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Časopis objavljuje naučne i stručne radove i informacije od interesa za stručnu i privrednu javnost iz oblasti mašinstva i srodnih grana vezanih za područje primjene i izučavanja mašinstva. Posebno se obrađuju slijedeće tematike:
- tehnologija prerade metala, plastike i gume,
- projektovanje i konstruisanje mašina i postrojenja,
- projektovanje proizvodnih sistema,
- energija,
- održavanje sredstava za rad,
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- informacije o novim knjigama,
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The journal publishes scientific and professional papers and information of interest to professional and economic releases in mechanical engineering and related fields. In particular, the following topics are treated:
- Technology for processing metal, plastic and rubber,
- Design and construction of machines and plants,
- The design of production systems,
- Energy,
- Maintenance funds for the work,
- Quality and efficiency of the system and the management of production and business systems,
- Information about new books,
- Information about scientific meetings
- Information from the University,

RIJEČ UREDNIKA

Poštovane kolegice i kolege

U ovom 61. broju Vašeg časopisa nudimo pet radova iz različitih, širih, oblasti mašinstva: jedan rad iz oblasti proizvodnih tehnologija, uže, obrada skidanjem strugotine; zatim jedan rad iz oblasti održavanja sredstava za rad-obezbjeđenje rezervnih dijelova; treći rad je iz oblasti energetskih postrojenja (hidraulika), kao i četvrti iz oblasti energetskih postrojenja ali iz oblasti korištenja komprimiranog zraka u rudarskim jamama,; peti rad smo, prema usvojenom konceptu sadržaja Časopisa, preuzeli sa jednog međunarodnog naučno-stručnog skupa održanog u Zenici, novembra 2018. godine, koji se odnosi na metode modeliranja procjene životnog ciklusa u proizvodnom sistemu metalskog kompleksa.

U okviru informacija obavještavamo Vas o dva značajna događaja za oblast mašinstva u Bosni i Hercegovini: godišnjici Mašinskog fakulteta u Zenici (42 godine) i promociji doktora nauka Univerziteta u Zenici za 2018. godinu.

U naporu promocije istraživačkih kapaciteta u bosni i Hercegovini na prvoj strani korica Časopisa prikazana je jedna Laboratorija Mašinskog fakulteta u Mostaru, a na zadnjoj strani predstavljen je jedan kapacitet za nabavu mašina za preradu drveta, što se najčešće smješta u oblast mašinstva.

Očekujemo Vaš doprinos razvoju struke i nauke, na Vašu korist, korist naše zemlje Bosne i Hercegovine i čitavog svijeta.

Vaš glavni i odgovorni urednik
Prof. emeritus dr. Safet Brdarević

EDITORIAL

Dear Colleagues

In this 61 issue of your Journal, we offer five papers from different, extensive, mechanical engineering: one working in the field of production technologies, rope, scraping; then one work in the field of maintenance of the means for work-providing the spare parts; the third is in the field of energy plants (hydraulics), as well as the fourth ones in the field of energy plants but in the field of compressed air use in mining pits; the fifth paper, according to the adopted concept of the journal's contents, took over from an international scientific and expert conference held in Zenica in November 2018 concerning the methods of modeling life cycle estimates in the production system of the metal complex.

We inform you about two significant events for the field of machinery in Bosnia and Herzegovina: the anniversary of the Faculty of Mechanical Engineering in Zenica (42 years) and the promotion of the Doctor of Science of the University of Zenica for 2018.

In the effort of promotion of research capacities in Bosnia and Herzegovina on the first part of the Journal, one Laboratory of the Faculty of Mechanical Engineering in Mostar was presented, and on the latter one capacity was presented for the procurement of woodworking machines, most often located in the field of machinery.

We expect your contribution to the development of the profession and science to your advantage, the benefit of our country of Bosnia and Herzegovina and the whole world.

Your editor in chief
Prof. emeritus dr. Safet Brdarević

SADRŽAJ

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VIŠECILJNA OPTIMIZACIJA PARAMETARA MQLC PROCESA TOKARENJA POMOĆU GREY-FUZZY PRISTUPA

MULTI-OBJECTIVE OPTIMIZATION OF MQLC TURNING PROCESS PARAMETERS USING GREY-FUZZY APPROACH

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REZIME

U ovom radu je istražen utjecaj različitih ulaznih parametara obrade na hrapavost obrađene površine, silu rezanja i proizvodnost tijekom procesa tokarenja korištenjem MQLC (minimalne količine za hlađenje i podmazivanje) sustava. Plan eksperimenata je definiran prema Taguchi metodi. Odabrano je ortogonalno polje L9 (3^4) gdje su četiri ulazna parametra varirana na tri razine. Parametri koji su varirani u eksperimentima su: brzina rezanja (v_c), dubina rezanja (a_p), posmak (f) te vrsta čeličnog materijala obratka. Siva relacijska analiza u kombinaciji s fuzzy logikom je korištena kako bi se pronašle razine ulaznih parametara obrade kojima se postižu optimalne vrijednosti odzivnih veličina procesa.

Original scientific paper

SUMMARY

In this paper the influence of different machining parameters on the surface roughness, cutting force and material removal rate during turning process using MQLC (minimum quantity lubrication and cooling) system was investigated. The experimental plan was defined using Taguchi's method. Orthogonal array L9 (3^4) was selected for four input parameters varied on three levels. Parameters that were varied in experiments are: cutting speed (v_c), depth of cut (a_p), feed rate (f) as well as workpiece steel material. The grey relational analysis in combination with fuzzy logic technique was used to find out the input parameters levels that lead to optimal process responses values.

1. INTRODUCTION

The modern concept of sustainable manufacturing or green manufacturing represents a lot of changes in rules and limitations in the manufacturing industry. Most of them are related to proper use and disposal of waste during the manufacturing processes and balancing between the economic, ecological and sociological aspects of manufacturing. The most commonly used cutting fluids (CFs) in machining processes are still conventional emulsions. In recent years, in manufacturing industry special attention on machining processes and use of conventional CFs was given. A significant component in sustainable stability of machining process represents proper choice of type and quantity of CFs as well as proper choice of appropriate combination of cutting parameters, cutting tool and workpiece materials. During past decades, several

technologies have been developed with the aim to increase effectiveness of machining processes and fulfilment of sustainability requirements: cooling with cold compressed air (CCA), cryogenic cooling (CC) with different gasses, high pressure cooling (HPC), minimum quantity lubrication (MQL) and minimum quantity lubrication and cooling (MQLC), near dry machining (NDM). Also, the solution in the way of fulfilling previously listed demands hides in applying various methods and techniques of planning and optimization of the manufacturing systems. Today there are different methods like Taguchi method (TM), artificial neural networks (ANN), grey relational analysis (GRA), genetic algorithm (GA), fuzzy logic (FL), adaptive neuro-fuzzy technique (ANFIS) and etc. Above mentioned alternative techniques and methods represent a challenge for many scientists and researchers because they have to fulfill all technical and economic requirements placed for achieving of ultimate goals of machining process. From above listed cooling, flushing and lubricating techniques, the MQL and MQCL methods are extremely popular to use in the machining processes due to improvement of the machining processes productivity, reduction of purchasing costs and disposal CFs as well as the reduction of the machine/tool system cleaning time and energy consumption compared with conventional cutting fluid systems. Mozammel et al. [1], Senevirathne et al. [2], Gurraj et al. [3] are argued that very important parameters during MQL and MQLC machining are type and ratio of cutting fluids and lubricant, pressure (2-6 bar), flow rate (5-500 ml/h), number (1-2), distance (5-30 mm) and angle (30-60°) of nozzles. Mourad et al. [4] during turning of X210Cr12 steel with multilayer coated cutting tool concluded that MQL technique has a positive effect on reducing friction between cutting tool and workpiece. In their investigation temperature in the cutting zone is reduced and consequently the tool wear is lower about 23.34% compared with conventional and about 40% compared with dry machining. Yunn et al. [5] reported about experiments carried out using the MQL technique during milling of Inconel 718. The authors used different combinations of oil and water ratio in the MQL system (10:90, 40:60, 60:40 and 100:0) and oils with different viscosities. For all experiments the pressure was 5 bar, nozzles were 20 mm away from the cutting zone at an angle of 45°. Oil flow for all combinations of oil and water ratios is 20 ml/h, 60 ml/h and 100 ml/h. The authors pointed out that with lower ratio of oil and water (with lower viscosity oils) during high milling with higher flow can achieve more efficient aerosol penetration into the cutting zone. In this research, the optimum water and oil ratio and the flow rate where the best output performance values are obtained during milling Inconel 718 alloys are 60:40 and 60 ml/hr. Ekinović et al. [6] presented an investigation of the MQL turning process of X5CrNi18-10 stainless steel with the objective of screening and selecting the most important MQL parameters on machinability of austenitic stainless steel. Results indicated that the most important parameters for simultaneous reducing of surface roughness and cutting forces were oil and water flow rate followed by the spray distance. Faga et al. [7] analyzed the effect of varied cutting speed with constant feed and depth of cut on the tool wear, energy consumption, cutting force and surface roughness during turning titanium Ti-6Al-4V alloy under different machining conditions (dry machining, conventional emulsion, MQL technique and MQLC technique). The authors confirmed that during variation of input factors using MQL or MQCL techniques, the relationship between the type of oil, delivered quantity and the delivery method in the cutting zone represents a significant influence on control and efficiency of the mentioned techniques. Shokoohi et al. [8] conducted a research on hardened steel AISI 1045 during turning process by using dry machining, conventional cooling emulsion, and MQCL techniques where CO_2 as a cooling medium is used. Under the conditions of MQCL technique and cooling with conventional emulsion two types of vegetable oils were used. By analysis of variance with regard to the output values like surface roughness, energy consumption and shape of the separated chips, it is evident that the type of vegetable oil has a significant influence from the point of view of its viscosity. Better output values are achieved by oil with lower viscosity. The aerosol (oil particles) penetrates more efficiently into the cutting tool/workpiece zone and the cutting zone is better cooled compared with dry and conventional machining. Zerti et al. [9] carried out multi-objective optimization by grey relational analysis (GRA) technique that is based on Taguchi design analysis in order to simultaneously optimize surface quality and productivity. The tool-material pair used in this study is AISI D3 steel/ mixed ceramic tool. Zerti

et al. [10] investigated the influence of the different machining parameters represented by cutting speed (v_c), depth of cut (a_p), and feed rate (f) on the output values expressed through surface roughness, cutting force and power, and material removal rate (*MRR*) during dry hard turning operation of martensitic stainless steel (AISI 420). Authors applied response surface methodology (RSM) and artificial neural network (ANN) approaches for modeling of process responses values. The results indicated that (*Ra*) is strongly influenced by the feed rate (80.71%), while the depth of cut has the highest influence on the cutting force (65.31%), cutting power (37.56%) and material removal rate (36.45%). Furthermore, ANN and RSM models were found to predict well experimental results.
In this paper GRA in combination with fuzzy logic approach is applied to find out the combination of input turning parameters levels that lead to optimal process responses: resultant cutting force, surface roughness and material removal rate during machining of three different steels using MQLC system.

2. EXPERIMENTAL SETUP

The experiments were carried out on a conventional PA-501A Potisje lathe with the ISO designation CNMG 120408-WG quality coated carbide insert of cutting tool. The workpieces materials used for experiments were: St 50-2, C45, 42CrMo4. All experimental tests were carried out by the use of an advanced MQLC system, which generates oil-on-water droplet aerosol with a constant pressure supply of 2 bar.

The cutting forces were measured using a Kistler 5070 dynamometer connected with DynoWare software. From their values the resultant cutting force *Fr* is calculated. Measurements of the surface roughness parameter *Ra* were performed on a Perthometer M1 type (Mahr) profilometer, at five different locations. Material removal rate, MRR was calculated as follows:

$$MRR = v_c a_p f \tag{1}$$

where v_c [m/min] is cutting speed, a_p [mm] is depth of cut, f [mm/rev] feed rate.
Experimental setup is presented in Figure 1.

2.1. Planning experiments with Taguchi method

Planning experiments with Taguchi method includes the use of orthogonal arrays for organizing input parameters and levels on which those parameters should be varied. In this paper, in order to reduce the number of experiments Taguchi L_9 orthogonal array is selected. Input parameters are cutting speed v_c, depth of cut a_p, feed rate f as well as steel workpiece material (St 50-2, C45 and 42CrMo4). The parameters with their levels selected for conducting the experiments are shown in Table 1. The outputs *Fr*, *Ra* and *MRR* are measured for all 9 experiments and are shown in Table 2 respectively.

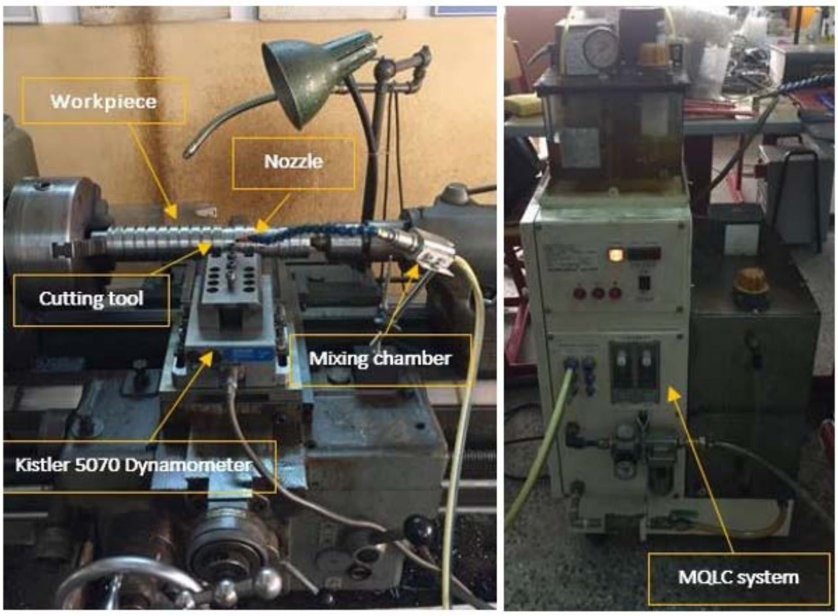


Figure 1. *Experimental setup*

Table 1. Machining parameters and their levels

Parameter /Level	Symbol	Level 1	Level 2	Level 3
Cutting speed v_c [m/min]	A	58	110	162
Depth of cut a_p [mm]	B	1	2	3
Feed rate f [mm/rev]	C	0.107	0.214	0.321
Workpiece material	D	St 50-2	C45	42CrMo4

Table 2. Experimental plan and results

Trial No.	Input parameters				Outputs		
	A	B	C	D	*Fr* [N]	*Ra* [µm]	*MRR* [mm^3/s]
1.	1	1	1	1	512.91	1.55	103.39
2.	1	2	2	2	1676.44	0.9	413.57
3.	1	3	3	3	3067.77	1.4	930.53
4.	2	1	2	3	901.24	0.6	392.18
5.	2	2	3	1	2376.87	1.22	1176.53
6.	2	3	1	2	1086.96	1.15	588.26
7.	3	1	3	2	1140.26	0.88	866.35
8.	3	2	1	3	786.09	0.85	577.57
9.	3	3	2	1	1929.60	1.22	1732.71

3. METHODOLOGY

3.1. Grey relational analysis (GRA)

Grey relational analysis (GRA) is applied for determining the optimum conditions of various input parameters considered to obtain the best quality characteristics considering single and multiple responses [11-15].

Raw data cannot be used in GRA so in the first step the measured output values of *Fr*, *Ra* and *MRR* should be normalized to a range between 0 and 1. Expressions which are used for normalization by GRA are different depending on characteristic of response. If the characteristic of response is of ‘’higher-the-better’’, Eq. [2] is used, whereas, if the response is of ‘’lower-the-better’’ characteristic, Eq. [3] is used.

$$x_i^*(k) = \frac{x_i(k) - min\, x_i(k)}{max\, x_i\,(k) - min\, x_i\,(k)} \tag{2}$$

$$x_i^*(k) = \frac{max\, x_i(k) - x_i(k)}{max\, x_i(k) - min\, x_i(k)} \tag{3}$$

$i = 1,2,\ldots,m$ and $k=1,2,\ldots,n$.

where, $x_i(k)$ are the observed and $x_i^*(k)$ are the normalized data for the i^{th} experiment and k^{th} response respectively.

After normalization, the grey relational coefficient (*GRC*) is calculated. *GRC* expresses the relationship between ideal and normalized data. *GRC* value can be estimated using Eq. [4].

$$\xi_i(k) = \frac{\Delta_{min} + \zeta\Delta_{max}}{\Delta_{0i}(k) + \zeta\Delta_{max}} \tag{4}$$

where $\Delta_{0i}(k)$ is difference between $x_i^0(k)$ and $x_i^*(k)$ ($x_i^0(k)$ is an ideal sequence). ζ is distinguishing coefficient. It takes value between 0 and 1. Generally, ζ=0.5 is preferred. A higher *GRC* value of experiment indicates that it is closer to the optimal solution with respect to a particular response.

