influence of Industry 4.0 and Industry 5.0 was also realized on this profession. First, the transformation of consulting companies is necessary, so that they can respond to the challenges of other companies and maximize their benefits.

THE ROLE OF CONSULTANTS AND THE QUALITY OF THEIR SERVICES

"Management consulting is an industry and practice that helps organizations improve their performance by analyzing existing problems and developing plans for improvement" [16]. Consultants are persons with specialized knowledge and leadership skills, who strive to understand the difficulties encountered by their clients and guide them to the optimal solution through external consulting. Consultants find their solutions by analyzing positive cases and choosing the best business practices [11].
According to the statistical portal for market data, market research and market studies [16], management consulting is a branch of the economy that records market growth year after year. In the period from 2011-2020., the global consulting market reached a value of more than an incredible 18 trillion dinars (160 billion US dollars). Despite this, a survey found that the biggest challenge for consulting firms is attracting and developing new businesses.

One of the important reasons why consulting services are engaged is technological development, constantly changing market dynamics and new consumer trends [15]. These market conditions require organizations to be alert and always have a strategy ready for action, which often necessitates the need for specialized support.

The quality of consulting services is directly related to client satisfaction. Clients' satisfaction also depends on their expectations, that is, if clients receive the quality of service they expected (or better), they will be satisfied, otherwise they will consider that the quality of service is not at a high enough level [10]. Service satisfaction is considered a synonym for quality [6].

Satisfaction with the quality of the service increases the possibilities of re-engagement of consultants, and spreading positive information about them will contribute to their reputation and profitability. By yourself, you, the consulting organization, will become more competitive in the market.

The success of project management largely depends on the abilities and competencies of the consultants. That is why the emphasis is on their constant improvement of knowledge and skills.

IMPACT OF INDUSTRY 4.0 ON CONSULTING COMPANIES

One of the characteristics of Industry 4.0 is digitization, which spread very quickly among business units thanks to its superiority. Organizations, whose management recognized the opportunity in the digitized approach to work, and which were financially capable enough, quickly and efficiently adopted digitization. Technological support, among other things, further improved management performance [9]. This directly means that such organizations achieved greater competitiveness, better profitability and a larger market share.

If we bring the above into relation with the consultants, it can be said that it was important to adapt, but also to acquire knowledge about it, to understand the way that system works, to gain experience in relation to its operation and application, and therefore to raise the quality of its services to higher level.

The essence of digitalization is not only the purchase of digital technologies, but the penetration of these technologies into every element of the business process. By understanding this essence on the part of consultants, they create a key product to offer in the market. Namely, the competitiveness of consultants is reflected in their knowledge, skills and ability to transfer knowledge to other organizations and help them overcome the challenges they face.

Some authors have pointed out one interesting thing [7], which is that digital transformation requires the participation of management in adaptation rather than the development of skills in handling technologies. And that is precisely the reason why the need for hiring management consultants has increased.

In addition to digital, other modern technologies have arrived on the market, which fundamentally changed the way of working in production facilities, enabling a new era in economic development. With their incredible capabilities, they provided organizations with a multitude of benefits that would save time and energy, and at the same time lead to better quality products. For the consultants, it meant that great changes are on the doorstep, that they must react quickly, and that by mastering the news and adapting to it, they ensure competitiveness on the market. With the knowledge they gain through each new process, consultants are able to advise others on how to transform their production and make it more modern.

Some authors [1, 16] found that the productivity of companies does not keep pace with technological progress. The reason for this discrepancy is the difficulty of human adaptability, that is, the managers' ignorance of how to organize production, manage it, and finally how to get employees to accept changes.

In addition to specialized technical skills and digital capabilities at all levels of the organization [3, 4, 14], the complexity of Industry 4.0 requires adequate managerial competence as well as teamwork. The manager should recognize and understand the connections and reactions between the systems, in order to notice the disturbances of different indicators and decide accordingly [12]. If this is not the case, the company would decide to hire consultants, as external support, to overcome the adjustment.

IMPACT OF INDUSTRY 5.0 ON CONSULTING ORGANIZATIONS

After some time, it was realized that the complete system could be further improved, which led to a new industrial revolution - Industry 5.0. Many organizations are still in the phase of accepting the novelties that this revolution has brought with it. Also, there is a lot of talk about top quality - Quality 5.0, which will be an indisputable source of competitiveness among companies. Therefore, it can be said that the consulting role during the introduction of Quality 5.0 will be very significant.
Depending on the ability and speed of consultants to adapt to the news, and acquire knowledge on how to introduce and apply the highest form of quality in the most optimal way, the demand for their work on the market will grow, and thus competitiveness and profitability.
What sets Industry 5.0 apart from other industrial revolutions is its focus on people and their needs. Personalization of production is today considered the highest level of modern production. Following trends, creating original products, putting personal stamps on the product, and other types of differentiation and creation of unique products is the focus of all production sectors.

SUCCESS FACTORS OF CONSULTING ORGANIZATIONS

By improving their performance, i.e. gaining experience and enriching the knowledge of consultants, organizing additional training, purchasing and applying modern technologies, consulting organizations influence the satisfaction of clients and increase the quality of their services.
The most important factors of the competitiveness of a consulting organization are the capacity and competence of employees. Their ability to understand clients' problems and to see the optimal solution has a great impact on the competitiveness of the organization in which they are employed.
As in any other type of work, service providers, or in this case consultants, are responsible for the project they are committed to [2]. The fact is that the choice of consulting organizations is chosen based on their reputation [2], that is, based on the experience gained and the sum of the positive outcomes they have contributed to.
Through various projects, consultants encounter new challenges and knowledge that can later represent an advantage over competitors. Every new project is an opportunity to learn something new and improve existing competencies.
One of the important factors for the success of consultations is the teamwork and empathy that prevails in consulting organizations. The relationship that employees have with their supervisor is also very important. The amount of freedom that consultants have when working with other businesses can also affect work performance and the level of client satisfaction.
Many studies have witnessed the negative impacts of strong leadership in organizations. By transferring authority and providing more freedom to consultants in the field, it has a positive effect on the final outcome of the consultation. By optimal distribution of authorization, clients indicate a greater degree of trust and reliability in the consulting organization.

