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POSSIBILITY OF USE THE KAONA QUARTZITE (EAST SERBIA)[**]

Abstract

The locality of "Kornjica" is located in the area of the village Kaona, about 5 km from the main road Majdanpek-Kučevo-Požarevac-Belgrade, or about 10 km west of Kučevo. Quartzites and quartz metaconglomerates on the surface of about 2 km^2 were studied at the site "Kornjica". Quartzites and quartz metaconglomerates build a package of layers of thickness about 150 m, which are white, solid, compact and cores. The thickness of pure quartzites is 30 to 40 m, which is multiple interlayered with the other quartzites and quartz metaconglomerates. The rocks are of different compactness and composition. Sometimes, the relict pseptic structures are observed in them as well as the quartz-serie binders. From the existing three horizons of quartzite and quartz metaconglomerates (Kalenić, Hadži-Vuković, 1974), the oldest package occurs at Kaona, which is considered to signify the passage of vendor in the Cambrian. The field geological explorations, petrological tests, chemical tests, physical-mechanical tests and directed technological research (in the laboratory conditions) were carried out. The obtained results of research, along with the already existing data, have enabled the definition of quartzite deposits near Kaona, as well as determining the possibility of using these rocks as the mineral raw materials (whose quality would meet the prescribed standards for use in metallurgy, refractory and chemical industries).

Keywords: *quartzite and quartz metaconglomerates, petrographic characteristics, physical-mechanical characteristics, chemical characteristics, quartzite quality, East Serbia*

1 INTRODUCTION

The location of "Kornjica" is located, by air line, about 10 km in the west of Kučevo, in the attic of Kaona village (East Serbia, Figure 1). This orographic region belongs to the South Carpathians; it is a hydrographic part of the central river basin of the river Pek,and it administratively belongs to the Branicevo District (Municipality of Kučevo). For the immediate vicinity of the explored area, besides the river Pek that flows in the immediate vicinity, the Kaonski stream is of great importance. The metamorphic complex in the Kaona region (*Kalenić, Hadži - Vukovic, 1974*) was insufficiently studied from the aspect of quartzite exploration as the quartz mineral resource. In order to solve the set problems, in addition to the field observations, a detailed geological exploration the metamorphic complex was carried out on an area of about

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0.60 km^2. Interpretation of the obtained results of exploration, along with already existing data, has enabled defining the quartzite deposit near Kaona, development the necessary graphic and other documentation, as well as determining the possibility of applying these rocks as mineral raw materials.

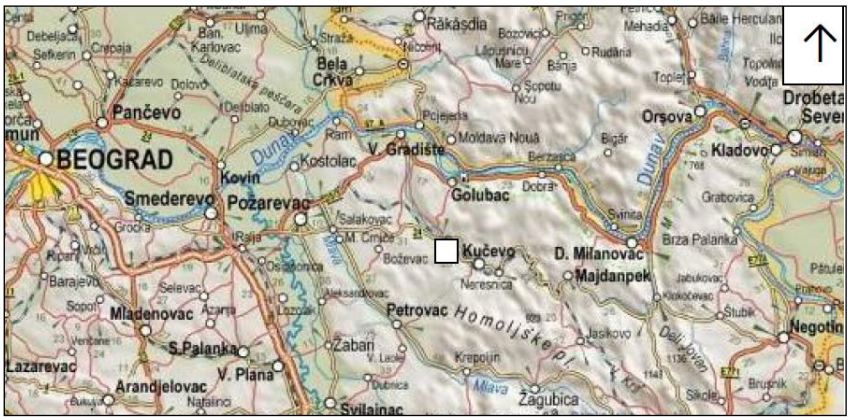

Figure 1 *Geographical position of the Kaona quartzites*

2 BASIC GEOLOGICAL DATA AND OVERVIEW OF PREVIOUS EXPLORATIONS

The Kaona area belongs to the Kucevo OGK leaf, scale 1: 100,000 with the mark L-34-128. The leaf Kučevo is located between 44^{0}20'4 and 44^{0}40' of the north latitude, and 21^{0}30´ and 22^{0}0´ of the east longitude GMT. Includes Braničevo, upper river Mlava, Stig, a part of Homolje and North Kučaj.The boundaries of the explored area are located in a part of the Kladurovo leaf (L-34-128-Ca, scale 1: 25,000). A wider surrounding of the explored area (Figure 2) is built of the Palaeozoic, Mesozoic and Kenoosic rocks (*Kalenić, Hadži-Vuković 1974*).