Grey relational grade (*GRG*) can be calculated by averaging the *GRC* values that correspond to individual experiment, Eq. [5].

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i\,(k) \tag{5}$$

where n is number of process responses.
The corresponding experiment with the highest *GRG* presents the best combination of input process parameters values that lead to the optimal process responses.

3.2. Fuzzy logic approach in grey relational analysis
Fuzzy logic theory was developed to deal with decision making problems that are difficult to deal with because of their uncertain and vague information. This theory converts the imprecise linguistic terms to understandable numerical values by considering different fuzzy membership functions [15-17]. The use of ''higher-the-better'' and ''lower-the-better'' performance characteristics in GRA produces some uncertainty within the results. Fuzzy logic can be effectively used in these cases to reduce and control these uncertainties [15]. Also, the grey based fuzzy technique can make significant improvement in the performance characteristics of the process [18-22]. Each fuzzy logic system consists of four components: the fuzzification module, the fuzzy inference module, the defuzzification module and the knowledge base. Fuzzification module uses different membership functions to convert inputs into linguistic variables. The membership function defines how the values of the input and output are mapped to a membership value between 0 and 1. There are various available membership functions such as triangular, trapezoidal, Gaussian etc. The fuzzy inference engine uses the knowledge base of fuzzy IF-THEN rules and performs fuzzy reasoning for generating the fuzzy (linguistic) output values. The defuzzification module converts the aggregated fuzzy values into a crisp non-fuzzy outputs [23].

3.3. ANOVA method
ANOVA method is used to define the significance of each input process parameter and to find out their contribution on the process responses values [14, 15].

4. RESULTS AND DISCUSSION
4.1. Grey relational analysis
The process responses values for all 9 experiments are used to calculate the grey relational coefficients. The data are firstly normalized and brought to a range between 0 and 1 by using Eq. (2) for *MRR* which has ''higher-the-better'' characteristic and Eq. (3) for *Fr* and *Ra* because they have ''lower-the-better'' characteristic. After normalization the grey relational coefficients (*GRC*) for each process response are calculated by using Eq. (4) and the grey relational grade (*GRG)* by using Eq. (5). Based on the obtained *GRG*, ranking is given to identify the best input parameters combination. From ranking, it is observed that fourth experiment has the highest *GRG* of 0.715 This input parameters combination can be considered as the best combination to perform an experiment and to reach better process responses values. All calculated values are shown in Table 3.

4.2. Grey-fuzzy reasoning analysis
In this paper to perform grey-fuzzy reasoning analysis Mamdani fuzzy inference system was used. Grey relational coefficients for *Fr*, *Ra*, *MRR* are inputs to fuzzy logic system, while *GRG* is considered as output (Figure 2). For each input in fuzzy logic system three triangular membership functions were used: low (L), medium (M) and high (H). On the other side five triangular membership functions were used for output: very low (VL), low (L), medium (M), high (H), very high (VH) (Figure 3).

Table 3. Normalized data, grey relational coefficients and grey relational grades

Trial No.	Normalized data			Grey relational coefficient			*GRG*	Ranking
	Fr	*Ra*	*MRR*	*Fr*	*Ra*	*MRR*		
1	1.000	0.000	0.000	1.000	0.333	0.333	0.556	5
2	0.545	0.684	0.190	0.523	0.613	0.382	0.506	7
3	0.000	0.158	0.508	0.333	0.373	0.504	0.403	9
4	0.848	1.000	0.177	0.767	1.000	0.378	0.715	1
5	0.270	0.347	0.659	0.407	0.434	0.594	0.478	8
6	0.775	0.421	0.298	0.690	0.463	0.416	0.523	6
7	0.754	0.705	0.468	0.671	0.629	0.485	0.595	4
8	0.893	0.737	0.291	0.824	0.655	0.414	0.631	3
9	0.445	0.347	1.000	0.474	0.434	1.000	0.636	2

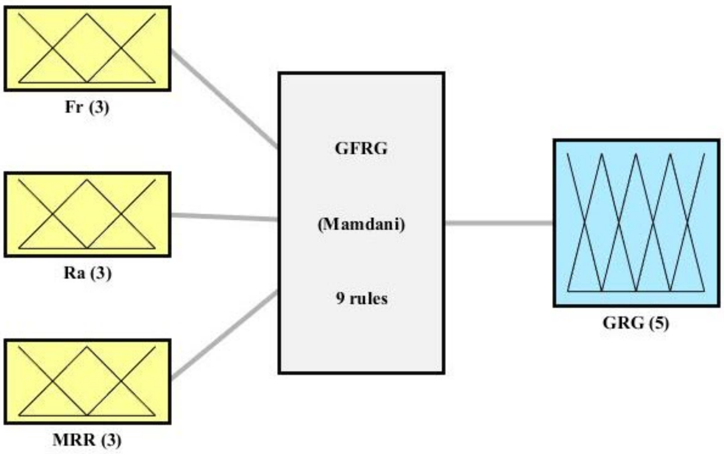


Figure 2. *Structure of three inputs and one output fuzzy logic system*

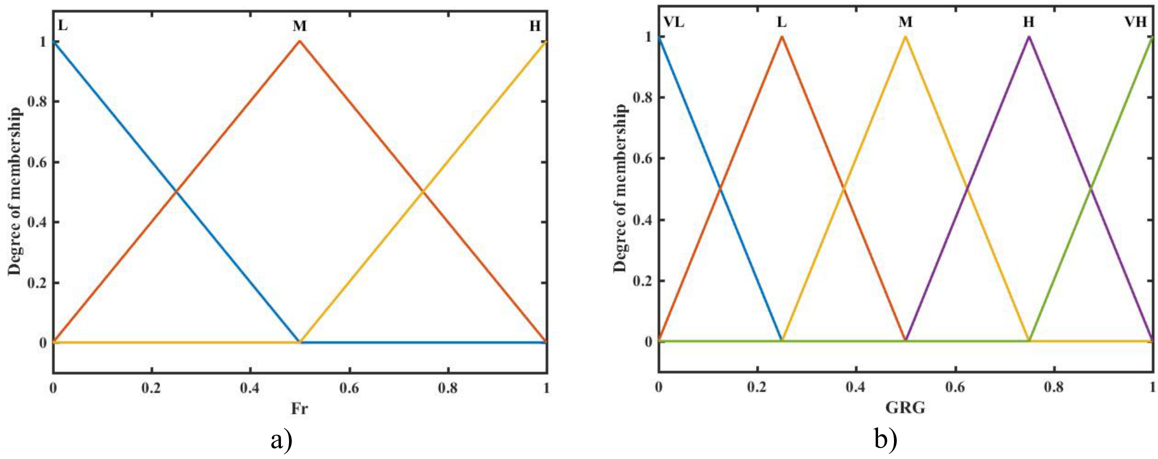


Figure 3. *Membership functions used for: a) Fr input, b) GRG output*

The fuzzy inference system performs fuzzy reasoning using fuzzy IF-THEN rules. Here, a set of nine rules was developed to model the relation between inputs (grey relational coefficients of *Fr*, *Ra* and *MRR*) and output (grey relational grade).

The graphical representation of the developed nine rules can be seen in Figure 4.

Fuzzy inference process was defined by the following: and method: min, or method: max, implication: min, aggregation: max and defuzzification method: centroid.

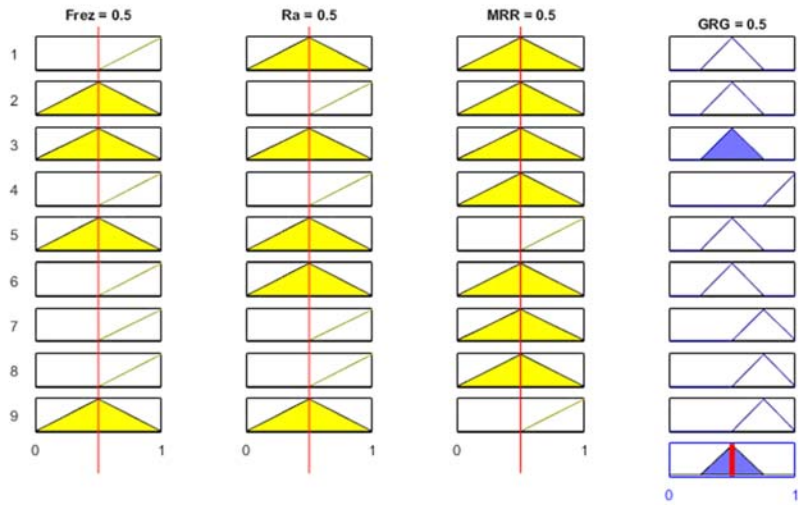


Figure 4. *Graphical representation of fuzzy IF-THEN rules*

Finally, the deffuzifier from the Matlab R2015b toolbox converted fuzzy values into *GFRG* numerical values. In order to assess the prediction accuracy of developed fuzzy logic model, the *GRG* and *GFRG* values were compared. Mean absolute percentage error (MAPE) was used as comparison measure. MAPE of 7.92% proves good prediction accuracy of developed fuzzy logic model. These comparison results, *GRG* and *GFRG* values and MAPE are shown in Figure 5.

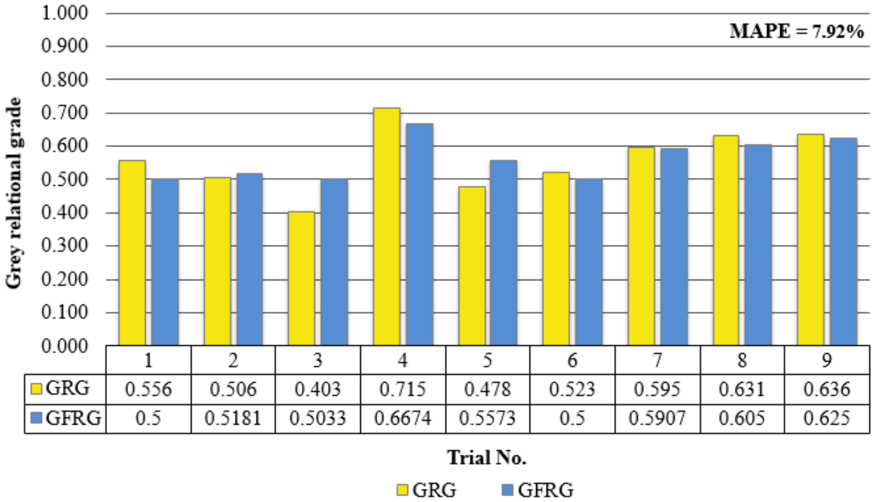


Figure 5. *Comparison between grey relational grade (GRG) and grey-fuzzy reasoning grade (GFRG)*

The higher values of *GFGR* determined the best multiple process responses characteristics. Analysis of the means was performed for *GFRG*. Difference between maximal and minimal average of GFRG values defines the rank of input parameters that affects the multiple responses. These values are listed in Table 4. Figure 6 shows main effects of input parameters on *GFRG*. Greater inclination of input parameter line defines a higher influence of that parameter on the multiple responses characteristics.

Table 4. Response table for grey-fuzzy reasoning grade (*GFRG*)

Level / Parameter	Cutting speed v_c [m/min] A	Depth of cut a_p [mm] B	Feed rate f [mm/rev] C	Workpiece material D
Level 1	0.5071	**0.5860**	0.5350	0.5608
Level 2	0.5749	0.5601	**0.6035**	0.5363
Level 3	**0.6069**	0.5428	0.5504	**0.5919**
Max-Min	0.0998	0.0433	0.0685	0.0556
Rank	1	4	2	3

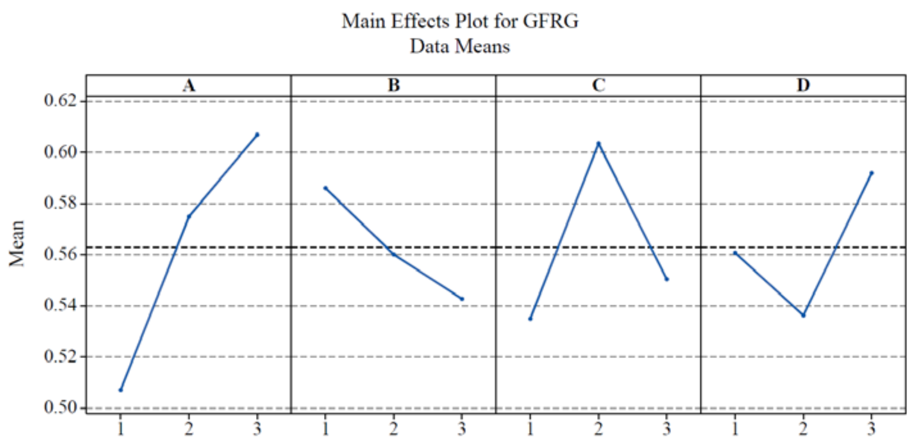


Figure 6. *Main effects plot for grey-fuzzy reasoning grade (GFRG)*

Based on Table 4 and Figure 6 the optimum setting of input process parameters is identified as cutting speed 162 m/min, depth of cut 1 mm, feed rate 0.214 mm/rev and workpiece material 42CrMo4, represented as $A_3B_1C_2D_3$. This is marked in bold font in Table 4. The use of these conditions will at the same time minimize *Fr* and *Ra* and maximize *MRR* throughout turning within the range of studied process parameters.

4.3. Analysis of variance (ANOVA)

To analyse the significance of input parameters on multiple responses characteristics, the obtained *GFRG* was subjected to ANOVA (Table 5). It can be seen from Table 5 that the degrees of freedom for residual error are zero. Normally this happens because the experimentation with 4 parameters at 3 levels, using Taguchi L_9 OA, does not provide enough data. Hence ANOVA pooling should be conducted. ANOVA pooling is a process of revision and re-estimation of ANOVA results in order to ignore an insignificant parameter whose contribution is less [14, 24] In this paper the depth of cut and workpiece material are parameters that have the smallest influence on *GFRG*. Aiming to develop later a functional relationship between *GFRG* and controllable process parameters (v_c, a_p and f), ANOVA pooling was done by exception workpiece material parameter (Table 6). From the pooled ANOVA it is obvious that cutting speed is the most influential parameter that contributes towards *GFRG* by 50.51% . It is followed by feed rate with contribution of 25.13% and depth of cut of 9.22%.

Table 5. Analysis of variance for grey-fuzzy reasoning grade (before pooling)

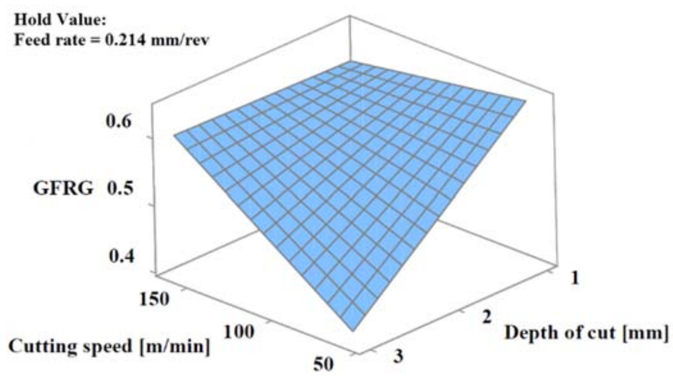
Source	DF	Adj SS	Adj MS	F	P	% Contribution
A	2	0.015570	0.007785	*	*	*
B	2	0.002844	0.001422	*	*	*
C	2	0.007747	0.003873	*	*	*
D	2	0.004665	0.002332	*	*	*
Residual error	0	*	*			
Total	8	0.030825				

Table 6. Analysis of variance for grey-fuzzy reasoning grade (after pooling)

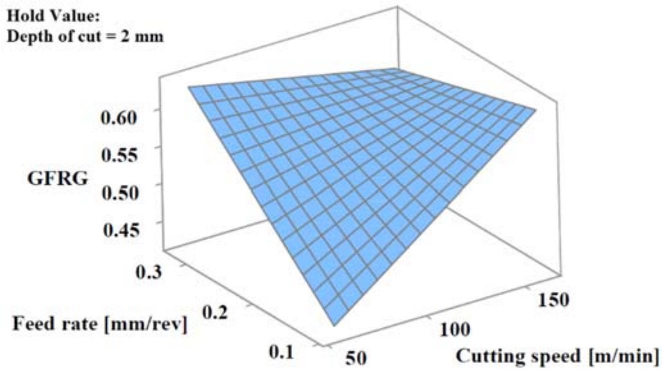
Source	DF	Adj SS	Adj MS	F	P	% Contribution
A	2	0.015570	0.007785	3.34	0.231	50.51
B	2	0.002844	0.001422	0.61	0.621	9.22
C	2	0.007747	0.003873	1.66	0.376	25.13
Residual error	2	0.004665	0.002332			15.13
Total	8	0.030825				100.00

In order to define the relationship between the input process parameters and the obtained *GFRG* the following regression equation was developed (Eq. (6)). Based on the regression model corresponding surface plots were created and presented in Figure 7.