NEGATIVE INFLUENCE OF MODERN TECHNOLOGY ON CONSULTING SERVICES

Industry 4.0 has affected consulting services by reducing direct contacts and providing greater opportunities for clients [8]. Digitization and technological progress have enabled human communication without physical presence, which has influenced the current way of conducting consultations. This caused changes in the work of consultants, forcing them to adapt and apply technological innovations, to achieve competitiveness in the market.
Some of the technologies that are within the reach of businesses in the 21st century is: Big Data, Blockchain, Artificial Intelligence, Machine Learning, Neural Networks and others. All these technologies deal with data, which can process a large amount of data in a short period of time. Their application in industry enables decision-making up to 100 times faster [13]. At the same time, decisions based on basic data reduce the risk of wrong decisions. These technologies also can reveal a large amount of data that was not possible before. This means that there is a saving of time first, and then comprehensiveness of data that would not be possible with manual collection [5].

Easier access to data, as well as a large number of available analytical tools, also reflected the frequency of engagement of consulting services. Clients now have a wider range of options at their fingertips, which they can use themselves when processing data.

CONCLUSION

Based on the above, it can be concluded that the influence of Industry 4.0 and Industry 5.0 was reflected to a large extent on all production and service activities. Unlike others, consulting companies, like teachers, must master the knowledge necessary for successful management in a period of turbulent change, so that they can help other companies with their consulting.

Managers at all levels are faced with something new and different than what they have done so far. Trainings and trainings become their daily routine, to achieve competitiveness in the market. However, when managers are not up to the challenges, they hire external help, as a safe support, who can show them the right way.

Consulting companies must invest the most in their employees because they are their main tool on the market, and the knowledge they acquire is their key product. Regardless of the effort that consultants must make, to keep up with the changes, those changes are the basis of their business. Every change in the market represents a new opportunity for them, which they must seize first.

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TECHNO-ECONOMIC ANALYSIS OF THE SOLAR POWER PLANT IN THE TOWN OF ZRENJANIN

Luka Đorđević[1], Jasmina Pekez[1], Borivoj Novaković[1], Mića Đurđev[1], Dejan Bajić[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: luka.djordjevic@tfzr.rs

Abstract: Due to the crisis caused by the COVID-19 pandemic, and the situation caused by the conflict in Ukraine, the world, including the Republic of Serbia, is on the threshold of a major energy crisis. Increased demand and reduced supply on the world market, and taking into account the dependence of the energy systems of the vast majority of countries on conventional energy sources, heralds, reductions and restrictions on electricity in a large number of countries in the world. The Republic of Serbia, as a country with a positive potential of renewable energy sources, makes very little use of these natural potentials. In this paper, a simulation was performed using PVsyst software and a techno-economic analysis of the installation of a 1 MW solar power plant in the territory of the city of Zrenjanin, as well as its contribution to the Serbian energy system.
Key words: renewable energy, Serbia, PVsyst, solar energy, solar power plant.

INTRODUCTION

According to [1], the increase in industrial growth is directly related to the increase in the need for electricity. On its path of development, humanity has always sought the most accessible and environmentally friendly form of electricity [2].
Since the main sources of energy are conventional, they have the largest share in obtaining electricity, and with the increase in the use of conventional fuels, the negative impact on the environment also increases. Renewable energy sources (RES) represent sources of natural resources such as sunlight, wind, tide, hydro, biomass and geothermal energy, which are naturally renewed [3,4]. Energy production using photovoltaic (PV) conversion systems is clean, environmentally friendly and cost-effective energy production technology [5].
The 21st century is characterized by a large, but still insufficient increase in the amount of energy produced from renewable energy sources [4]. The current global energy transition from a fossil-based primacy to a low-carbon energy sector is increasingly included in national energy strategies. The basis of these documents is the policy of increasing the share of energy from RES [6].
We are witnessing the energy dependence of a large number of countries on oil and its derivatives requiring large economic costs, and we are already seeing negative effects on national economies and the international security situation in the current events caused by the epidemic and conflict in Ukraine. The total world oil consumption is close to 4 billion tons per year, while the total reserves amount to 120-160 billion tons [7,8]. According to [9], it is assumed that fossil fuels are used to produce 80% of the world's energy production. In the period from 2015 to 2040, forecasts are such that global energy consumption will increase every year by 2.3%.
Earth receives about 1.8×10^{11} MW of energy from the sun. This amount of energy makes solar energy the most widespread and largest source of renewable energy on the planet. The current energy needs of the entire planet are much less than the energy we get from the sun. The sun is also an inexhaustible source that does not lead to environmental pollution [10].
Looking at renewable energy sources, Serbia has good energy potential. The potential of close to 4 Mtoe per year can satisfy 25% of the annual energy needs in Serbia. If that potential is compared with the potential of some European countries that lack renewable energy sources, Serbia's potential is great [11]. During January, Serbia has an average solar radiation of 1.1 kWh/m^2 per day in the north of the country to 1.7 kWh/m^2 per day in the south. During July, solar radiation is from 5.9 to 6.6 kWh/m^2 per day. The average value of global solar radiation per year for the territory of Serbia ranges from 1200 kWh/m^2 per year (northwest) to 1550 kWh/m^2 per year (southeast). This potential gives Serbia favorable conditions for using solar energy and converting it into electrical and thermal energy [12,13]. Figure 1. shows global horizontal solar irradiation in the period 1994 – 2018 in Serbia [14].

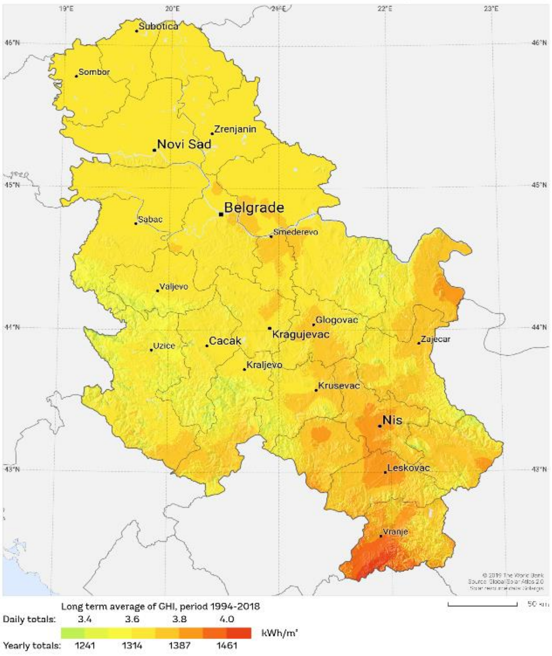

Fig. 1. Global horizontal solar irradiation in Serbia

MATERIALS AND METHODS

The methodology used in this paper includes mathematical relations, geographical information of the study area, and specifications of the PV modules and inverters in order to evaluate the various performance indicators of grid connected PV system. The simulation for this paper was done for the period from January 1 to December 31, 2021.