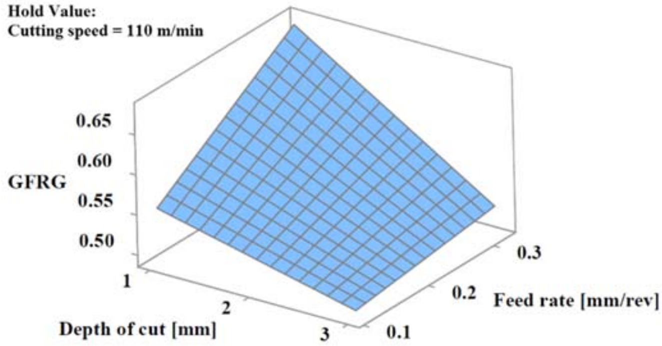
$$GFRG = 0.386 + 0.00103\,A - 0.1279\,B + 2.11\,C + 0.001115\,A{*}B - 0.01188\,A{*}C - 0.231\,B{*}C \quad (R^2=0.81) \qquad (6)$$



a)



b)



c)

Figure 7. *Surface plots showing the effects of different process parameters on GFRG values*

4.4. Confirmation test

After the optimal combination of input process parameters was found out, in order to check the improvement in the process responses values a confirmation experiment was performed. Results of that experiment are shown in Table 7 and they are compared with responses values from initial parameters setting. Data form Table 7 reveal that optimal parameters setting lead to *Fr* of 661.14 N, *Ra* of 0.65 μm and *MRR* of 577.57 mm^3/s. Thus the experimental *GFRG* is 0.735, which shows an improvement by 0.235.

Table 7. Comparison table for initial and optimal parameters settings

	Initial parameters setting	Optimal parameters setting	
		Prediction	Experiment
Setting levels	$A_1B_1C_1D_1$	$A_3B_1C_2D_3$	$A_3B_1C_2D_3$
Fr (N)	512.91	-	661.14
Ra (μm)	1.55	-	0.65
MRR (mm^3/s)	103.39	-	577.57
GFRG	0.5	0.6994	0.735
Improvement in GFRG		0.1994	0.235

6. CONCLUSION

In this present paper in order to conduct an optimization of multiple process responses: cutting force, surface roughness and material removal rate an experimentation with four input parameters was conducted. These process parameters are: cutting speed, depth of cut, feed rate and workpiece material. Taguchi L_9 (3^4) orthogonal array was used to accomplish experiments in turning operation using MQLC system.

– From the investigation it was found out that cutting speed of 162 m/min, depth of cut of 1 mm, feed rate of 0.214 mm/rev and workpiece material 42CrMo4 is optimal combination of input parameters levels.

- ANOVA defined cutting speed as the most influential parameter on the process responses.
- Improvemet of the grey-fuzzy reasoning grade from 0.5 to 0.735 confirmed the improvement in the turning process and in process responses: cutting force, surface roughness and material removal rate. This improvement proved the suitability and effectiveness of grey-fuzzy approach in solving such multi-objective optimization problems.

7. REFERENCES

[1] Mozammel, M., Munish, K. G., Gurraj, S., Grzegorz, K., Danil, Y. P.: *An Approach to Cleaner Production for Machining Hardened Steel Using Different Cooling-Lubrication Conditions.*, Journal of Cleaner Production, DOI:10.1016/j.jclepro.2018.03.279, 2018.

[2] Senevirathne, S. W. M. A. I., Punchihewa, H. K. G.: *Reducing surface roughness by varying aerosol temperature with minimum quantity lubrication in machining AISI P20 and D2 steels*, The International Journal of Advanced Manufacturing Technology, 94:1009–1019, 2018.

[3] Gurraj, S., & Munish, K. G., Mozammel, M., Vishal S. S.: *Modeling and optimization of tool wear in MQL-assisted milling of Inconel 718 superalloy using evolutionary techniques*, The International Journal of Advanced Manufacturing Technology, https://doi.org/10.1007/s00170-018-1911-3, 2018.

[4] Mourad, N., Mohamed A. Y., Riad, K., Salim, B., Tarek. M.: *Comparative assessment of cooling conditions, including MQL technology on machining factors in an environmentally friendly approach*, International Journal of Advanced Manufacturing Technology, DOI 10.1007/s00170-016-9958-5, 2017.

[5] Yunn, S. L., Chin, H. L., Hsien, M. L.: *Study of Oil-Water Ratio and Flow Rate of MQL Fluid in High Speed Milling of Inconel 718*, International Journal of Precision Engineering and Manufacturing, DOI: 10.1007/s12541-017-0033-4, Vol. 18, pp. 257-262, 2017.

[6] Sabahudin, E., Edin, B., Muhamed M., Adnan, M.: *Taguchi Based Screening Approach In The MQL Turning Process Of X5 CrNi 18-10 Stainless Steel,* Journal of Trends in the Development of Machinery and Associated Technology Vol. 21, No. 1, 2018, ISSN 2303-4009 (online), 5-8, 2018.

[7] Maria, G. F., Paolo, C. P., Matteo, R., Luca, S., Vincenzo, T.: *Technological and Sustainability Implications of Dry, Near-Dry, and Wet Turning of Ti-6Al-4V Alloy*, International Journal Of Precision Engineering And Manufacturing-Green Tchnology, Vol. 4, No. 2, pp. 129-139, 2017.

[8] Yousef, S., Ehsan, K., Rassolian, S.: *Machining and Ecological Effects of a New Developed Cutting Fluid in Combination with Different Cooling Techniques on Turning Operation*, Journal of Cleaner Production, Doi:10.1016/j.jclepro.2015.01.055, 2015.

[9] Zerti, O., Yallese, M., Zerti, A., Belhadi, S., Girardin, F.: *Simultaneous improvement of surface quality and productivity using grey relational analysis based Taguchi design for turning couple (AISI D3 steel/mixed ceramic tool (Al2O3+ TiC))*, Int J Ind Eng Comput 9:173–119, 2018.

[10] Zerti, A., Mohamed, A., Yallese, Ikhlas, M., Salim, B., Abdelkrim, H., Tarek. M.: *Modeling and multi-objective optimization for minimizing surface roughness, cutting force, and power, and maximizing productivity for tempered stainless steel AISI 420 in turning operations*, The International Journal of Advanced Manufacturing Technology https://doi.org/10.1007/s00170-018-2984-8, 2019.

[11] Suhail, A.H., Ismail, N., Wong, S.V., Abdul Jalil, N.A.: *Surface roughness identification using the grey relational analysis with multiple performance characteristics in turning operations*, Arabian Journal for Science and Engineering, Vol. 37, No. 4, 1111-1117, doi: 10.1007/s13369-012-0229-y, 2012.

[12] Gopalsamy, B.M., Mondai, B., Ghosh, S.: *Optimisation of machining parameters for hard machining: grey relational theory approach and ANOVA*, The International Journal of Advanced Manufacturing Technology, Vol. 45, No. 11, 1068-1086, doi: 10.1007/s00170-009-2054-3, 2009.

[13] Ahilan, C., Kumanan, S., Sivakumaran, N.: *Application of grey based Taguchi method in multi-response optimization of turning process*, Advances in Production

Engineering & Management, Vol. 5, No. 3, 171-180, 2010.
[14] Senthilkumar, N., Sudha, J., Muthukumar, V.: *A grey-fuzzy approach for optimizing machining parameters and the approach angle in turning AISI 1045 steel*, Advances in Production Engineering & Management, Vol. 10, No. 4, 195-208, 2015.
[15] Partha Protim, D., Sunny, D., Shankar, C., Ranjan Kumar, G.: *Multi-Objective Optimization of Wire Electro Discharge Machining (WEDM) Process Parameters Using Grey-Fuzzy Approach*, Periodica Polytechnica Mechanical Engineering, 63(1), 16-25, 2019.
[16] Zadeh, L.A.: *Fuzzy sets*, Information and Control, 8(3), 338-353, 1965.
[17] Dewangan, S., Gangopadhyay, S., Biswas, C.K.: *Multi-response optimization of surface integrity characteristics of EDM process using grey-fuzzy logic based hybrid approach*, Engineering Science and Technology, an International Journal, 18(3), 361-368, 2015.
[18] Pattnaik, S., Karunakar, D.B., Jha, P.K., *Multi-characteristic optimization of wax patterns in the investment casting process using grey-fuzzy logic*, Int. J. Adv. Manuf. Tech., 67 (5-8), 1577-1587, 2013.
[19] Liu, N.M., Horng, J.T., Chiang, K.T.: *The method of grey fuzzy logic for optimizing multi-response problems during the manufacturing process: a case study of the light guide plate printing process*, Int. J. Adv. Manuf. Tech., 41, 200-210, 2009.
[20] Ahilan, C., Kumanan, S., Shivakamaran, N.: *Multi objective optimization of CNC turning process using grey based fuzzy logic*, Int. J. Mach. Mach. Mater., 5, 434-451, 2009.
[21] Krishnamoorthy, A., Rajendra Boopathy, S., Palanikumar, K., Paulo Davim, J.: *Application of grey fuzzy logic for the optimization of the drilling parameters for CFRP composites with multiple performance characteristics*, Measurement, 45, 1286-1296, 2012.
[22] Chiang, K.T., Chang, F.P.: Application of grey-fuzzy logic on the optimal process design of an injection-molded part with a thin shell features, Int. Commun. Heat. Mass. Transfer, 33, 94-101, 2006.
[23] Madić, M., Radovanović, M., Ćojbašić, Ž., Nedić, B., Gostimirović, M.: *Fuzzy Logic Approach for the Prediction of Dross Formation in CO_2 Laser Cutting of Mild Steel*, Journal of Engineering Science and Technology Review, 8(3), 143-150, 2015.
[24] Biswajit Das, Roy, S., Rai, R.N., Saha, S.C.: Application of grey fuzzy logic for the optimization of CNC milling parameters for Al-4.5%Cu-TiC MMCs with multi-performance characteristics, Engineering Science and Technology, an International Journal, doi: 10.1016/j.jestch.2015.12.002, 2015.

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OBEZBJEĐENJE REZERVNIH DIJELOVA

PROVIDING OF RESERVE PARTS

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REZIME

Rezervni dijelovi su dijelovi mašina, postrojenja i opreme (tehnički sistemi) koji trebaju biti na raspolaganju za zamjenu pri otkazu istih iz raznih razloga – lomovi, istrošenosti i deformisanosti. Njihovom zamjenom se posmatrani tehnički sistem stavlja u mogućnost funkcionalnog korištenja.
Da bi se omogućila mogućnost otklanjanja otkaza tehničkih sistema zamjenom dijelova isti se moraju obezbijediti, a zalihama upravljati, kao i čitavim procesom obezbjeđenja rezervnih dijelova.
U radu je prikazan proces obezbjeđenja rezervnih dijelova kroz nabavu, popravku i održavanje zaliha.

Professional paper

SUMMARY

Spare parts are parts of machines, plants and equipment (technical systems) that should be available for replacement when canceling them for various reasons - breaks, abrasion and deformation. By replacing them, the observed technical system places itself in the possibility of functional use.
In order to enable the possibility of eliminating failures of technical systems by replacing parts, they must be provided, managed by stock, as well as by the entire process of providing spare parts.
The paper presents the process of providing spare parts through the purchase, repair and maintenance of inventories.

1. UVOD

Dijelovi mašina, postrojenja i opreme (tehnički sistemi) se upotrebom troše, habaju, deformišu, lome i na druge načine onesposobljavaju za konstrukcijom određenu namjenu tehničkog sistema.
Vraćanje tehničkih sistema u stanje mogućnsti funkcionisanja često se vrši zamjenom onesposobljenog dijela (uz često još neke radnje održavanja). Da bi se to moglo moraju biti na raspolaganju rezervni dijelovi, koji se moraju imati na zalihi, a prethodno obezbijediti na jedan od mogućih načina.
U radu se prikazuju mogućnosti obezbjeđenja rezervnih dijelova u zavisnosti od stanja na tržištu, tehničkih mgućnosti funkcije održavanja i samog poslovnog sistema, karakteristika tehničkog sistema za koji se obezbjeđuje rezervni dio, tehničkih karakteristika samog rezervnog dijela i ekonomskih faktora.
Sam proces upravljanja rezervnim dijelovima i materijalima održavanja sadrži više međusobno povezanih aktivnosti, koje se po vremenskom redoslijedu mogu podijeliti na faze:

1. INTRODUCTION

By using parts of machines, plants and equipment (technical systems) become worn, deformed, broken or otherwise disabled for the construction of a specific purpose of the technical system.
The return of technical systems to the state of functionality is often done by replacing the disabled part (often with some other maintenance actions). In order for this to be possible, spare parts must be available, they must be in stock, and previously provided in one of the possible ways.
The paper presents the possibilities of providing spare parts depending on the market situation, the technical possibilities of the maintenance function and the business system itself, the characteristics of the technical system for which the spare part is provided, the technical characteristics of the spare part itself and the economic factors.
The process of managing the spare parts and maintenance materials itself contains several interconnected activities, which can be divided into stages in the timetable:

- planiranje,
- obezbjeđenje i
- upravljanje zalihama.

Ovaj tekst obrađuje fazu obezbjeđenja rezervnih dijelova.

2. OBEZBJEĐENJE REZERVNIH DIJELOVA

Ova faza upravljanja rezervnim dijelovima obuhvata sve aktivnosti potrebne da rezervni dio bude na raspolaganju u momentu i na mjestu intervencije funkcije održavanja na tehničkom sistemu u otkazu, koja se otklanja zamjenom dijelova.

Obezbjeđenje rezervnih dijelova se može vršiti na sljedeće načine:

- nabavom od odabranog isporučioca,
- popravkom oštećenog dijela i
- sopstvenom izradom rezervnih dijelova.

Koji od ovih načina će se koristiti za konkretan tehnički sistem, u konkretnom poslovnom sistemu i konkretnom vremenu zavisi od više uticajnih faktora od kojih se mogu identifikovati kao glavni:

- stepen hitnosti potrebe rezervnog dijela,
- složenost konstrukcije rezervnog dijela (oblik, dimenzije, materijal, kvalitet obrađenih površina, potreba za termičkom obradom),
- količine potrebnih rezervnih dijelova,
- vrsta rezervnog dijela po mogućnosti korištenja (standardni, namjenski),
- vrsta osnovne djelatnosti poslovnog sistema za čiji tehnički sistem treba rezervni dio (pogodno je da je to iz metalskog kompleksa),
- proizvodne mogućnosti funkcije održavanja poslovnog sistema (postojanje radionice za održavanje) i
- politike održavanja sredstava za rad u poslovnom sistemu.

U zavisnosti od konfiguracije ovih faktora u konkretnom poslovnom sistemu u datom vremenu, optimalan izbor za konkretan rezervni dio odnosno tehnički sistem će biti različit.

2.1. Nabava

Ovaj pristup podrazumijeva isporuku rezervnog dijela od kvalifikovanog dobavljača sa najpovoljnijim uslovima:

- kvalitet,
- rok isporuke,
- garancija i
- cijena.

- planning,
- providing
- inventory management.

This text deals with the phase of providing spare parts.

2. PROVISION OF SPARE PARTS

This spare part management phase includes all the activities necessary to ensure that the spare part is available at the moment and at the place of intervention of the maintenance function on the technical system in the cancellation, which is eliminated by replacing the parts.

The provision of spare parts can be carried out in the following ways:

- Purchasing from the selected supplier,
- repair of the damaged part and
- by own production of spare parts.

Which of these ways will be used for a specific technical system, in a particular business system and in concrete time depends on several influential factors where that as the main ones can be identified these:

- the degree of urgency of the needs of the spare part,
- the complexity of the construction of the spare part (shape, dimensions, material, quality of treated surfaces, the need for thermal treatment),
- the quantities of spare parts required,
- type of spare parts according to uses (standard, dedicated),
- the type of core business system business whose technical system needs a spare part (it is suitable that it is from a metal complex),
- production possibilities of the maintenance function of the business system (existence of the maintenance workshop) and
- maintenance policies for operating the business system.

Depending on the configuration of these factors in the specific business system at a given time, the optimal choice for a specific spare part or technical system will be different.

2.1. Providing

This approach involves the delivery of a spare part from a qualified supplier with the most favorable conditions:

- quality,
- delivery time,
- warranty,
- price.

Prva dva uslova imaju prioritet u izboru dobavljača.
Nabava može da se izvrši od različitih dobavljača:
- nabava pri kupovini tehničkog sistema,
- nabava od proizvođača tehničkog sistema,
- nabava od veleprodaje i
- nabava od maloprodaje.

Koji će se od ovih načina koristiti zavisi od već navedenih finasijskih mogućnosti poslovnog sistema.

2.1.1. Nabava pri kupovini tehničkog sistema

Ovo je najpovoljniji način obezbjeđenja iz više razloga:
- rezervni dijelovi su originalni i istog kvaliteta jer ih izrađuje proizvođač tehničkog sistema,
- cijene su niže i do 30% od cijena pri naknadnoj kupovini,
- isporuka je odmah, pri isporuci tehničkog sistema čiji je to rezervni dio i
- povećava pouzdanost funkcionisanja tehničkog sistema.