Meteorological data and site information

The meteorological information was obtained from Meteonorm 8.0 through PVsyst software. Simulated solar power plant is located in the city of Zrenjanin, Republic of Serbia. The geographical location (Figure 2.) of the site is 45º 21’ 00’’ N – Latitude, and 20º 22’ 48’’ E – Longitude.

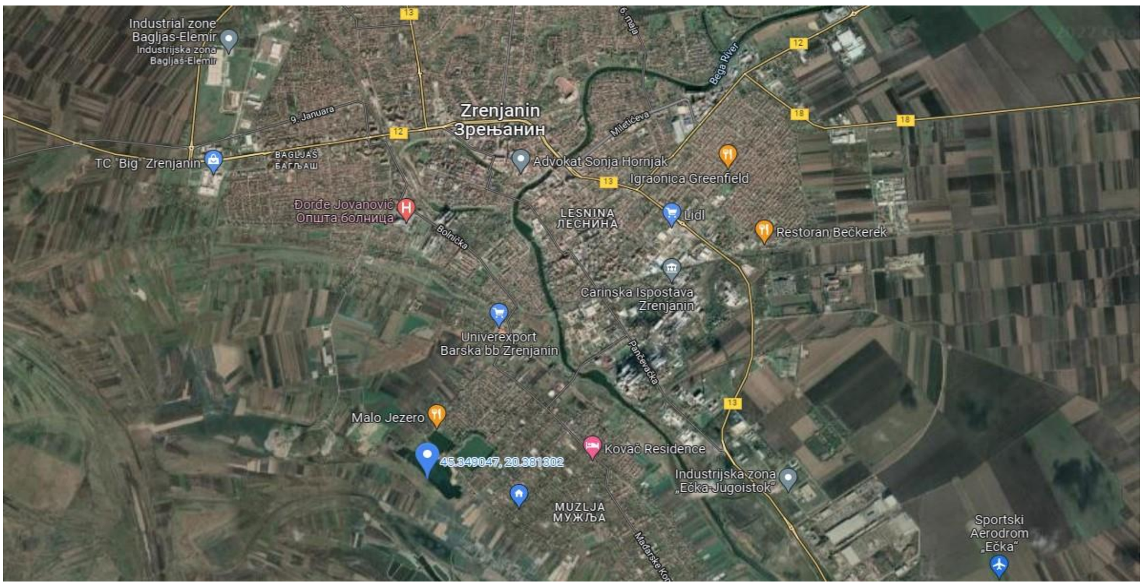

Fig. 2. Site information

Orientation and schematic for the proposed PV system

According to the Photovoltaic Geographical Information System – PVGIS, the optimal azimuth and tilt for the location used are -1º and 36º, respectively. Figure 3. shows the used orientation.

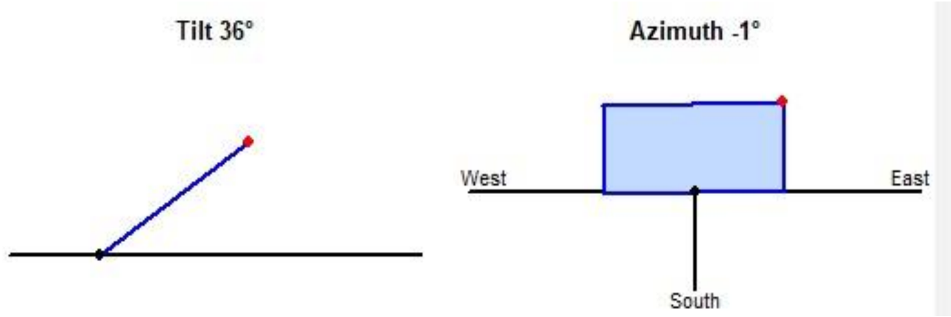

Fig. 3. The used orientation

Figure 4. shows the layout of a grid connected photovoltaic system. The PV system is made up of 2299 PV modules, 8 inverters, 1 fuse box, 1 utility meter and the grid lines.

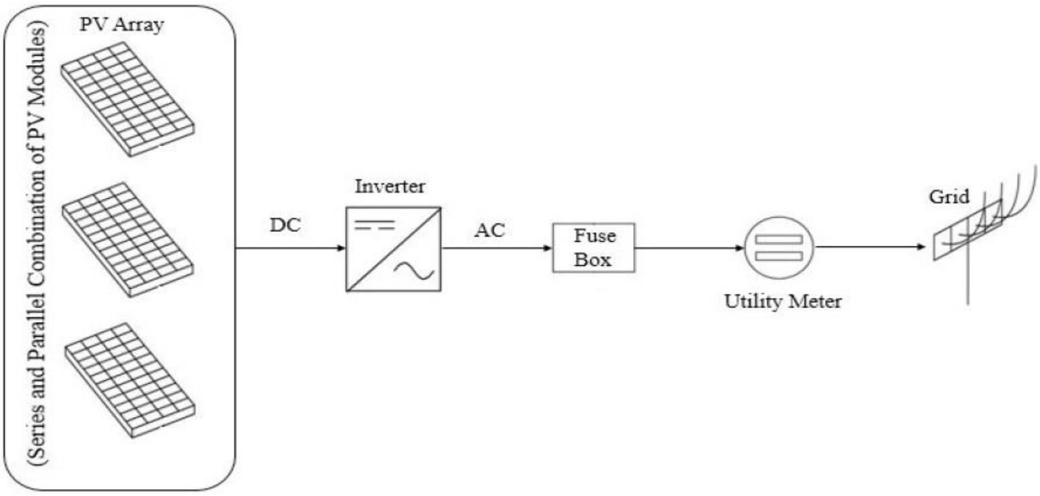

Fig. 4. Layout of grid connected PV system [15]

Characteristics of the PV modules and inverters

The PV module used for the analysis was LG435QAC-A6 (Monocrystalline/N-type) manufactured by LG. To achieve the designed power output of 1MW a total of 2.299 units were used. The technical description of the PV modules is shown in Table 1.