Mana ovog načina je što se tim staraju zalihe odnosno angažiraju sredstva i povećavaju troškovi zaliha koji čine značajnih 10-30% nabavne cijene rezervnog dijela godišnje (4, 7).
Poseban zadatak pri realizaciji ovog načina obezbjeđenja rezervnih dijelova je optimiziranje količine nabave u kontekstu upravljanja zalihama. To sigurno nije količina rezervnih dijelova potrebna u životnom vijeku tehničkog sistema.
Ovaj način pomaže u obezbjeđenju specijalnih rezervnih dijelova odnosno dijelova posebne namjene.

2.1.2. Obezbjeđenje rezervnih dijelova za tehničke sisteme u garantnom roku

U savremenim uslovima razvoja tržišta tehničkih sistema, posebno složenijih i skupljih obavezno se u okviru garantnih uslova ugovara obaveza proizvođača odnosno isporučioca za snabdijevanje rezervnim dijelovima za neki dogovoreni rok, naravno uz plaćanje naručioca.
Ovaj rok treba da odgovara ritmu pojave novih modela i tipova posmatranog tehničkog sistema.
Ovaj način posebno je prisutan kod specijalnih rezervnih dijelova, ali nije rijedak ni kod složenijih tipskih rezervnih dijelova koji su ustvari funkcionalni sklopovi (pumpe, ventilatori, kompresori).

The first two conditions have priority in the choice of the supplier.
Purchases can be made from different suppliers:
- purchase when purchasing a technical system,
- purchase from a manufacturer of a technical system,
- purchase from wholesale and
- purchase from retail.

Which of these methods will be used depends on the aforementioned financial possibilities of the business system

2.1.1. Purchase when purchasing a technical system

This is the most favorable way of securing for a number of reasons:
- spare parts are original and of the same quality as they are made by the manufacturer of the technical system,
- prices are lower up to 30% of the prices for subsequent purchase,
- delivery immediately, when delivering a technical system whose spare part is,
- increases the reliability of the functioning of the technical system.

The disadvantage of this purchase is that you are storing supplies or hiring funds and increasing inventory costs that make up a significant 10-30% of the purchase price of the spare part per year (4, 7).
A special task in implementing this method of providing spare parts is to optimize the quantity of supplies in the context of inventory management. This is certainly not the amount of spare parts required in the lifetime of the technical system.
This method helps in the provision of special spare parts or parts for special purposes.

2.1.2. Provision of spare parts for technical systems within the warranty period

In the modern conditions of development of the market of technical systems, especially more complex and expensive, it is obligatory, within the warranty terms, to oblige the manufacturer or supplier to supply spare parts for an agreed period, of course with the payment of the contracting authority.
This deadline should correspond to the rhythm of the emergence of new models and types of the observed technical system.
This method is especially present in special spare parts, but it is not unusual for more complex spare parts, which are actually functional circuits (pumps, fans, compressors).

2.1.3. Nabava rezervnih dijelova od proizvođača tehničkog sistema tokom njegovog životnog vijeka, van garantnog roka

Ovaj način obezbjeđenja rezervnih dijelova ima više dobrih karakteristika:

- proizvođač tehničkog sistema ima iskustva u njihovoj izradi pa će i njihov kvalitet biti zadovoljavajući,
- postoji velika vjerovatnoća da će proizvođač posmatranog tehničkog sistema moći formirati ekonomičniju veličinu serije za više svojih kupaca, te time smanjiti prodajnu cijenu,
- ne mora postojati tehnička dokumentacija za naručeni rezervni dio.

Ovaj način obezbjeđenja rezervnih dijelova je pogodan za specijalne rezervne dijelove, složenije i skuplje.

2.2. Nabava rezervnih dijelova od veleprodaje

Odnosi se uglavnom na standardne i tipske rezervne dijelove. Uslov je da je narudžba za više dijelova.

Postoji mogućnost ugovaranja višegodišnjih isporuka, što najčešće omogućava nižu nabavnu cijenu.

Ovaj način nabave rezervnih dijelova primjenjuju veliki poslovni sistemi koji imaju brojna sredstva za rad.

Veleprodaje u ovom slučaju okrupnjavaju potrebe pojedinačnih kupaca i imaju ulogu njihovih skladišta rezervnih dijelova uz sve mogućnosti optimizacije zaliha rezervnih dijelova. Vrijeme isporuke je najčešće kraće nego nabava od izvornih proizvođača rezervnih dijelova, a ponuda se obično širi i na materijale za održavanje sredstava za rad odnosno tehničkih sistema.

2.3. Nabava rezervnih dijelova od maloprodaje

Ovaj način nabave se najčešće primjenjuje na standardne rezervne dijelove i materijale za održavanje niže složenosti i cijene (kotrljajni ležajevi, filteri, lampe,...).

Osnovna karakteristika ovog načina obezbjeđenja rezervnih dijelova su:

- isporuka odmah,
- najviše cijene i
- plaćanje odmah.

2.1.3. Purchase spare parts from the manufacturer of the technical system during its lifetime, beyond the warranty period

This way of providing spare parts has several good features:

- the manufacturer of the technical system has experience in their production, so their quality will be satisfactory,
- there is a high possibility that the manufacturer of the observed technical system will be able to form a more economical size of the series for more of its customers, thereby reduce the selling price,
- there must be no technical documentation for the ordered spare part.

This way of providing spare parts is suitable for special spare parts, more complex and expensive.

2.2. Purchase spare parts from wholesale

It relates mainly to standard and type spare parts. The requirement is that the order is for more parts.

There is the possibility of contracting multi-year deliveries, which usually allows a lower purchase price.

This way of purchasing spare parts is applied by large business systems that have a lot of working resources.

Wholesale in this case encompasses the needs of individual buyers and play the role of their spare parts warehouse with all the possibilities of optimizing the stock of spare parts. Delivery times are usually shorter than purchases from original spare parts manufacturers, and the offer is usually extended to maintenance materials for work or technical systems.

2.3. Purchase spare parts from retail

This procurement method is most commonly applied to standard spare parts and materials to maintain lower complexity and price (roller bearings, filters, lamps, ...).

The basic characteristic of this mode of securing spare parts is:

- shipment immediately,
- the most cost i
- payment immediately.

2.4. Popravak rezervnih dijelova

Ovaj način rješavanja problema rezervnih dijelova se primjenjuje u situacijama kada su oštećenja takve vrste i obima da je moguće vraćanje u ispravno stanje odabranim tehnološkim postupkom (zavarivanje, navarivanje, ponovno spajanje odlomljenih ili nanovo izrađenih dijelova, površinske obrade, termičke obrade i drugi odgovarajući postupaci) i uz cjenovno (trošak) prihvatljiv postupak, te rješavanje hitnosti potrebe rezervnih dijelova, koju drugi postupci ne mogu zadovoljiti.

Primjenjuje se kod specijalnih rezervnih dijelova, velike složenosti i nabavne cijene.

Može da se realizira na jedan od načina:

- posebnom narudžbom od kvalifikovanog vanjskog dobavljača (rok isporuke, kvalitet izrade, garancija i cijena) i
- popravak u poslovnom sistemu vlasnika tehničkog sistema za koji treba posmatrani rezervni dio.

Za pravi način obezbjeđenja potrebno je imati tehničku dokumentaciju rezervnog dijela, definisane zahtjeve kvaliteta, rok ispravke i način prijema (kontrola).

Primjenjuje se kod poslovnih sistema čija je osnovna djelatnost takva da ne raspolaže tehnološkim mogućnostima da izvrši takvu popravku rezervnog dijela odnosno njegova funkcija održavanja to ne može (nema takvu radionicu za održavanje).

Sopstvena popravka rezervnog sistema vrši se u poslovnim sistemima koji raspolažu posebnim kapacitetima za popravak (mašine, ljudi, slobodni kapaciteti) i dokumentacijom rezervnog dijela (često se radi naknadno u momentu pojave kvara odnosno otkaza tehničkog sistema).

Dobra strana ovog načina obezbjeđenja rezervnih dijelova je zadovoljavanje zahtjeva hitnosti potreba. Pri tome su troškovi (cijena koštanja) rezervnog dijela najčešće upitni.

2.5. Sopstvena izrada rezervnih dijelova

Ovaj način obezbjeđenja rezervnih dijelova vrši se u velikim poslovnim sistemima koji zadovoljavaju više od jednog od sljedećih uslova:

- da imaju veći broj istih ili sličnih tehničkih sistema za koje treba izraditi rezervni dio,
- da imaju tehničku dokumentaciju održavanih tehničkih sistema ili da je mogu napraviti u relativno prihvatljivim rokovima (defektaža vrste i mjesta otkaza pri otklanjanju istog),

2.4. Repair of spare parts

This way of solving the problem of spare parts is applied in situations where damage of this type and volume is possible to return to the correct state by the selected technological process (welding, welding on, re-joining broken or reworked parts, surface treatment, thermal treatment and other appropriate procedures) and with the cost acceptable procedure. This also solves the urgency of the need for spare parts, which other procedures cannot meet.

It is applied with special spare parts, great complexity parts and purchase price.

It can be realized in one of the following ways:

- a special order from a qualified external supplier (delivery deadline, quality of production, guarantees and prices) and
- repair in the business system of the owner of the technical system.

For the right providing, it is necessary to have the technical documentation of the spare part, the defined quality requirements, the deadline for the correction and the method of receipt (control).

It is applied to business systems whose basic activity is such that it does not have the technological capabilities to perform such repair of the spare part, or its maintenance function cannot do it (it does not have such a maintenance workshop).

The own repair of the spare system is done in business systems that have special repair facilities (machines, people, free capacities) and documentation of the spare part (it is often done later at the moment of failure or technical failure).

The good side of this way of securing spare parts is meeting the urgency requirement. In doing so, the cost of the spare part is most often questioned.

2.5. Own production of spare parts

This way of securing spare parts is done in large business systems that meet more than one of the following conditions:

- have a number of the same or similar technical systems for which a spare part should be made,
- have technical documentation of the maintained technical systems or that they can be made in relatively acceptable deadlines (defect type and place of cancellation when removing it),

- da imaju tehnološke mogućnosti izrade rezervnih dijelova (mašine, ljudi) sa raspoloživim kapacitetima u skladu sa stepenom hitnosti obezbjeđenja rezervnog dijela (moment otklanjanja otkaza) odnosno da imaju radionice za održavanje i
- da je sopstvena izrada ekonomski približno prihvatljiva (cijena koštanja) u odnosu na druge načine obezbjeđenja rezervnih dijelova.

- have the technological capability of making spare parts (machines, people) with available capacities in accordance with the degree of urgency of providing the spare part (the moment of fault removal), that they have workshops for maintenance and
- that its own production is economically acceptable (cost price) in relation to other ways of providing spare parts.

5. ZAKLJUČAK

Obezbjeđenje rezervnih dijelova i materijala za održavanje je značajan skup aktivnosti u okviru upravljanja istim u nastojanju obezbjeđenja raspoloživosti sredstava za rad posebno tehničkih sistema, za osnovnu djelatnost poslovnih sistema, naročito proizvodnih.

Realizira se u komunikaciji funkcija održavanja, finansijske i komercijalne funkcije poslovnih sistema.

U redovnim poslovnim sistemima najčešće se primjenjuje kombinacija prikazanih metoda obezbjeđenja rezervnih dijelova i materijala za održavanja, u zavisnosti od konkretnih uslova poslovnog sistema i stanja na tržištu.

Za efikasnu realizaciju nabave u poslovnom sistemu treba:

- definisati podjelu aktivnosti između funkcija održavanja, finasija i komercijale,
- napraviti proceduru za svaki način obezbjeđenja,
- definisati potrebnu dokumentaciju za svaki način obezbjeđenja rezervnih dijelova i materijala za održavanja: tehničku, finasijsku i komercijalnu, te
- iskoristiti sve mogućnosti za smanjenje troškova rezervnih dijelova odnosno održavanja istih.

6. CONCLUSION

The provision of spare parts and maintenance materials is a significant set of activities within the management of the same in an effort to provide the availability of funds for the operation of special technical systems, for the basic activity of business systems, especially production.

It is realized in communication of functions of maintenance, financial and commercial functions of business systems.

In regular business systems, a combination of the presented methods of providing spare parts and maintenance materials is usually applied, depending on the specific conditions of the business system and the market situation.

For efficient realization of procurement in the business system it is necessary:

- to define the division of activities between the functions of maintenance, finances and commercials,
- to make a procedure for each mode of providing spare parts,
- to define the necessary documentation for each method of providing spare parts and maintenance materials: technical, financial and commercial, and
- -to use all options for reducing the cost of spare parts and maintaining them.

7. REFERENCES

[1] XXXX: Nastavni program predmeta Upravljanje rezervnim dijelovima i materijalima za održavanje, Mašinski fakultet, Zenica

[2] Grupa autora: *Rezervni dijelovi (planiranje, upravljanje i supstitucija,* Zbornik radova XIV majski skup jugoslovenskih održavalaca sredstava za rad, knjiga II, Osijek, 1983.

[3] Grupa autora (u redakciji Brdarević S.): *Upravljanje rezervnim dijelovima,* Zbornik predavanja na seminaru Upravljanje rezervnim dijelovima, Mašinski fakultet, Zenica, 1984.

[4] Brdarević S.: *Održavanje sredstava za rad,* Mašinski fakultet, Zenica, 1987.

[5] Brdarević S., Halep A.: *Održavanje*, Mašinski fakultet, Zenica, 2013.

[6] Grupa autora (u redakciji Brdarević S.): *Planiranje održavanja,* Mašinski fakultet, Zenica, 1987.

[7] Adamović Ž.: *Planiranje i upravljanje rezervnim dijelovima – upravljanje zalihama*, OMO, Beograd, 1988.

[8] Milovanović N., Stanivuković D.: *Organizacija sredstava za rad – poglavlje*

Obezbjeđenje rezervnih dijelova. Univerzitet u Novom Sadu 1990.
[9] Blomberg J.D., Le May S., Hana J.B.: *Logistika.* , MATE, Zagreb, 2006
[10] Milovanović-Golubović V.: *Logistika.* , Megatrend Univerzitet Beograd, 2005
[11] Bulatović M.: *Logistika.* , Inžinjerska komora, Podgorica, 2013

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EFFECT OF THE TURBINE CLOSING TIME ON THE WATER FLOW IN THE SUPPLY SYSTEM OF A DIVERSION HYDROPOWER PLANT WITH A SURGE TANK

EFEKT VREMENA ZATVARANJA TURBINA NA TOK VODE U DOVODNOM SISTEMU DIVERZIONE HIDROELEKTRANE S VODOSTANOM

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Preliminary Notes

SUMMARY
In this paper, a model based on numerical solution of two ordinary differential equations is used to obtain the water level in the surge tank and the static pressure in the headrace tunnel – the properties of essential importance for the functioning of the water supply system during the turbine shut-off. The model allows a fast and reliable simulation of the hydraulic processes in the headrace tunnel and the surge tank. It was validated by comparing the numerical results with the data available from the experiments conducted under real conditions in a surge tank of the HPP Jablanica. This model is used to analyze of influence of different parameters on variations of water level oscillation in the surge tank and the static pressure in the headrace tunnel.

Preliminarni rad

SUMMARY
U ovom radu je korišten model baziran na numeričkom rješavanju sistema dvije diferencijalne jednačine da bi se dobio nivo vode u vodostanu i pritisak u dovodnom tunelu – osobine od krucijalne važnosti za funkcionisanje dovodnog sistema vode za vrijeme ispada agregata. Metod omogućava brzu i pouzdanu simulaciju hidrauličkih procesa u dovodnom tunelu i vodostanu. Validacija je izvršena upoređujući rezultate numeričkog proračuna sa dostupnim rezultatima eksperimenta izvedenim u realnim uslovima na HE Jablanica. Model je korišten za analizu uticaja različitih parametara an varijacije oscilacija nivoa vode u vodostanu i pritiska u dovodnom tunelu.

1. INTRODUCTION

Surge tanks are auxiliary water storage units constructed in hydropower plants between the main reservoir and the power house [1, 2]. Surge tanks play a very important role in diversion hydropower plants. They protect water supply components from negative impact of water hammer, neutralizing strong pressure rises and drops appearing in penstock during the turbine start or closure. Appropriate shapes and dimensions of surge tanks are decisive for their proper operation, so that a reasonable attention is paid to these during design of a new power plant or in refurbishment of existing power plants.

Beside the surge tank operation, the turbine opening or closing time may also influence the flow development in the water supply system, where the headrace tunnel and the penstock are of primary interest. The opening/closure time cannot be varied arbitrarily, since it is related to the operation of a number of other mechanical and electrical components in the power plant, and it is an integrated element of the plant automation, so that it has to be carefully chosen in order to provide proper functioning of the power plant.

In this paper, a model based on numerical solution of two ordinary differential equations [3] is used to obtain the water level in the surge tank and the static pressure in the headrace tunnel – the properties of essential importance for the functioning of the water supply system during the turbine shut-off. The method allows a fast and reliable simulation of the hydraulic processes in the headrace tunnel and the surge tank. It was validated by comparing the

numerical results with the data available from the experiments conducted under real conditions in a surge tank of the hydropower plant Jablanica, Bosnia-Herzegovina. Consequently, here it is used to analyze the effect of turbine closure time onto the pressure development in the headrace tunnel in the case of a generic cylindrical surge tank.

2. METHOD

A typical diversion hydropower plant system with the reservoir, the intake tunnel, the surge tank with orifice, and the penstock is shown in Figure 1. The momentum equation for the water flow in the headrace tunnel of this system can be written in the form [4,7]:

$$\frac{L}{g}\frac{dQ_\mathrm{t}}{dt} = A_\mathrm{t}(-z - h_\mathrm{f} - h_\mathrm{j}) \tag{1}$$

where L is the length of the headrace tunnel, g is the gravitational acceleration, Q_t is the water flow rate in the tunnel, t is the time, A_t is the cross-sectional area of the tunnel, z is the vertical position of the water free surface in the surge tank measured from the free surface level in the reservoir, h_f is the head loss caused by friction in the tunnel, and h_j is the minor head loss in the junction of the tunnel and the surge tank.

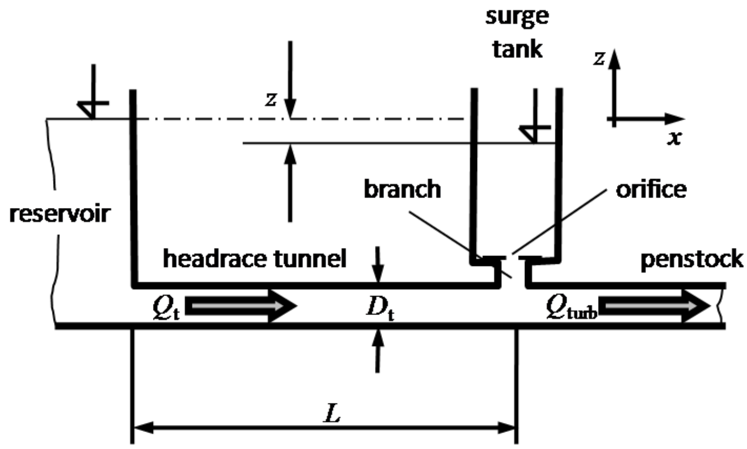

Figure 1. *A typical water supply system with a surge tank in a diversion hydropower plant.*

The friction loss in the tunnel is calculated using Darcy-Weisbach equation:

$$h_\mathrm{f} = \lambda \frac{L}{D_\mathrm{t}}\frac{v_\mathrm{t}^2}{2g} \tag{2}$$

where λ is the friction coefficient, v_t is the flow velocity in the tunnel (proportional to the flow rate Q_t), and D_t is the tunnel diameter.

The minor head loss in the junction is given by the formula:

$$h_\mathrm{j} = \xi_\mathrm{j}\frac{v_\mathrm{t}^2}{2g} \tag{3}$$

where ξ_j is the minor loss coefficient in the junction (like a T-branch).

The continuity equation for the surge tank reads:

$$\frac{dz}{dt} = \frac{1}{A_\mathrm{v}}(Q_\mathrm{t} - Q_\mathrm{turb}) \tag{4}$$

where A_v is the area of the water free surface in the surge tank, and Q_turb is the water flow rate through the penstock toward the turbines. All quantities on the right-hand side of eq. (4) are regarded as functions of time t. Obviously, eq. (4) is coupled with eq. (1) through the quantities Q_t and z.

In the algorithm employed here, which is described in the previous publication [3], the geometric data (L, A_t, A_v) are assumed to be known, as well as the flow rate toward the turbines Q_turb. The considered time interval is divided into a number of finite time steps. The mutually coupled eqs. (1) and (4) are solved at each time step, starting from the initial one and proceeding the calculation to the next step until the complete time interval is processed. In doing so, the time derivatives are replaced by finite differences (implicit Euler method). First, eq. (1) is solved for Q_t, then eq. (4) is solved for z, delivering a temporary value of the water level in the surge tank. In order to resolve the inter-equation coupling, the process is repeated

several times within each time step until the convergence is reached. If the surge tank has a variable cross section (such as in the case of tanks with side chambers), the free surface area A_v depends on its current displacement z and has to be recalculated based on the known tank geometry and assuming that the water free surface is flat and horizontal during the entire process.

The described method depends considerably on reliable assessment of the friction and the minor loss. While the former is relatively easy to estimate (e.g. using Colebrook equation), the latter depends on topology and geometric features, as well as on flow conditions of the specific case, and can be found in various engineering tables and diagrams or using empirical formulae, such as those given in [5]. An approximate value of the minor loss coefficient ξ_j of 20, defined with respect to the area-averaged water velocity in the tunnel v_t as indicated by eq. (3), is adopted in this work based on the computational fluid dynamics (CFD) simulations done in [3] for both flow directions (flow from the tunnel to the surge tank, and reverse flow from the tank to the tunnel).

3. RESULTS AND DISCUSSION

3.1 Validation case

The results described here show the calculations done for the test case under real conditions in HPP Jablanica [8]. The diameter of the headrace tunnel is 6,3 m, its length is 1950 m, and the diameter of the surge shaft is 13 m. The tank contains an 80 m long side chamber at the position between 51.5 m and 59 m above the tunnel axis. The initial conditions are: water flow rate through the headrace tunnel of 72 m^3/s and the water level in the surge tank is 44,41 m. In the simulation, 10 s after the initial instant of time, the flow rate through the penstock is linearly decreased to zero over the closure period of 8 s.

Fig. 2 shows the history of the free surface level in the tank, compared to the experimental values [6, 3]. The agreement of the results is acceptable. For the operation of the plant, the maximum level during the first water rise is the most important. Obviously, the simulation predicted this value reasonably well, although the test in real conditions shows a certain damping in the subsequent cycles (especially, during the water sinking), which is not captured by the simulation. The reason for this discrepancy might be in the adopted value of the minor loss coefficient.

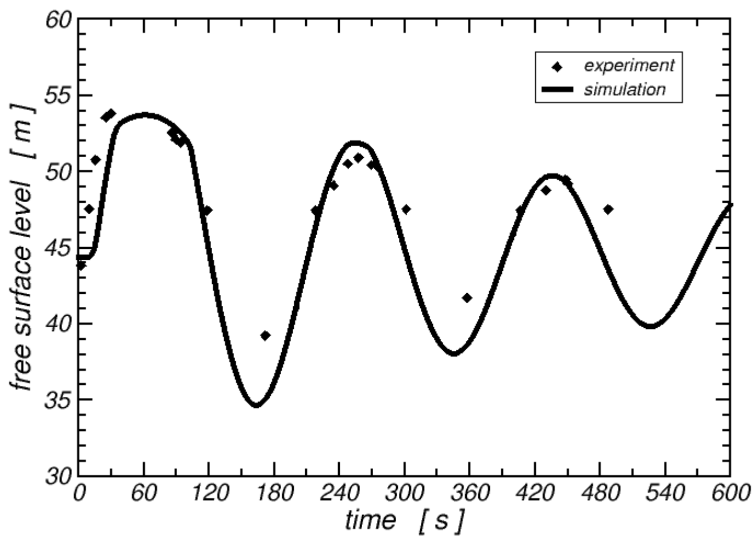

***Figure 2**. Water level oscillation in the surge tank of HPP Jablanica for initial conditions $Q_0 = 72$ m³/s, $H_0 = 44,41$ m above the tunnel axis.*

3.2 Generic case

A cylindrical surge tank whose diameter is 10 m is installed at the end of the headrace tunnel which is 2000 m long and whose diameter is 5 m. Three different types of turbine wicket-gate closure are considered: *linear*, *smooth* (described by a cosine function) and *sudden* closure. The linear and smooth closure are completed within 5 s. The calculated static pressure variation at the junction of the surge tank and the headrace tunnel, obtained for three different initial water levels, 50 m, 40 m, and 30 m above the tunnel axis, are shown in Fig. 3. The initial water flow rate is adopted to be 50 m^3/s. While the maximum pressure depends on the initial water level (higher initial water level, higher static pressure), the pressure rise during the closure is more-or-less the same in all three cases and amounts to about 0.8 bar. Obviously, the difference between the linear and smooth closure is negligible, while the sudden closure implies slightly higher maximum pressure values with slightly faster variation in time.

In Fig. 4, the variation of the static pressure for different closure times at three different initial water levels is shown. The maximum pressure reduces with increase of the closure time, as expected, and the differences in the maximum pressure are found to be about 0.1 bar or less than that for the closure times between 5 s and 10 s.

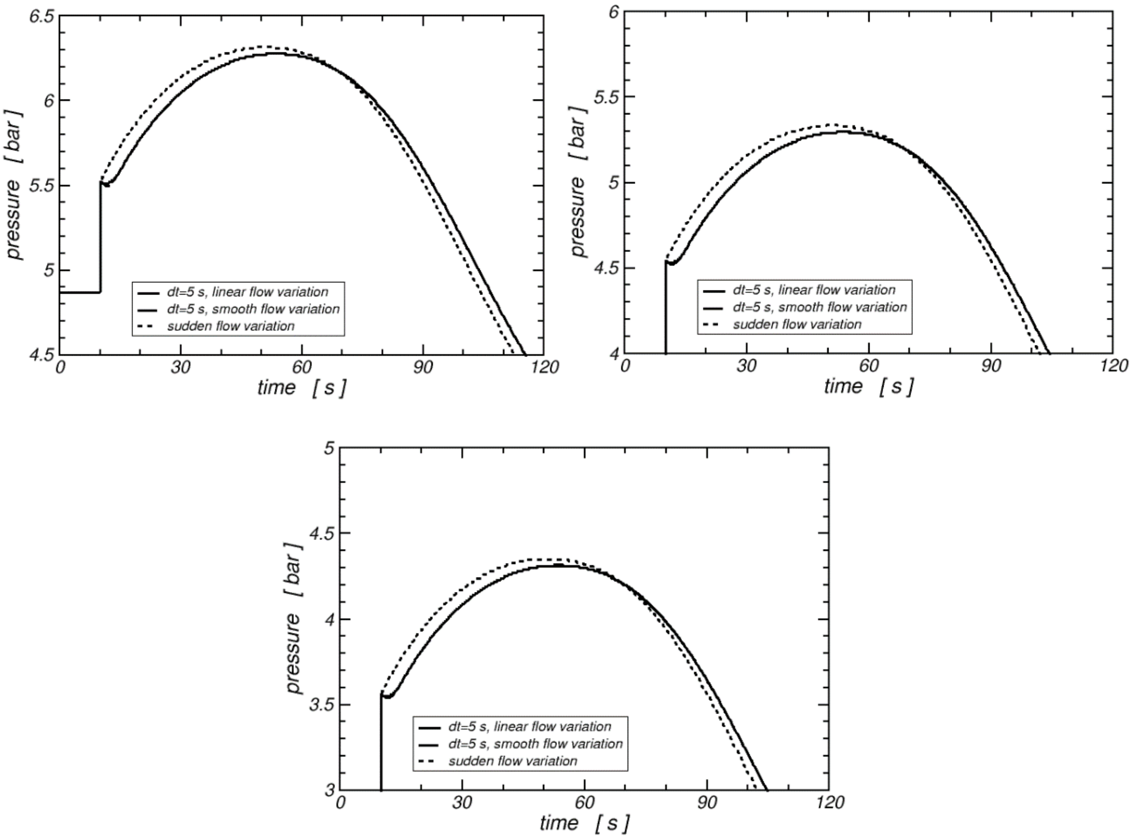

Figure 3. *Static pressure variation in the junction for three different initial water levels in the tank: 50 m (top left), 40 m (top right), 30 m (bottom)*

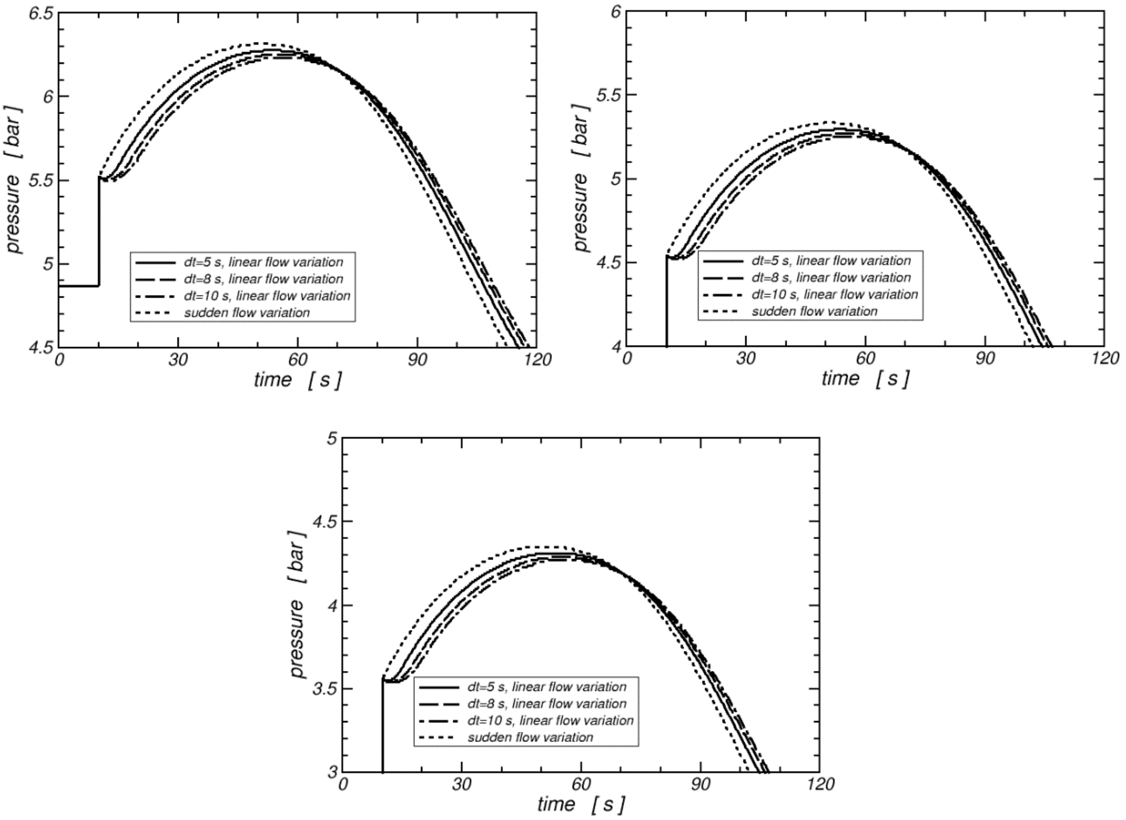

***Figure 4**. Static pressure variation in the junction for different closure times ate three different initial water levels in the tank: 50 m (top left), 40 m (top right), 30 m (bottom)*

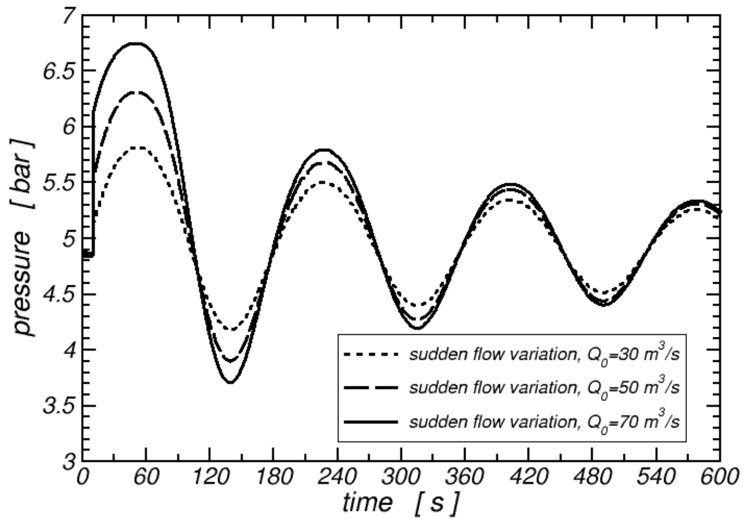

***Figure 5**. Static pressure variation in the junction during sudden closure for three different initial flow rates, at the initial water level of 50 m above the tunnel axis.*

Fig. 5 shows the static pressure variation in the junction for three different initial water flow rates through the headrace tunnel. As expected, the pressure rise is larger for larger initial flow rates. As the results shown reveal, the maximum pressure during the first rise seems to be proportional to the initial water flow rate, while in the subsequent cycles it is not; a certain damping of the maximum pressure is detected, apparently being ever stronger in the further cycles, so that the effect of the initial flow rate diminishes. Interestingly, the period of oscillations remains the same for all initial

flow rates and throughout the entire simulated time.