A total of 8 Huawei's model SUN2000-125KTL-M0 inverters were used. This inverter has a maximum MPP voltage of 850V, minimum MPP voltage of 625V, and maximum efficiency of 99%.

Table 1. PV module specification

Model	LG435QAC-A6
Maximum Power (Pmax)	435 W
Power Tolerance	0 ~ +3
MPP Current (Impp)	10.59 A
Short Circuit Current (Isc)	11.20 A
MPP Voltage (Vmpp)	41.1 V
Open Circuit Voltage (Voc)	48.0 V
Efficiency	21.9 %

PV Syst - simulation software

To evaluate the performance of the solar power plant in this paper, the PV Syst simulation software was used. It is often used by engineers and researchers to estimate plant energy yields and optimally design solar power plants, as well as to improve system design and better understand the operation of photovoltaic systems. Using detailed hourly simulation data PV Syst accurately predicts the system yields.

RESULTS AND DISCUSSION

Table 2 shows the main results of technical analysis obtained by simulation using PV Syst software. The total amount of global horizontal irradiation is 1262.6 kWh/m^2. The table shows that the lowest horizontal radiation was in December – 25.2 kWh/m^2, while the highest was recorded in July – 188.1 kWh/m^2. The average ambient temperature was the lowest in January with 0.22^{o}C and the highest in July with 23.82^{o}C, while the average annual temperature at the location of the simulated power plant is 12.44^{o}C. The average performance ratio is 0.795. The highest performance ratio is 0.854 in February, while the lowest is 0.735 in April. We notice that with an increase in the ambient temperature (and thus the temperature of the PV module), the performance ratio decreases.
It is noticeable that more energy was injected into the grid during summer. This is closely related to the higher intensity of solar radiation during this period. The total amount of energy injected into the grid is 1137 MWh. This amount of energy injected into the grid meets 0.109 % of the total energy needed for the city of Zrenjanin, or the electricity needs of 271.5 households.

Table 2. Main results of technical analysis

Mos	Global horizontal irradiation	Ambient Temperature	Global incident in coll. plane	Energy injected into grid	PR	Energy data 2021, (city Zrenjanin) Energy taken in 2021 from the transmission system	Percentage of meeting the needs of the city of Zrenjanin for electricity	The number of households that the solar power plant can satisfy (average consumption of 349 kWh per month) [16]
	kWh/m^2	^{o}C	kWh/m^2	MWh	%	MWh	%	HH
Jan	32.7	0.22	48.9	40.7	0.832	99,565	0.041	116.6
Feb	50.4	2.25	72.4	61.8	0.854	89,458	0.069	177.1
Mar	98.9	7.3	127.2	106.4	0.837	98,566	0.108	304.9
Apr	131.8	12.72	144.2	105.9	0.735	86,345	0.123	303.4
May	164.4	17.88	162.7	125.7	0.772	74,228	0.169	360.2
Jun	178.5	21.41	169.8	134.3	0.791	77,032	0.174	384.8
Jul	188.1	23.82	182.6	142.7	0.782	81,180	0.176	408.9
Aug	162.9	23.59	173.9	136.7	0.786	75,981	0.180	391.7
Sep	109.3	17.63	133.2	106.8	0.802	74,702	0.143	306.0
Oct	78.0	12.57	108.3	85.2	0.787	88,126	0.097	244.1
Nov	42.4	7.37	68.3	57.1	0.836	95,177	0.060	163.6
Dec	25.2	1.76	39.5	33.5	0.848	105,722	0.032	96.0
Year	**1262.6**	**12.44**	**1430.9**	**1137.0**	**0.795**	**1,045,081**	**0.109**	**271.5**

Taking from the official websites of the manufacturers of the equipment required for the installation of the solar power plant, table 3 shows the individual and total prices required for its construction.

Table 3. An overview of the costs of setting up a solar power plant

Equipment	Quantity	Price/pc (€)	Total (€)
Panel LG 435 QAC-A6	2299	450	1,034,550
Additional equipment	2299	21.75	50,003.25
Inverter SUN2000-125KTL-M0	8	10,000	80,000
TOTAL	1,164,553.25		
Maintenance costs			
Cleaning (annually)	1	5,000	5,000

From table 3, we can see that €1,164,553.25 is needed to set up a 1 MW solar power plant with the above-mentioned equipment. The cost of installation does not include the cost of labor that would be required for its implementation. Also, according to the PV Syst software and the price of an average working hour in the Republic of Serbia, it was found that €5,000 is needed for the maintenance of a solar power plant in the first year of its operation.
According to [17-19], data were taken for the financing plan (the amount of funds from own sources and loans), the average annual inflation and interest rate for funds taken from loans. For the loan repayment period, a time period of 25 years was taken (the manufacturer's guarantee period for the equipment that was used). The year 2023 was taken as the start of operation of the simulated power plant. 0.1 € was taken as the selling price of electricity (the current average price of 1kWh in Serbia). Inflation is not taken into account in the price of electricity, i.e., annual increase in the price of electricity. A summary of the data is given in Table 4.

Table 4. Summary of the data

Time period of the project	25 years
Start year	2023.
Year of completion*	2047.
Inflation rate/year	5 %
FUNDS FOR PROJECT FINANCING	
Own funds	200,000 €
Loan funds	970,000 €
Interest rate	2 %
SALE OF ELECTRICITY	
Price	0.1 €/kWh
Inflation	0 %
Period required for payment	12.7 years

*Solar panels (solar power plant) will still be in use even after the expiration of the 25-year period, only with a lower degree of utilization, as well as the assumption that the panel manufacturing technology will be such that the said solar panels will be unprofitable for use.