4. CONCLUSION

A model based on numerical solution of two ordinary differential equations is used to obtain the water level in the surge tank and the static pressure in the headrace tunnel – the properties of essential importance for the functioning of the water supply system during the turbine shut-off. It was validated by comparing the numerical results with the data available from the experiments conducted under real conditions in a surge tank of the HPP Jablanica. The method allows a fast and reliable simulation of the hydraulic processes in the headrace tunnel and the surge tank

This model is used to analyze of influence of different parameters on variations of water level oscillation in the surge tank and the static pressure in the headrace tunnel. Influence of different types of turbine wicket-gate closure, different initial water levels above the tunnel axis, and different initial water flow rate are considered. Results of analysis obtained by model presented in this paper could be used during projecting a new hydro power plant as well as for optimal exploitation regimes of existing hydro power plants.

5. REFERENCES

[1] Wylie, E. B. and Streeter, V. L. *Fluid Transients*, McGraw-Hill, New York, USA., 1978

[2] J. Pickford, *Analysis of surge,* Macmillan and Co, Ltd., London, UK,1969

[3] M. Torlak, B. Šeta, A. Bubalo, Comparative use of FVM and integral approach for computation of water flow in a coiled pipe and a surge tank*,* in *Sustainable Hydraulics in the Era of Global Change*, Eds. S. Erpicum, B. Dewals, P. Archambeau, M. Pirotton, Proceedings of the 4thIAHR Europe Congress, Liege, Belgium,2016

[4] M.H. Chaudhry, *Applied hydraulic transients*, 3rd ed., Springer, 2015.

[5] I.E. Idelchik, *Handbook of hydraulic resistance,* Atomic energy commission and National Science foundation, Washington DC, USA, 1966.

[6] M. Torlak, A. Bubalo, E. Džaferović, Numerical Analysis of Water Elevation in a Hydropower Plant Surge Tank, in *Proceedingsof 6th IAHR meeting of the Working Group "Cavitation and Dynamic Problems in Hydraulic Machinery andSystems*", Ljubljana, Slovenia, September 9-11, pp. 339 – 346, 2015.

[7] Y.A. Cengel, J.M. Cimbala, *Fluid Mechanics, Fudamentals and Application*, McGraw-Hill, New York , USA, 2006

[8] Y. Vaillant, *Jablanica, Additional Hydraulic Study in View of Optimizing the Operation of the Plant*, ANDRITZ HYDRO, internal report, 2013.

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PRIMJENA KOMPRIMIRANOG ZRAKA U JAMAMA "HALJINIĆI", JP EP BIH D.D. - SARAJEVO, ZD RMU "KAKANJ" D.O.O. KAKANJ

APPLICATION OF COMPRESSED AIR IN PIT "HALJINIĆI", JP EP BIH D.D. - SARAJEVO, ZD RMU "KAKANJ" D.O.O. KAKANJ

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REZIME
Analizirajući osnovnu problematiku jama pogona „Haljinići“, pogonska energija predstavlja jednu od osnovnih faza rada bitnih za funkcionisanje pogona, te se praćenje i rješavanje problematike vezane za ovaj segment rada, nameće kao ključni u cilju realizacije svih planiranih veličina. Proizvodne aktivnosti, način eksploatacije, vrsta opreme koja se koristi pri tome i niz drugih faktora u značajnoj mjeri zahtijevaju visoku pouzdanost sistema pogonske energije. Da bi se postigli navedeni ciljevi, pored pouzdanosti mašina, osnovni uslov predstavlja pogonska energija (električna energija i komprimirani zrak).

Categorization of paper

SUMMARY
During analysis of main problems in the pit "Haljinići", the drive energy represents one of the most important phases of the operation for functioning of the section, so imying and solving problems related to this segment, and automatically set itself as the key factor in realitation of all planned goals. Production activities, exploitation types, differebt types of equipment and much more other factors that are using require a high responsibilùity of the power generation system. In order to achieve these goals, in addition to the reliability of machines, basic requirement is the drive energy (electricity and compressed air).

1. UVOD

Dugogodišnja tradicija eksploatacije uglja jamama Rudnika "Kakanj" nikad nije dozvoljavala da tehnološki proces bude ispod nivoa trenutka u kojem sredstva rada zadovoljavaju najveći stepen sigurnosti i humanizacije rada. Razlika između postojeće i nove tehnologije za transport i dopremu jeste u pogonskoj energiji, komprimirani zrak, koja u pogonu "Haljinići" ima razvijenu infrastrukturnu mrežu. Samo priključivanje na postojeću primarnu-magistralnu mrežu preko zračnih vodova (sekundarni vodovi) postrojenje "ranžirnog voza" postavljeno na gornju šinu dovodi u eksploatacijsku spremnost. Glavni razvod komprimiranog zraka sačinjavaju okiten cijevi odgovarajućeg prečnika (PE 100, 110x10,0 S 5/SDR 11 PN 16, [1]) nazivnog pritiska 16 bara, povezane odgovarajućom prirubničkom vezom, čime je omogućeno prilagođavanje dužine cjevovoda konkretnim potrebama u jami.

1. INTRODUCTION

A long tradition of coal exploitation in Mine „Kakanj“ never allowed that technical process should be below the level in which means of work satisfies the biggest stage of security and humanization of labour.
The difference between existing and new technology for transport and delivery is in drive energy, compressed air, which section "Haljinići" possess developed infrastructure network. The sole connection on existing primary-main network via air ducts (secondary ducts) plant „marshalling train“ positioned on upper rail leads to exploitation readiness.
Main divorce of compressed air is consisted from rounded pipes with corresponding diameter (PE 100, 110x10,0 S 5/SDR 11 PN 16, [1]) of nominal pressure 16 bars, connected with corresponding flanged connections, where adjustment of pipeline length is allowed according to concrete needs in mines.

Energiju komprimiranog zraka za potrebe pogona "Haljinići" se dobiva preko instaliranih postrojenja za komprimirani zrak koji svojim karakteristikama zadovoljavaju postojeće potrebe kao i za nova postrojenja.

The compressed air energy for the needs of section „Haljinići“is receiving through mounted installations for compressed air which together with its characteristics are satisfying existing needs and new plants.

2. TEHNIČKE KARAKTERISTIKE KOMPRESORSKIH POSTROJENJA I PRATEĆIH SKLOPOVA POGONA

a. Lokalitet pogon "Haljinići"
Kompresorsko postrojenje

2. TECHNICAL CHARACTERISTICS OF COMPRESSED PLANTS AND FOLLOWING CIRCUITS

a. Location pit "Haljinići"
Compressed plant

Tabela 1. *Tehničke karakteristike kompresorskog postrojenja [4]*
Table 1. *Technical characteristics compressed plant [4]*

Tip Type	EKO 45s-10	EKO 45s-10
Proizvođač-Manufacturer	"EKO MAK" TURSKA "EKO MAK" TURKEY	"EKO MAK" TURSKA "EKO MAK" TURKEY
Serijski broj-Serial number	45992/2012	45993/2012
Kapacitet-Capacity	7,8 [m^3/min]	7,8 [m^3/min]
Radni pritisak: Working pressure:		
Maksimalno	10 [bar]	10 [bar]
Maximum	10 [bar]	10 [bar]
Minimalno	5 [bar]	5 [bar]
Minimal	5 [bar]	5 [bar]

Tabela 2. *Tehničke karakteristike sušača zraka [4]*
Table 2. *Technical characteristics air dryer [4]*

Tip-Type	ERD-450
Proizvođač Manufacturer	"EKO MAK" TURSKA "EKO MAK" TURKEY
Kapacitet Capacity	7,5 [m^3/min]
Nominalni ulazni pritisak zraka Nominal input air pressure	7 [bar]

Tabela 3. *Tehničke karakteristike filtera za prečišćavanje zraka [4]*
Table 3. *Technical characteristics filter for air purification [4]*

Tip Type	Grade H 150
Proizvođač Manufacturer	"EKO MAK" TURSKA "EKO MAK" TURKEY
Filtracija čestica Particle filtration	do 0,01 [mikron]
Filtracija ostataka ulja Filtration of residual oil	do 0,01 [mg/m^3]
Masa Mass	5,6 [kg]

b. Lokalitet jama "Begići-Bištrani"

b. Location pit "Begići-Bištrani"

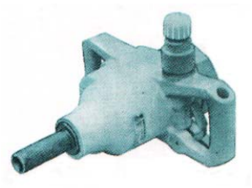
***Tabela 4.** Tehničke karakteristike kompresorskog postrojenja [4]*
***Table 4.** Technical characteristics compressed plant [4]*

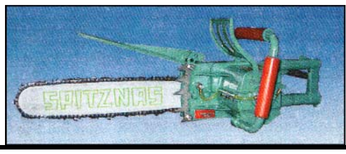
Tip-Type	EKO 45s-10	EKO 45s-10
Proizvođač-Manufacturer	"EKO MAK" TURSKA "EKO MAK" TURKEY	"EKO MAK" TURSKA "EKO MAK" TURKEY
Serijski broj-Serial number	45990/2012	45991/2012
Kapacitet-Capacity	7,8 [m^3/min]	7,8 [m^3/min]
Radni pritisak-Working pressure:		
Max.	10 [bar]	10 [bar]
Min.	5 [bar]	5 [bar]

U jamama pogona "Haljinići" trenutno se koriste pneumatske jamske bušilice, rotaciono udarni uvrtači i pneumatske lančane pile za drvo.
Pogon ima mogućnost korištenja pneumatskog čekića, čekića za bušenje, pneumatske centrifugalne (muljne) pumpe, mašina za izolaciju jamskih prostorija (torketiranje) i drugih pneumatskih alata i pomagala koji posjeduju certifikat za rad u jamama ugroženim metanom i opasnom ugljenom prašinom.

In pits "Haljinići" currently in sage are pneumatic cavity drills, rotary impact screwdrivers and pneumatic chainsaws for wood.
It can be used also pneumatic hammers, hammers for drilling, pneumatic centrifugal (sludge) pumps, machine for isolation of cave rooms (torketing) and other pneumatic equipment and tools that possess certificates for working in mines endangered with methane and dangerous coal dust.

***Tabela 5.** Prikaz alata koji se do sada koriste u određenim fazama rada kako za potrebe pripremanja i eksploatacije tako i za potrebe održavanja i montaže opreme [4]*
***Table 5.** Is shown equipment and tool that are till this moment used in certain work stages, for the needs of preparation and exploitation, so as for the needs of maintenance and mounting of equipment [4]*

RB	Naziv	Tip	Potrošnja zraka (m^3/min)	Priključak (")	Broj okretaja (o/min)	Masa (kg)
1.	Mašina za izolaciju torketiranje Machine for isolation torketing 	Viktor 100 L	0,28	R 1/2"	-	505
2.	Pneumatska bušilica Pneumatic drill 	8/BŠU-A	2,5	R 3/4"	1300	11,75

3.	Rotaciono-udarni uvrtač Rotary-impact screwdriver 	Z4D/UU-32	1,6	R 1/2"	3500	10
4.	Rotaciono-udarni uvrtač Rotary-impact screwdriver 	Unior art.1572	0,269	R 3/8"	5500	5,6
5.	Pneumatska centrifugalna pumpa Pneumatic centrifugal pump 	CP-600-25A	2,6	-	-	19
6.	Pneumatska lančana pila za drvo Pneumatic chainsaw for wood 	"Spitznas"	2,9	R 3/4"	4200	17,3
7.	Pneumatski bušaći čekić Pneumatic drilling hammer 	VK23	2,5	R 1"	2100	23

3. PROVJERA PARAMETARA MREŽE KOMPRIMIRANOG ZRAKA

Da bi se provjerilo zadovoljenje mreže komprimiranog zraka odabrana je dionica od rezervoara do kote K+293,39 m na kraju glavnog transportnog niskopa jame "Seoce" kao najnepovoljnija za proračun pada pritiska u razvodnoj mreži.

3. NETWORK COMPRESSED AIR PARAMETER CHECK CONTROL

In order to check satisfaction of compressed air networks, it was chosen route from reservoir K+293,39 at the end of main transport excavation of the cave „Seoce“ as the most unfavourable for pressure fall estimating in distribution network at this moment.

3.1. Gustoća atmosferskog zraka

3.1. Atmospheric air density

$$\rho_o = \frac{P_o}{R \cdot T_o} = \frac{1{,}013 \cdot 10^5}{287 \cdot (273+10)} = 1{,}247 \quad [\mathrm{kg/m^3}], \tag{1}$$

gdje je: where is:

$P_o = 1{,}013 \cdot 10^5$ [Pa], → atmosferski pritisak. → atmospheric pressure. (2)

$R = 287$ [J/kgK], → gasna konstanta. → gas constant. (3)

$T_o = (273 + 10) = 283$ [K], → temperatura atmosferskog zraka. → atmospheric air temperature. (4)

3.2. Gustoća komprimiranog zraka

3.2. Compressed air density

$$\rho = \frac{P_r}{R \cdot T} = \frac{7 \cdot 10^5}{287 \cdot (273+30)} = 8{,}05 \quad [\mathrm{kg/m^3}], \tag{5}$$

gdje je :
where is:

$P_r = 7 \cdot 10^5$ [Pa], → radni pritisak. → work pressure. (6)

$T = (273 + 30) = 303$ [K], → temperatura komprimiranog zraka. → compressed air temperature. (7)

3.3. Zapreminski protok komprimiranog zraka

3.3. Compressed air volum

$$q = \frac{\rho_o}{\rho} \cdot q_u = \frac{1{,}247}{8{,}05} \cdot 6{,}45 = 1 \quad [\mathrm{m^3/min}], \tag{8}$$

3.4. Unutrašnji prečnik magistralnog voda zraka

3.4. Internal diameter of the main air line

$$D = \sqrt{\frac{4 \cdot q}{60 \cdot \pi \cdot v}} = \sqrt{\frac{4 \cdot 1}{60 \cdot 3{,}14 \cdot 10}} = 0{,}046 \quad [\mathrm{m}], \tag{9}$$

gdje je:
where is:

$v = 10$ [m/s], → brzina strujanja zraka kroz vod zraka. → air flow rate through air line. (10)

Usvojena je polietilenska tvrda cijev PE 100 110x10,0 S 5/SDR 11 PN 16, prema JUS G.C6.620 (unutarnji prečnik cijevi D=90 [mm]). Za jame ugrožene metanom i opasnom ugljenom prašinom sva cijevna armatura mora posjedovati certifikat o antistatičnosti (prema standardu EN 60079-0, odnosno BAS 60079-0 koji je važeći u BiH, tačka 26.13), [6].

Adopted is polyethylene hard tube PE 100 110x10,0 S 5/SDR 11 PN 16, according to JUS G.C6.620 (internal diameter of pipe D=90 [mm]). For pits endangered with methane and dangerous coal dust all pipe fitting must possess certificate about antistaticity (according to standards EN 60079-0, i.e. BAS 60079-0 which is valid in B&H, point 26.13), [6].

3.5. Koeficijent trenja pri strujanju zraka kroz vod zraka

3.5. Coefficient of friction in air flow through air line

$$\lambda = \frac{1}{\left(2\cdot\log\frac{D}{k}+1{,}14\right)^2} = \frac{1}{\left(2\cdot\log\frac{90}{0{,}007}+1{,}14\right)^2} = 0{,}011, \tag{11}$$

gdje je:

where is:

k = 0,007 [m/s], → apsolutna hrapavost unutrašnjeg zida cijevi. (12)
→ absolute roughness of inner tube wall.

Stvarna brzina strujanja zraka kroz vod zraka:
Real speed of air flow through air line:

$$v = \frac{4\cdot q}{60\cdot\pi\cdot D^2} = \frac{4\cdot 1}{60\cdot 3{,}14\cdot 0{,}09^2} = 2{,}62 \quad \text{[m/s]}, \tag{13}$$

3.6. Pad pritiska u magistralnom vodu zraka

3.6. Pressure fall in main air line

$$\Delta p_m = \frac{v^2\cdot\rho}{2}\left(\lambda\frac{l_m}{D}+\Sigma\xi\right) = \frac{2{,}62^2\cdot 8{,}05}{2}\left(0{,}011\frac{723}{0{,}09}+3{,}85\right), \tag{14}$$

$$\Delta p_m = 2547 \quad \text{[Pa]}. \tag{15}$$

gdje je:

l_m = 723 [m] → dužina magistralnog voda zraka- length of main air line (16)

$\Sigma\,\xi$ → ukupni koeficijent lokalnih otpora u magistralnom vodu zraka, (17)

$$\Sigma\xi = z_{ul}\cdot\xi_{ul} + z_k\cdot\xi_k + z_{vent}\cdot\xi_{vent} + z_{rač}\cdot\xi_{rač}, \tag{18}$$

$$\Sigma\xi = 1\cdot 0{,}25 + 3\cdot 0{,}5 + 2\cdot 0{,}3 + 1\cdot 1{,}5 = 3{,}85. \tag{19}$$

- Ulaz voda zraka:
  - z_{ul} = 1 → broj ulaza.
  - ξ_{ul} = 0,25 → koeficijent gubitka.
- Krivine voda zraka:
  - z_k = 3 → broj krivina (lukova).
  - ξ_k = 0,5 → koeficijent gubitka.
- Ventili voda zraka:
  - z_{vent} = 2 → broj ventila.
  - ξ_{vent} = 0,3 → koeficijent gubitka.
- Račva T oblika-odvajanje:
  - $z_{račvi}$ = 1 → broj račvi.
  - $\xi_{račve}$ = 1,5 → koeficijent gubitka.