Figure 5. shows a diagram of the annual profit (in thousands of €) and the funds needed to set up the power plant. From the figure, we can see that in the year the power plant was installed, the invested funds greatly exceeded the profit. In all subsequent years, the profit brought by the power plant is positive, because apart from the initial investment in the equipment, the only outflow of funds is reflected in the maintenance of the equipment, which amounts to €5,000 per year (adjusting to the annual inflation of 5%, the funds needed for maintenance in the last year of work will amount to €16,125). Also, we can see from the diagram that there is a noticeable decrease in the inflow of funds from year to year. The mentioned decrease is a consequence of the degradation of solar panels over time and lower efficiency, which leads to a decrease in the production of electricity.
Table 5 provides a detailed overview of the economic results of the simulation. The price of electricity for preferential energy producers in the Republic of Serbia is currently €0.27. For the sake of a more transparent price for the profitability of setting up such a power plant, the average price of selling electricity for households was taken as 0.1 €, which is 2.7 times less than the price of electricity that this power plant would generate at the moment, and no increase in the price of electricity was calculated for the time period considered.
According to these parameters, the solar power plant pays back the invested funds after 12.7 years, i.e., the end of 2034. At the end of the simulated time period, the solar power plant makes a profit of 200.2 %. Maintenance costs from the initial €5,000, based on annual inflation of 5%, end up being €16,125.

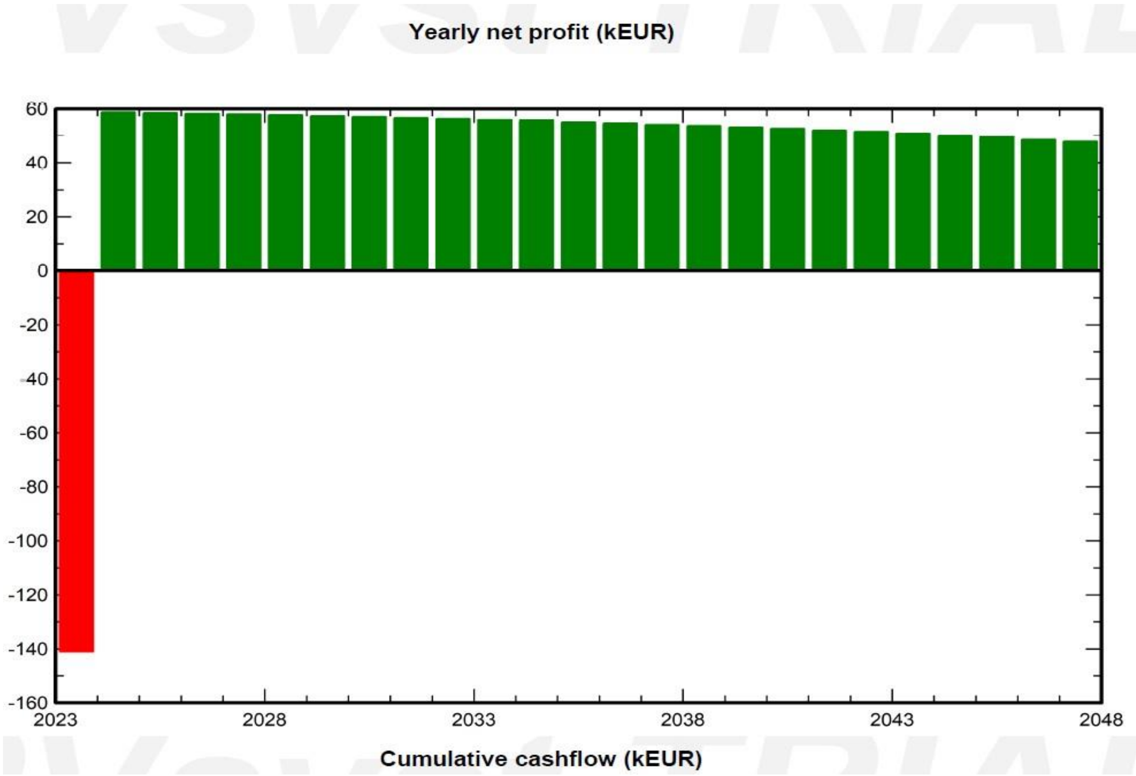

Fig. 5. Annual net profit of the simulated power plant (in thousands of €)

Table 5. Detailed overview of the economic results of the simulation (in €)

Year	Electricity sale	Loan principal	Loan interest	Maintenance costs	Taxes	After tax profit	Cumul. profit	Amorti.
2023	113,710	30284	19400	5000	89310	59026	-140974	7,7 %
2024	113,710	30890	18794	5250	89665	58776	-82198	15,4 %
2025	113,710	31507	18177	5513	90021	57513	-23685	23,1 %
2026	113,710	32137	17546	5788	90375	58238	34553	30,9 %
2027	113,710	32780	16904	6078	90728	57948	92501	38,6 %
2028	113,710	33436	16248	6381	91080	57644	150145	46,5 %
2029	113,710	34135	15579	6700	91430	57325	207471	54,3 %
2030	113,710	34787	14987	7036	91777	56990	264461	62,2 %
2031	113,710	35482	14201	7387	92121	56639	321100	70,1 %
2032	113,710	36192	13492	7757	92461	56269	377369	78,1 %
2033	113,710	36916	1278	8144	92797	55881	433250	86,0 %
2034	113,710	37654	12030	8552	93128	55474	488724	94,0 %
2035	113,710	38407	11277	8979	93454	55047	543771	102,0 %
2036	113,710	39175	10508	9428	93773	54598	598368	110,1 %
2037	113,710	39959	9725	9900	94085	54126	652495	118,2 %
2038	113,710	40758	8926	10395	94389	53631	706126	126,3 %
2039	113,710	41573	8111	10914	94685	53111	759237	134,4 %
2040	113,710	42405	7279	11460	94970	52566	811803	142,6 %
2041	113,710	43253	6431	12033	95245	51993	863796	150,7 %
2042	113,710	44118	5566	12635	95509	51391	915187	159,9 %
2043	113,710	45000	4684	13266	95760	50759	965949	167,2 %
2044	113,710	45900	3784	13930	95996	50096	1016042	175,4 %
2045	113,710	46618	2866	14626	96218	49400	1065442	183,7 %
2046	113,710	47755	1929	15358	96423	48668	1114110	192,0 %
2047	113,710	48710	974	16125	96610	47900	1162010	200,2 %
∑	**2842741**	**970000**	**272096**	**238635**	**2332010**	**136010**	**1162010**	**200,2 %**

CONCLUSION

Using PV Syst software, a simulation of the techno-economic analysis of a 1MW solar power plant was made. The main conclusions are:

- The total amount of global horizontal irradiation is 1262.6 kWh/m^2,
- The average performance ratio is 79.5%,
- The total annual energy injected into gird was 1,137 MWh,
- The simulated solar power plant meets the needs of 271.5 households,
- Invested funds are returned in a period of 12.7 years,
- In the expected time period of 25 years of operation, the profit of the solar power plant amounts to 200.2% in relation to the invested investment.

Taking into account the capacities of renewable energy sources in the Republic of Serbia, the accelerated increase in the use of these sources recorded in previous years, as well as the current announcements of the authorities in the country on this topic, it was concluded that Serbia is slowly moving towards more developed countries in terms of the use and increase in the use of production opportunities electricity and reduction of environmental pollution.

This work fills the gap in theoretical research, which is very scarce in the Republic of Serbia on this topic. Based on the literature research, a very small number of authors dealt with the possibilities of using the solar potential on the examples of setting up solar power plants and their specific contribution to the Electric Power Industry of Serbia, as well as comparing the efficiency of solar power plants.

The data obtained in this paper provide useful information about the possible net electricity obtained from such a system and are expected to serve as reference material for future research, as well as to give a picture of how and how much a solar power plant installed like this would contribute to the electricity grid of Serbia.

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SOLAR ENERGY AND ENERGETIC INDEPENDENCE OF AN OBJECT

Dejan Bajić[1], Luka Đorđević[1], Borivoj Novaković[1], Milan Marković[1], Verica Gluvakov[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: bajicdejan.98@hotmail.com

Abstract: In this paper the solutions for improving the energetic efficiency of the object (music studio) that is located on Novi Sad's suburbia will be discussed. This paper contains information and calculation done in PVGIS software that shows the amount of electrical energy that can be obtained by installing solar panels on the studio's roof. Moreover, consumption of electrical energy in this object during the period of one year will be presented, as well as calculation about how many solar panels are needed for the energetic independence of the object.
Key words: renewable energy, PVGIS, solar energy, solar panels

INTRODUCTION

Energy will always be one of the topics that occupy the attention of scientists and engineers. The demand for energy is getting higher all over the world [1]. According to [2] the global energy consumption will be increased by 53% by 2030. The transition from fossil fuels to renewable sources of energy is the key to sustainable development [3]. Nowadays, only 9% of the global energy consumption comes from renewable sources of energy [4]. One of the challenges of the future will be the limitation of supplies of fossil fuels [5].
Speaking about solar energy and energetic independence, the main goal is to transform an object to a totally independent one of the national energetic system, which is most of the time hard to achieve because of the unpredictable meteorological conditions. So usually an object can be transformed to a partially independent one, which means that some amount of energy for devices that are used in an object has been obtained from the solar radiation while the rest of the energy comes from the national energetic system.
According to [6], Serbia has a great potential for converting solar to electrical energy using solar panels. In the region of Novi Sad the average of daylight hours and sunshine hours is shown in the Figure 1 [7].

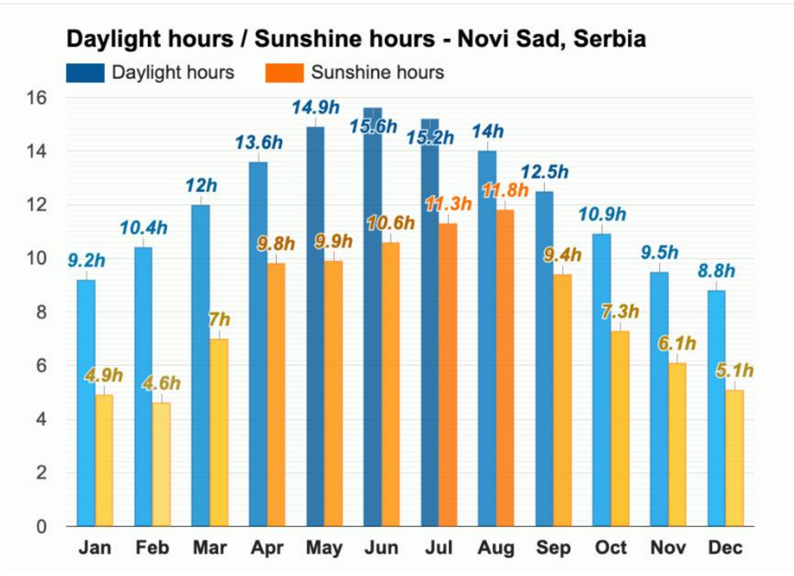

Fig. 1. Average daylight and sunshine hours in Novi Sad during the year [7]

This potential can be used on small local projects such as the one described in this paper, but also globally by setting solar power plants on convenient locations.

CHARACTERISTICS OF THE OBJECT

In this chapter the basic characteristics of this object will be presented. The object contains of a single room. The only source of energy used in this room for air-conditioning and heating system, electronic devices and lighting is energy provided by the national energetic system.

The orientation of an object and position of the door and windows are very important when we speak about energetic efficiency. The object is oriented in the north-south direction, the aluminum door (0,92x2 m) and one aluminum window (1,45x1,15 m) are located on the eastern side of the building, while the other window (1,45x1,15 m) is located on the southern side of the object (figure 2.). The base of the object is 4x5 meters and the average height is 2,5 m. The roof construction contains of a single concrete block with a wooden construction over it covered with tiles. The roof is peaked 4,5° (South towards North), higher side is 2,7 m high, while the lower, southern side is 2,3 m high.

The object is made of bricks. The walls are covered with 0,02 m thick mortar from the inside and outside. The object has a good thermal insulation, it is covered with 0,03 m thick styrofoam from the outside.