- Air line input:
  - z_{ul} = 1 → number of inputs.
  - ξ_{ul} = 0,25 → loss coefficient.
- Air line curves:
  - z_k = 3 → number of curves.
  - ξ_k = 0,5 → loss coefficient.
- Air line valves:
  - z_{vent} = 2 → number of valves.
  - ξ_{vent} = 0,3 → loss coefficient.
- T twitch shapes - separation:
  - $z_{twitches}$ = 1 → number of twitches.
  - $\xi_{twitches}$ = 1,5 → loss coefficient.

3.7. Pritisak zraka na kraju magistralnog voda (K+293,39 m)

3.7 Air pressure at the end of main air line on (K+293,39 m)

$$p = p_r - \Delta p_m = 7 - 0{,}02547 = 6{,}975 \text{ [bar]}, \quad (20)$$

Tabela 6. *Parametri pada pritiska za apsolutni radni pritisak 7 [bar]*
Table 6. *Parameters of fall pressure for absolute work pressure 7 [bar]*

Protok Flow	7,8	7,8	7,8	7,8	m^3/min
Nominalna dužina cjevovoda Nominal length of pipeline	10.500	5500	2500	1500	mm
Nominalni unutarnji promjer cjevovoda Nominal internal diameter of pipeline	Ø90	Ø90	Ø90	Ø90	mm
Apsolutni radni pritisak Absolute work pressure	7	7	7	7	bar
Pad pritisak Fall pressure	0,93	0,46	0,22	0,13	bar

Tabela 7. *Parametri pada pritiska za apsolutni radni pritisak 10 [bara]*
Table 7. *Parameters of fall pressure for absolute work pressure 10 [bars]*

Protok Flow	7,8	7,8	7,8	7,8	m^3/min
Nominalna dužina cjevovoda Nominal length of pipeline	10.500	5500	2500	1500	mm
Nominalni unutarnji promjer cjevovoda Nominal internal diameter of pipeline	Ø 90	Ø 90	Ø 90	Ø 90	mm
Apsolutni radni pritisak Absolute work pressure	10	10	10	10	bar
Pad pritiska Fall pressure	0,65	0,34	0,16	0,09	bar

4. ZAKLJUČAK

Dugogodišnja tradicija eksploatacije uglja u jamama Rudnika "Kakanj" nikad nije dozvoljavala da tehnološki proces bude „ispod“ nivoa trenutka u kojem sredstva rada zadovoljavaju najveći stepen sigurnosti i humanizacije rada. Uređaji i mašine koji se pogone komprimiranim zrakom moraju biti trajno priključeni na energetski izvor - kompresor. To je povezano s gubicima uslijed otpora i propuštanja, što je razlog daljeg povećanja visoke cijene komprimiranog zraka. Zbog te veze s izvorom, uređaji na komprimirani zrak su ograničeno pokretljivi, tj. samo onoliko koliko im omogućuje gibljivo crijevo. Na taj način, uvođenje komprimiranog zraka kao energetskog nositelja rješava problem jamskog prijevoza.

4. CONCLUSION

A long tradition of coal exploitation in Mine „Kakanj“ never allowed that technical process should be below the level in which means of work satisfies the biggest stage of security and humanization of labour. Devices and machines that are driving on compressed air must be permanently connected to energy source – compressor. That is connected with losses during resistance and leakage, which is the reason for further increase and higher price of compressed air. Because of that connection, devices with compressed air have limited mobility, i.e. limited with flexible hose. In that way, introduction of compressed air as an energy carrier solves the problem of pits transportation.

5. LITERATURA - REFERENCES

[1] Pravilnik o tehničkim normativima za strojeve s dizelskim motorima koji se koriste pri podzemnim rudarskim radovima u nemetanskim jamama ("Službeni list SFRJ", br. 66/78);.

[2] Zakon o rudarstvu Federacije Bosne i Hercegovine (Službene novine 26/10 – 05.05.2010. godine).

[3] Pravilnik o tehničkim normativima za podzemnu eksploataciju ugljena („Službeni list SFRJ“ , br. 4/89, 45/89, 3/90 i 54/90).

[4] PRP Primjena ranžirnog voza na komprimirani zrak tip MZP 2x3,2 t u jamama "Haljinići", JP EP BIH d.d. - Sarajevo, ZD RMU "Kakanj" d.o.o. Kakanj; mašinski dio.

[5] Pravilnik o tehničkim mjerama i zaštiti na radu pri rudarskim podzemnim radovima („Službeni list SFRJ“, br. 11/67, 35/67, 60/70, 9/71, 3/73 i 5/73).

[6] Pravilnik o tehničkim normativima za stabilne posude pod pritiskom ("Službeni list SFRJ", br. 16/83);

[7] http://www.riteh.uniri.hr/zav_katd_sluz/zvd_teh_term_energ/nas/kompresori_07/1_Uvod_2007.pdf. Pristupljeno 09.02.2018

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ATTRIBUTIONAL VERSUS CONSEQUENTIONAL LIFE CYCLE ASSESSMENT MODELLING IN METALWORKING PRODUCTION SYSTEM

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SUMMARY

Two different system modelling can be distinguished in life cycle assessment: attributional and consequential. Attributional modelling is used to describe the present state of the examined system and is characterised with use of allocation, no substitutions, market average suppliers, and cut-off principle. Consequential modelling is used to describe the consequences of changes in the demand within the system and use of substitutions, marginal suppliers, and system expansion. Although the ISO 14040 standard does not make a clear distinction between attributional and consequential modelling, it does provide basic instructions on how to deal with allocations and supports both types of modelling systems. Therefore, it is important to specify within the goal and scope of life cycle assessment study which modelling is used. This research applies attributional and consequential modelling in life cycle assessment to analyse a case of metalworking production system. The aim of research is to identify if the application of different system models can lead to different conclusions and interpretation of life cycle assessment results. The obtained environmental impacts from life cycle assessment show that two system models provide different results. However the choice which one to use depends on: if investigation has to separate the product from the rest of technosphere and environment, if inputs and outputs need to be attributed to the functional unit, or if there is need for comparative analysis of products and focus on the long-term effect of the changes.

1. INTRODUCTION

Life cycle assessment (LCA) is a comprehensive tool for evaluation of environmental impacts in all product and process life cycle stages [1]. Despite the fact that LCA takes the entire life cycle into account, still many assumptions and methodological choices have to be made throughout a study, which can lead to different outcomes [2]. The ISO 14040 [3] standard does not make a clear distinction between attributional and consequential LCA modelling (ALCA and CLCA), but it provides basic rules how the allocations in LCA should be performed. Therefore, it is important to specify in goal and scope of LCA study if ALCA or CLCA modelling is used. One of the first publicly published documents where ALCA and CLCA are being distinguished is Curran et al., 2005 [4]. ALCA, also called “accounting”, “retrospective”, or “descriptive”, evaluates the system as it is or was. On the other side, CLCA focuses on the consequences of changes in the demand within the system. Table 1 provides description and general differences between the ALCA and CLCA.

The International Reference Life Cycle Data System (ILCD) handbook [5], developed by the European Joint Research Centre, is one of the frequently cited documents in field of LCA. This handbook, which comprises several volumes, provides guidelines on how to perform LCA. ILCD handbook also defines ALCA and CLCA, however, recent research by [6] showed that it needs revision as some guidelines are found to be inconsistent with previous research on ALCA and CLCA. According to research presented in [7], changes to attributional systems have consequences beyond the system boundaries, i.e. in the parts that have been allocated away, or made less important through averaging.

Ecoinvent, one of the most used LCI databases, since version 3.0, contains three model systems that correspond to ALCA and CLCA [8], namely: cut-off, allocation at the point of substitution, and consequential. These system models describe how activity datasets are linked

to form product systems. Within these system models ALCA [8] can be divided into:

- value chain (economic or revenue allocation) - where a producer is fully responsible for the disposal of its wastes, and that he does not receive any credit for the provision of any recyclable materials;
- supply chain (mass allocation) attributional approach in which burdens are attributed proportionally to specific processes.

Table 1. Description of the ALCA and CLCA

ALCA	CLCA	Reference
Attributional LCI aims to answer how are environmentally things (pollutants, resources, and exchanges among processes) flowing within the chosen temporal window.	Consequential LCI aims to answer how will flows change in response to decisions.	[4]
System modelling approach in which inputs and outputs are attributed to the functional unit of a product system by linking and/or partitioning the unit processes of the system according to a normative rule.	System modelling approach in which activities in a product system are linked so that activities are included in the product system to the extent that they are expected to change as a consequence of a change in demand for the functional unit.	[9]
Economic, revenue or mass allocation; Average suppliers; No specific requirements to the functional unit; Market averages - Current relative production volumes of suppliers.	System expansion; Substitution; Functional unit reflects the conditions for substitution; Marginal, unconstrained suppliers - modern, competitive suppliers, when the product demand is generally increasing, old, uncompetitive suppliers, when the product demand is generally decreasing.	[7]
LCI modelling frame that inventories the inputs and output flows of all processes of a system as they occur. Modelling process along an existing supply-chain is of this type.	LCI modelling principle that identifies and models all processes in the background system of a system in consequence of decisions made in the foreground system.	[5]

There is a increased number of researches that involve comparison of ALCA and CLCA. Buyle et al. [2] performed a screening LCA of an apartment with ALCA and CLCA approach in order to identify and compare possible differences in results between the two approaches when applied on the same case. Their results showed that there is a shift of proportion between the environmental impacts per life cycle phases. Kua et al. [10] used ALCA and CLCA to evaluate and compare substitution of concrete with bricks on Singapore case study. Their results showed that for ALCA approach, the environmental impacts of replacing concrete with bricks may be increased, while using a CLCA approach, replacing concrete with bricks may result in small reduction of GWP. Parajuli et al. [11] evaluated environmental impacts of producing bioethanol and bio based lactic acid from standalone and integrated biorefineries using ALCA and CLCA. They concluded that for producing bio based products from an integrated system ALCA and CLCA approaches had similar impact pattern for most of the impact categories. In general, ALCA is more used than CLCA modelling, but one of the problems that occurs in some studies is that it is not defined if ALCA or CLCA is used.

Previously discussed show that LCA community has increased interest in distinguishing the ALCA and CLCA modelling choices. Following this trend, this investigation applies ALCA and CLCA modelling in order to analyse a case of metalworking production system. The aim of the research is to identify if two system models can

lead to different conclusions and interpretation of LCA results.

2. MATERIALS AND METHODS

Differences between ALCA and CLCA modelling will be shown on simple example with production of aluminium parts by milling. In this example joint production of A and B products is investigated. The functional unit is defined as production of one kilogram of product A that is made from aluminium alloy. System boundaries for ALCA and CLCA are different and shown in figures 1 and 2. The use of workshop building, milling machine, cooling fluid, and other consumables is not considered in system boundaries because of the negligible environmental impact.

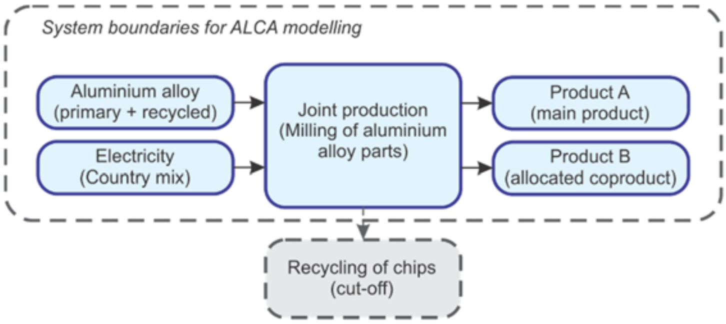

Figure 1. *System boundaries for ALCA modelling*

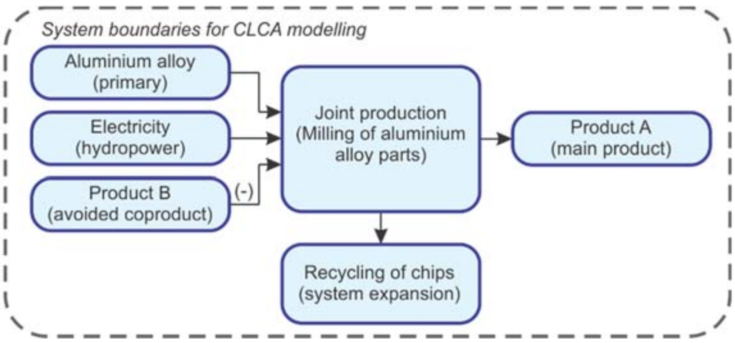

Figure 2. *System boundaries for CLCA modelling*

In ALCA modelling aluminium alloy is produced from primary (virgin) aluminium, and recycled aluminium. Electricity needed for production is from country mix that consists of electricity mainly from burning of lignite in power plants (66%) and hydropower (32%). Mass allocation was used for allocating the environmental impact between the products A and B. Recycling of waste chips is not included in ALCA modelling because of cut-off criteria.

Situation with increase in demand for product A where average supplier cannot satisfy the increase in demand is considered in CLCA modelling. Therefore, increase in demand for product A is compensated with marginal suppliers of aluminium alloy and electricity. In consequence of increased demand, only primary aluminium is used for production of aluminium alloy and hydropower is used instead of country mix. System expansion was used for allocation of environmental impacts between the products A and B. Recycling of waste chips is included in CLCA modelling because of system expansion.

Inventory for ALCA and CLCA modelling of aluminium parts production is shown in tables 2 and 3.

Table 2. Inventory for ALCA modelling of aluminium parts production

Activity	Name of the activity in Ecoinvent database	Amount	Note
Input flows			
Aluminium	Aluminium, cast alloy {GLO}| market for | Alloc Def, S	1.62 kg	1 kg (A product) + 0.5 kg (B product) + 0.12 (metal chips from milling 8%)
Electricity	Electricity, medium voltage {RS}| market for | Alloc Def, S	0.036 kWh	0.3 kWh is consumed for removal of 1 kg of metal chips
Output flows			
Product A	-	1.0 kg	Main product
Product B	-	0.5 kg	Environmental impact of coproduct is allocated with mass allocation

Table 3. Inventory for CLCA modelling of aluminium parts production

Activity	Name of the activity in Ecoinvent database	Amount	Note
Input flows			
Aluminium	Aluminium, cast alloy {GLO}| market for | Conseq, U	1.62 kg	1 kg (A product) + 0.5 kg (B product) + 0.12 (metal chips from milling 8%)
Electricity	Electricity, high voltage {RS}| electricity production, hydro, reservoir, alpine region | Conseq, S	0.036 kWh	0.3 kWh is consumed for removal of 1 kg of metal chips
Output flows			
Product A	-	1.0 kg	Main product
Product B	Product A (Avoided)	0.5 kg	Coproduct is avoided product with positive impact on the environment
Aluminium recycling	Aluminium, primary, ingot {GLO}| market for | Conseq, S	0.12 kg	Avoided product with positive impact on the environment

For life cycle impact assessment (LCIA) ReCiPe midpoint method was used [12]. ReCiPe expresses environmental impacts through the following 18 midpoint impact categories: climate change, terrestrial acidification, freshwater eutrophication, human toxicity, photochemical oxidant formation, particulate matter formation, freshwater ecotoxicity, marine ecotoxicity, natural land transformation, metal depletion, fossil depletion, ozone depletion, marine eutrophication, terrestrial ecotoxicity, ionising radiation, agricultural land occupation, urban land occupation, and water depletion. For purpose of investigation of differences between the ALCA and CLCA, and simplification of interpretation, only the results from climate change midpoint impact category will be analysed as climate change is most used as a single environmental indicator on midpoint level.

3. RESULTS

The results from ReCiPe midpoint method for climate change midpoint impact category are shown in figures 3 and 4 for ALCA and CLCA modelling.