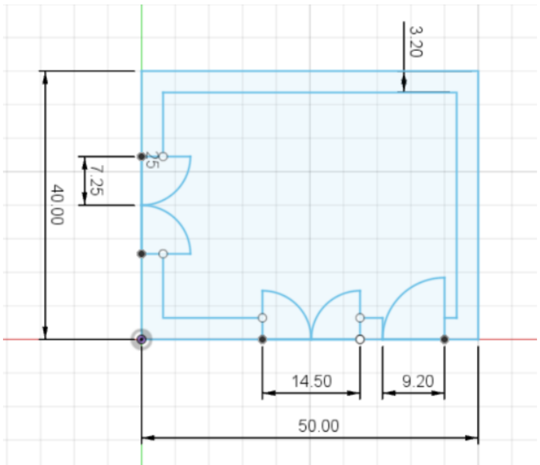

Fig. 2. Sketch of the object (top view) made in Fusion 360 in proportions 1:100

Energy consumption of the object

Generally speaking, this object does not need a lot of energy during the period of one year because it is not used every day nor the entire day, compared to objects that are used for living. On average, during the period of one year, the object is used for 5 hours a day.

In the Table 1, all the devices that are used in this music studio will be shown, as well as their specifications and energy consumption during a year based on the time they are exploited during this period.

Table 1. Energy consumption of the building

Device	Number of devices	Power of devices (W/h)	Average number of working hours during a year(h)	Energy consumption during a year (kWh)
Laptop	1	65	1825	118,63
Speaker	2	21	750	31,5
Guitar amplifier	1	15	1095	16,43
TV	1	65	1000	65
Air-	1	1000	450	450

conditioner				
Oil radiator	1	2000	750	1500
Lightbulbs	5	5	1750	43,75
Total energy consumption during a year (kWh/year)				2225,31

The calculation has shown that the annual energy consumption of this building is 2225,31 kWh. During this calculation it is assumed that every single device works with full capacity, so the maximum energy consumption is presented. The results from the table can be presented on the Figure 3, to emphasize which device consumes the majority of the used energy during the period of one year. From the Figure 3 it is evident that the biggest consumer is the oil radiator.

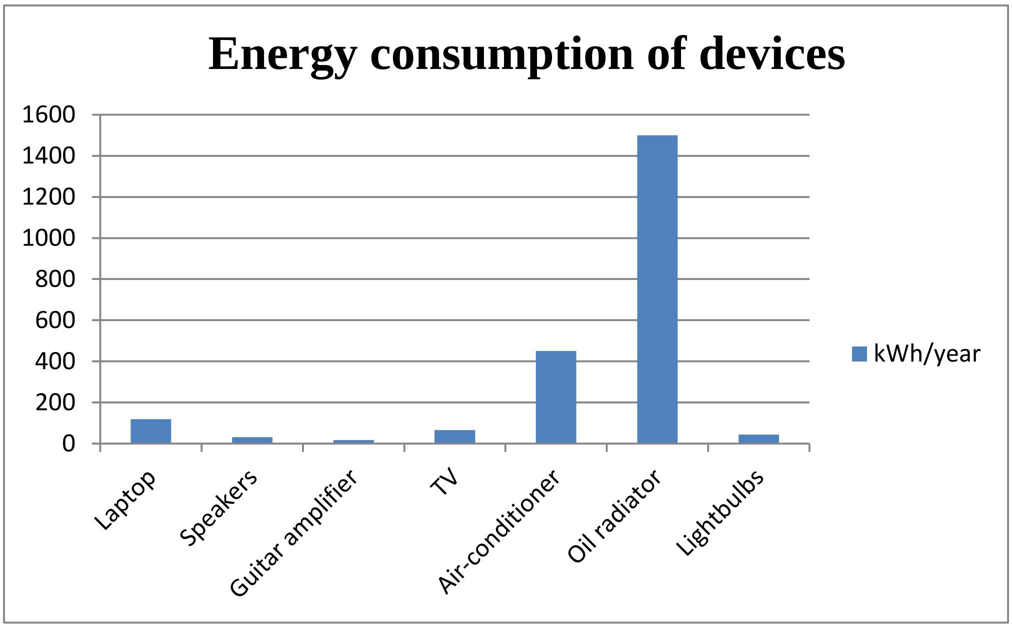

Fig. 3. Annual energy consumption of every device in the music studio

The energy consumption varies during different periods of the year. During the summer months, the main energy consumer is the air-conditioning system. On the other hand, during the winter months most of the energy is used for the heating of the room. All the other devices, except for the air-conditioner and oil radiator, are exploited to the same extent during every month. Table 2 and Figure 4 represent the energy consumption of every device during every month of the year.

Table 2. Energy consumption by months in kWh

Device	**Energy consumption by months in kWh**											
	jan	**feb**	**mar**	**apr**	**may**	**june**	**july**	**aug**	**sept**	**oct**	**nov**	**dec**
Laptop	9,88	9,88	9,88	9,88	9,88	9,88	9,88	9,88	9,88	9,88	9,88	9,88
Speakers	2,63	2,63	2,63	2,63	2,63	2,63	2,63	2,63	2,63	2,63	2,63	2,63
Guitar Amplifier	1,37	1,37	1,37	1,37	1,37	1,37	1,37	1,37	1,37	1,37	1,37	1,37
TV	5,41	5,41	5,41	5,41	5,41	5,41	5,41	5,41	5,41	5,41	5,41	5,41
Air-condition	0	0	0	0	56,3	112,5	112,5	112,5	56,3	0	0	0

Oil radiator	280	230	170	90	0	0	0	0	0	200	250	270
Light bulbs	3,64	3,64	3,64	3,64	3,64	3,64	3,64	3,64	3,64	3,64	3,64	3,64
Total for a month	303	253	193	113	79	135,5	135,5	135,5	79	223	273	293

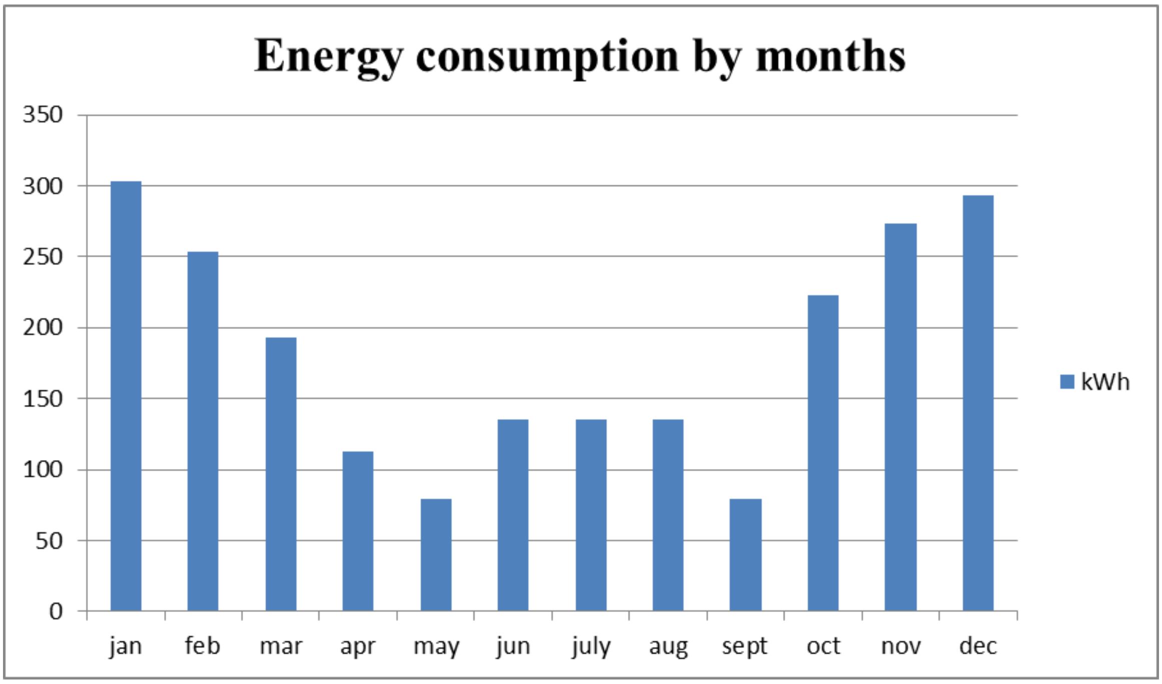

Fig. 4. Energy consumption by months

If we analyze these two figures from above, we can clearly see that the highest electricity consumption is reached during winter months, to be precise, in January (303 kWh), while the lowest consumption can be noticed in May and September, only 79 kWh, when neither the heating or cooling of the room is necessary due to convenient meteorological conditions in this period of the year in this area.

PVGIS CALCULATIONS

According to the calculations done in PVGIS, the total solar panel installed power should be 2000W, to cover all the needs of the object during the period of one year (figure 5). On this specific object 10 solar panels of 200W each can be installed on the roof. The dimensions of the panel are: 1,580 x 0,808 m [8], which gives the total surface of 1,27 m^2 per panel, and 12,7 m^2 for 10 panels, which is enough to provide 2231 kWh annually (figure 5), while the surface of the roof is 20 m^2. The step further could be made: the entire surface of the roof could be covered with solar panels, so that during the year there would be a greater surplus of the produced electrical energy, and it could be sold to the national energetic system [9].

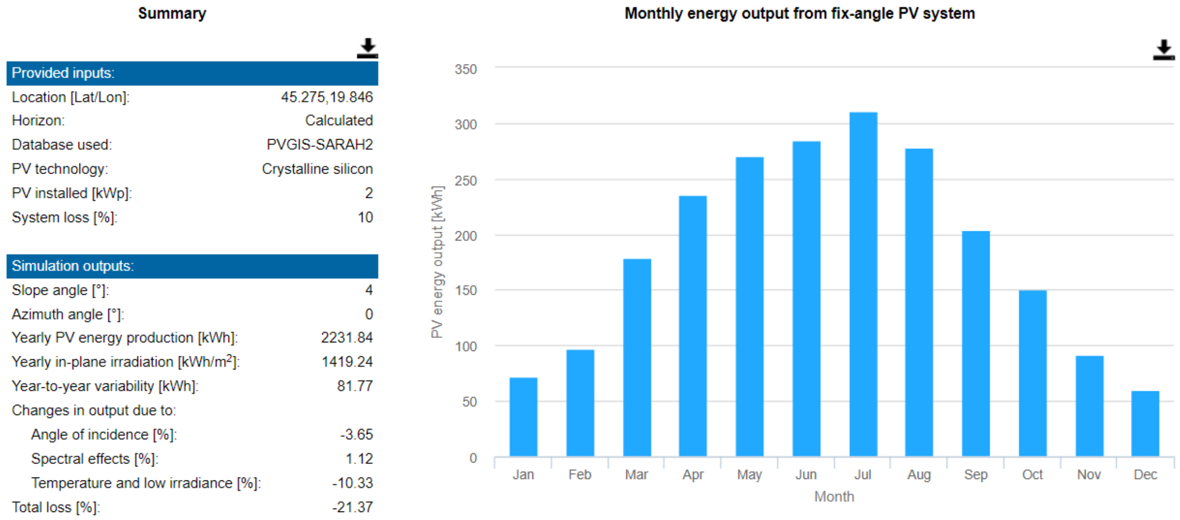

Fig. 5. PVGIS calculations

The highest production is achieved during the summer, which can complement the lack of electrical energy obtained from the solar panels during the winter, when the demand is the highest (Figure 4). This can be accomplished thanks to legislations in The Republic of Serbia. These legislations are about the total energy consumption and production of an object during the period of one year. If the annual production and consumption are equal, the electricity bills will be basically free of charge. During the summer, when the insolation and electricity production are the highest, an individual in The Republic of Serbia has the right to store or sell surplus of energy to the national energetic system. [9] By this, during the winter, when the consumption is higher than the production, the individual has the right to demand the amount of electrical energy that he stored during the summer, from the national energetic system.

CONCLUSION

As already said, the demand for energy is growing through the years. Also, in global, the goal is to achieve the Net-zero concept due to the air pollution that is caused by the excessive combustion of fossil fuels. The obligation of humanity is to take care of the Earth in terms of reducing pollution and increasing sustainable energy production and usage. Small steps, such as the one described in this paper, cannot have a big impact on the global energetic system; but if we start following examples like this one and if we start building bigger projects such as solar power plants, we can contribute to the energetic system of local communities. A project like this one can have a great impact on a budget of an individual in The Republic of Serbia, thanks to legislations described in the paper, as the calculation in this paper has shown. It is calculated that the annual production and demand for the electrical energy of the object are fairly equal so the great long-term economic benefits can be achieved. This project can serve as an example to other individuals in a local community and can encourage others to follow the path of sustainable development.

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