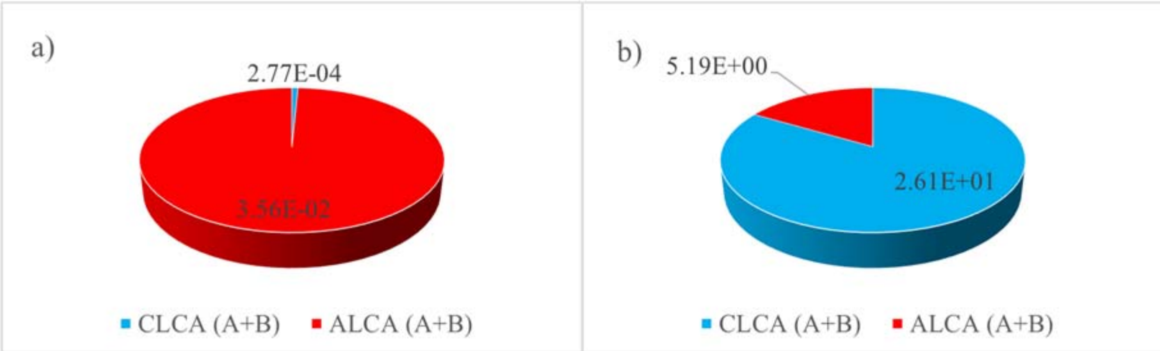

Figure 3. *Impact on climate change in kg of CO_2 eq. for: a) consumption of electricity for joint production of products A and B, b) consumption of aluminium alloy for joint production of products A and B*

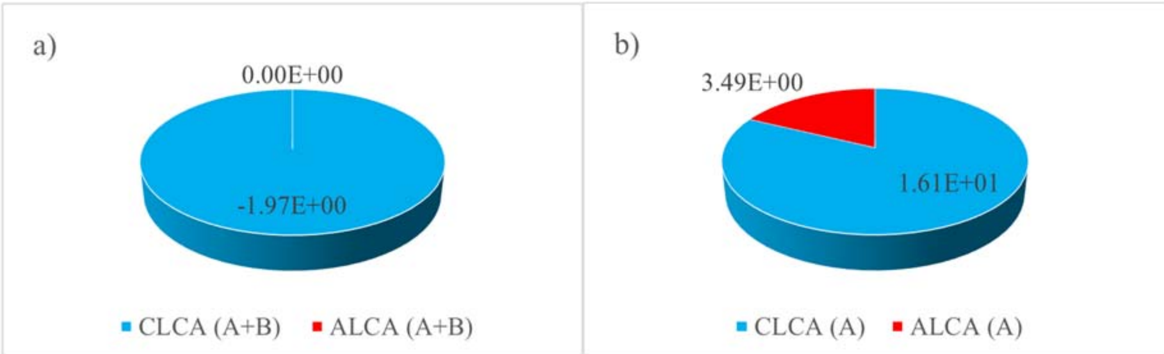

Figure 4. *Impact on climate change in kg of CO_2 eq. for: a) Recycling of aluminium for joint production of products A and B, b) product A*

4. DISCUSSION

As can be expected, ALCA and CLCA modelling provide different results (figure 4b). Although the environmental impact of electricity consumption for joint production of A and B products is much lower than the impact of aluminium consumption, the difference between results from ALCA and CLCA (figure 3a) is more than 100 times (2.77E-04 versus 3.56E-02). Reason for such results lies in the different source of electricity. The electricity in ALCA is from Serbian electricity mix, while the electricity used in CLCA is only from hydropower which is the cleaner energy source. The main differences in results of two modelling approaches are related to consumption of aluminium alloy (figure 3b). Considering the fact that use of virgin material has larger impact on the environment, aluminium alloy in CLCA modelling had larger environmental impact (5.19E+00 kg CO_2 eq.). Here one can easily see the difference between the two modelling approaches in Ecoinvent 3 LCI database where activity “Aluminium, cast alloy {GLO}| market for | Conseq, U” uses primary aluminium (marginal supplier) while activity “Aluminium, cast alloy {GLO}| market for | Alloc Def, S” uses primary and recycled aluminium (average supplier) for production of aluminium alloy. In ALCA modelling mass allocation was applied and result is same as in CLCA modelling where system expansion was applied with use of negative flows of product B (figure 2). If economic (revenue) allocation was applied instead of mass allocation, different results could occur. Including the recycling of aluminium chips in CLCA modelling provides environmental benefit (figure 4a). On the other side, recycling is excluded in the system boundaries of ALCA and therefore in CLCA benefits from recycling of aluminium for joint production of products A and B are -1.97E+00 kg CO_2 eq. Finally, when environmental impacts of product B are allocated, the product A generates impact on climate change of 3.49E+00 kg CO_2 eq. for CLCA, and 1.61E+01 kg CO_2 eq. for ALCA (figure 4b). Another point of interest would be different modelling of coproduct B flow. In general, for this example, results from CLCA produce larger environmental loading then ALCA.

5. CONCLUSIONS

This research represents an attempt to draw attention to differences between the ALCA and CLCA modelling where significantly different results can occur. Therefore, it is very important to address the modelling choice in goal and scope of LCA because it will impact the choice of activities in LCI, allocation rules, and finally, obtained LCA results. The main differences between the ALCA and CLCA can be identified as following: differences in activities included in within the system boundaries, differences in activities from Ecoinvent LCI database, differences in linking the activities within the system boundaries. It can be concluded that the choice which one to use depends on following: if investigation has to separate the product from the rest of technosphere and environment, if inputs and outputs need to be attributed to the functional unit, or if there is need for comparative analysis of products and focus on the long-term effect of the changes. Direction for future research is that experts in field of LCA should focus their efforts towards development of international guide for ALCA and CLCA. The new guide for ALCA and CLCA should be compatible with present ISO 14040 standard, gather proven findings of previous research, include all possible situations of ALCA and CLCA modelling, and it has to define how practitioners should select whether ALCA or CLCA is the right choice.

5. REFERENCES

[1] Guinee J.B., Gorree M., Heijungs R., Huppes G., Kleijn R., van Oers L., Sleeswijk A.W., Suh S., de Haes U.H.A., de Bruijn H., van Duin R. & Huijbregts M.A.J.: Handbook on Life Cycle Assessment, Operational guide to the ISO standards Vol. 1, 2a, 2b and 3, 2001.

[2] Buyle M., Braet J., Audenaert A.: Life cycle assessment of an apartment building: comparison of an attributional and consequential approach, Energy Procedia, Vol. 62, Pages 132 – 140, 2014.

[3] ISO 14040: Environmental management - Life cycle assessment - Principles and framework. Switzerland, Geneva, 2006.

[4] Curran, M.A., Mann, M., Norris, G.: The international workshop on electricity data for life cycle inventories. Journal of Cleaner Production, Vol. 13, No. 8, Pages 853-862, 2005.

[5] JRC-IEA: International Reference Life Cycle Data System (ILCD) Handbook—General guide for Life Cycle Assessment—Detailed guidance. First edition March 2010. Publications Office of the European Union, Luxembourg. 2010.

[6] Ekvall, T., Azapagic, A., Finnveden, G., Rydberg, T., Weidema, B.P., Zamagni, A.: Attributional and consequential LCA in the ILCD handbook, International Journal of Life Cycle Assessment, Vol. 21, Pages 293–296, 2016.

[7] Weidema, B.P, Pizzol, M., Schmidt, J., Thoma, G.: Attributional or consequential Life Cycle Assessment: A matter of social responsibility, Journal of Cleaner Production, Vol. 174, Pages 305-314, 2018.

[8] Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., and Weidema, B.: The ecoinvent database version 3 (part I): overview and methodology, The International Journal of Life Cycle Assessment, [online] Vol. 21, No. 9, Pages 1218–1230, 2016.

[9] Sonnemann, G., Vigon, B.: Global Guidance Principles for Life Cycle Assessment Databases. UNEP/SETAC Life Cycle Initiative, Paris/Pensacola, 2011.

[10] Kua, H.W., Kamath, S.: An attributional and consequential life cycle assessment of substituting concrete with bricks. Journal of Cleaner Production, Vol. 81, Pages 190-200, 2014.

[11] Parajuli, R, Trydeman Knudsen, M., Birkved, M., Njakou Djomo, S., Corona, A., Dalgaard, T.: Environmental impacts of producing bioethanol and biobased lactic acid from standalone and integrated biorefineries using a consequential and an attributional life cycle assessment approach, Science of the Total Environment, Vol. 598, Pages 497–512, 2017.

[12] Goedkoop, M.J., Heijungs, R., Huijbregts, M., De Schryver, A., Struijs, J., Van Zelm, R.: ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. In: Report I: Characterisation, first ed. 6 January 2009, 2009.

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NA MAŠINSKOM FAKULTETU UNIVERZITETA U ZENICI UPRILIČENA SVEČANOST POVODOM OBILJEŽAVANJA 42. GODINE RADA.

11. marta 2019. godine na Mašinskom fakultetu Univerziteta u Zenici upriličena je Svečanost povodom obilježavanja 42. godine rada ovog fakulteta.
Svečanosti su prisustvovali Rektor i prorektori Univerziteta u Zenici, predstavnici Vlade Zeničko-dobojskog kantona, zaposlenici fakulteta i Univerziteta i mnogobrojnih gosti.
Prof.dr.sc. Fuad Hadžikadunić, dekan Mašinskog fakulteta prezentirao je značajne rezultate rada ovog fakulteta u proteklih više od četrdeset godina, kao i trenutne prostorne kapactete, opremu i nastavni kadar kojim raspolaže fakultet, ali i planove za buduće investicije s ciljem što kavlitetnijeg obrazovanja studenata. Ovom prilikom prezentirane su realizovane aktivnosti u okviru projekta "“EE rekonstrukcija"“ na dijelu objekata Mašinskog fakulteta Univerziteta u Zenici i uručena zahvalnica gosp. Mensuru Sinanoviću, ministru Ministarstva za obrazovanje, nauku, kulturu i sport Zeničko-dobojskog kantona. Također, prezentirane su i aktivnosti projekta GIZ - EU ProLocal i novi studijski odsjek "“Dizajn i tehnologije u drvopreradi“.

Istaknuta je posebna važnost saradnje Mašinskog fakulteta sa privrednim subjektima, gdje se studentima pružaju različite mogućnosti usavršavanja.

S ciljem nastavka odlične saradnje Univerziteta i privrednih subjekata potpisan je Memorandum o poslovnoj saradnji između Univerziteta u Zenici i BH BIESSE Service za osnivanje trening i show-room centra u kampusu Univerziteta u Zenici. Memorandum su potpisali: gosp. Mensur Sinanović u ime Vlade Zeničko – dobojskog kantona, prof.dr.sc. Damir Kukić u ime Univerziteta u Zenici i gosp. Alan Lisica u ime BH BIESSE Service.

Na kraju ove svečanosti promoviran je novi studijski odsijek „Inženjerska i poslovna informatika – IPI.

Derviša Zahirović, MA prava

Stručni saradnik za informisanje.

ODRŽANA 15. PROMOCIJA DOKTORA NAUKA UNIVERZITETA U ZENICI

Na Ekonomskom fakultetu Univerziteta u Zenici, 19. marta 2019. godine održana je 15. po redu Promocija doktora nauka. Prof.dr.sc. Damir Kukić, rektor Univerziteta u Zenici promovirao je 18 doktora nauka, koji su doktorske disertacije odbranili u 2018. godini.

Za akademsku zajednicu današnja promocija je jedan od najljepših i najznačajnijih trenutaka iz razloga što to predstavlja jedan kontinuirani dokaz uspješnosti bavljenja naučnoistraživačkim radom. Ovo je također i veliki dan za društvo u cjelini jer dobijamo novu snagu, novo znanje. Veliki broj stručnjaka, među njima i nobelovci su utvrdili da je znanje put za bijeg iz siromaštva, kako materijalnog, tako i duhovnog, istakao je prof.dr.sc. Damir Kukić, rektor Univerziteta u Zenici.

U ime promoviranih doktora nauka obratila se Benjamina Londrc, koja je prisutnima prenijela svoja pozitivna iskustva stečena tokom studija na trećem ciklusu Pravnog fakulteta Univerziteta u Zenici, te pozvala kolege da se nastave baviti naučnoistrživačkim radom. Benjamina Londrc ima 28. godina i je najmlađi doktor nauka u Bosni i Hercegovini iz oblasti klasinčnog rimskog prava.

U prisustvu menadžmenta Univerziteta u Zenici, dekana fakulteta, mnogobrojnih gostiju, rodbine i prijatelja danas su promovirani sljedeći:

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Create equations with **MS** Word Equation Editor (some examples are given below).

$$O_i^4 = \overline{w_i} f_i = \overline{w_i}(p_i x_1 + q_i x_2 + r_i) \quad (1)$$

$$E_i = \frac{(o^i - y^i)^2}{2} \quad (2)$$

$$G(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} \quad (3)$$

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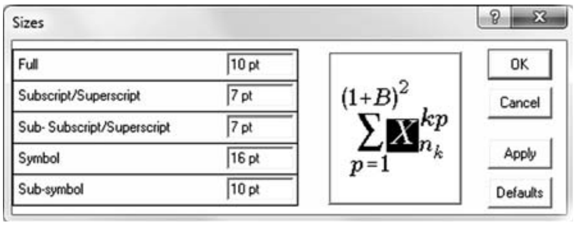

Slika 1. *Tekst unutar formula (samo za autore sa ex-YU prostora)*
Figure 1 *The texts under figures*
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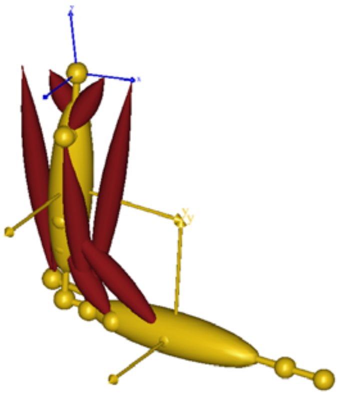

Figure 2. *Simplified musculoskeletal model of an arm*
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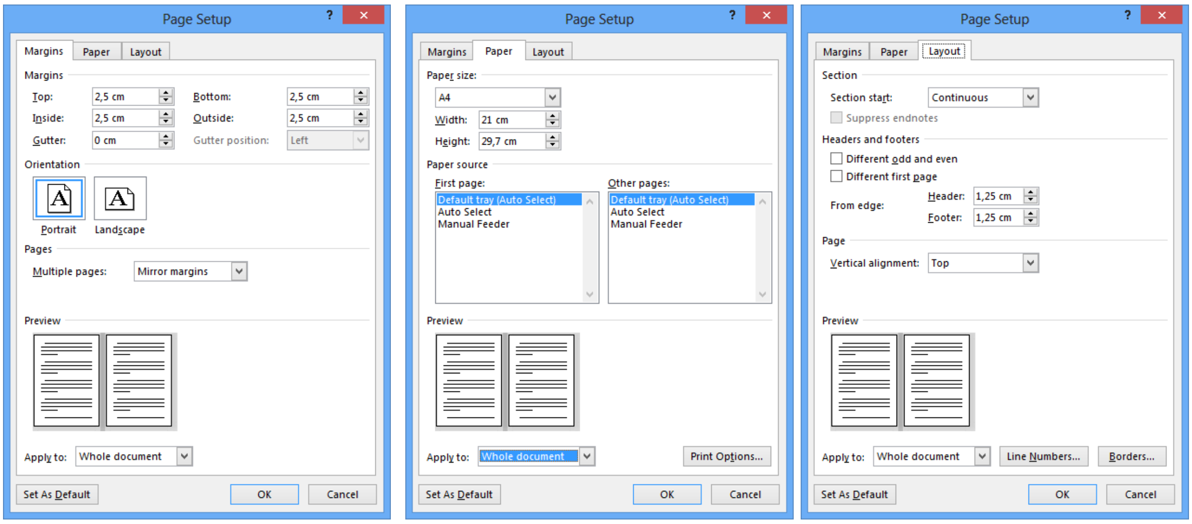

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Figure X. *Photography resolution of 300 dpi (min)*
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Engineering stress σ_e / MPa	Engineering plastic strain $\varepsilon_{e,pl}$ / %	True stress σ_t / MPa	True plastic strain $\varepsilon_{t,pl}$ / %
250,0	0,00	250,8	0,00
250,0	0,21	250,8	0,21
285,7	1,35	290,0	1,34
322,7	2,13	330,1	2,10
358,4	3,06	370,0	3,00
393,1	4,35	411,0	4,24
423,6	6,05	450,1	5,85
449,7	8,76	490,1	8,36
457,0	15,79	530,1	14,59
467,9	21,58	570,0	19,45
475,0	29,77	617,5	25,94

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[1] P.E. Nikravesh, *Computer-Aided Analysis of Mechanical Systems*, Prantice Hall Inc.,Englewood Cliff,NJ,1988.

[2] Gordon Robertson, Graham Caldwell, Joseph Hamill, Gary Kamen, Saunders Whittlesey: *Research Methods in Biomechanics,* Human Kinetics; 2nd edition, 2014.

[3] Imai, M.: *KAIZEN: the key to Japan's competitive success,* Editorial CECSA, Mexico. In Spanish, 1996.

[4] Nemoto, M.: *Total quality control for management. Strategies and techniques from Toyota and Toyoda Gosei,* Prentice-Hall, Englewood Cliffs, NJ, 1987.

[5] Cheser, R.: *The effect of Japanese KAIZEN on employee motivation in US manufacturing*, Int J Org Anal 6(3):197–217, 1998.

[6] Aoki, K.: *Transferring Japanese KAIZEN activities to overseas plants in China,* Int J Oper Prod Manag 28(6):518–539, 2008.

[7] Tanner, C.; Roncarti, J.: *KAIZEN leads to breakthroughs in responsiveness and the Shingo prize at Critikon*, Natl Prod Rev 13(4):517–531, 1994.

[8] Rink, J.: *Lean can save American manufacturing. Reliable plant.* http://www.reliableplant.com/Read/330/lean-manufacturing-save. Accessed at 14 April 2014.

[9] SolidWorks, http://www.solidworks.com (12.5.2015)

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