In recent years, the paleozoic metamorphic complex in the Kaona area has been relatively little investigated by our and foreign researchers who have been dealing with the individual research in terms of sedimentology (Kalenić, Milosavljević, 1987, 1988), paleontology (Djajić 1992), magmatism or metamorphism (Ivanović. 2000). Djajić states that the original sediments were deposited in the marine environment, probably by the end of Siluria and the beginning of Devon, and the spores of the first primitive land-based plants were together with the other material transported from the surrounding land or island into the deposition basin. Milosavljevic (1992) dealt with the quartzites of Turian and Sena in detail. She determines the quartzites of the Moravian Zone as a part of the Serbian-Macedonian mass that stretche from the Danube to Vlasina Lake, in a narrow zone of about 250 km in length. She describes quartizites as the rocks that appear as one, two or more successive discontinuous hori-zons (a few tens of meters thick) by the palinopalinological analyses of the proven lower Devon age.

Petrologic - sedimentological studies of quartzites have proved that they are metamorphic sediments (quartzites of the Moravian Zone according to the preserved relict structures and textures are determined as the

primary conglomerates and sand-stones formed by the shallow water sedimentation). Metamorphism caused the recrystallization and loss of contours of the primary grains and fragments. A large amount of silicon binder is present pri-marily because of isochemical and exoechemic dissolution and redissolution of silicon during and after diogenesis. By analyzing the quartz pebbles, detritic minerals (primarily zircon), it has been proved that the clastic quartzite material originated of the rocks from the metamorphic region. The occurrence of chloritoids and pyrophyllites in the matrix of metaclastite of the Moravian zone were studied by Milovanović et al. (1994). These authors believe that chloritoide, pyrophilic and chlorite were formed at temperatures around 350^0S ± 50^0S and pressures of 2-3 kbar.

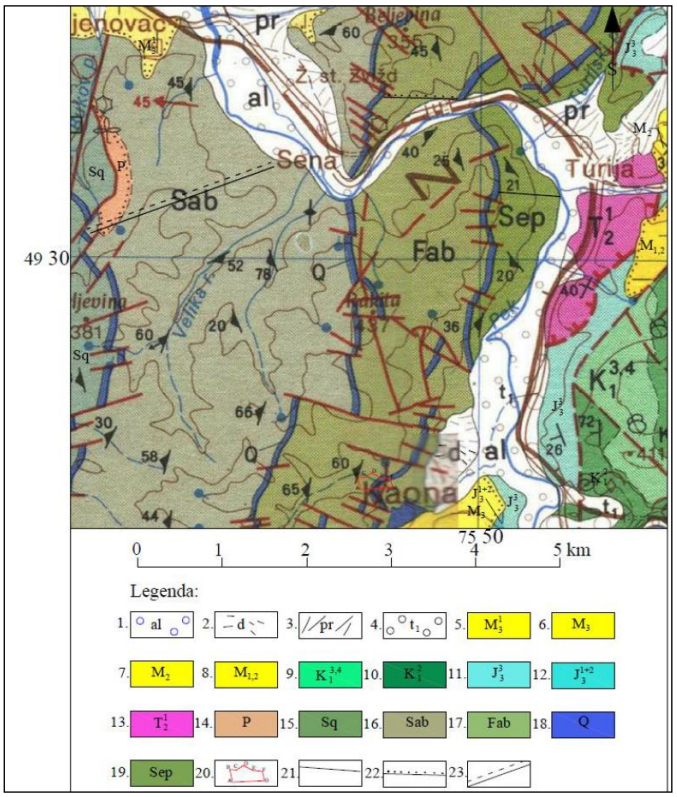

Figure 2 *Geological map of a wider area of explored Kaona territory (Kučevo a part of the leaf Kučevo 1:100 000 (Kalenic, Hadzi Vukovic, 1974) with a view of geological columns (Kalenic et al. 1987)*

Legend: 1. alluvium; 2. deluvium; 3. proluviums; 4. river terrace; 5. gravel, sand, clay and limestone; 6. sands and gravels; 7. conglomerates, sandstones, clays, tuffs and coal; 8. conglomerates, shales with coal and marl; 9. massive and banked limestones; 10. marl, marly limestone and limestone with a pink bump; 11. banked and layered limestone, marl limestone and marl; 12. banked and plate limestones with pink bumps; 13. dolomitic limestone and limestone; 14. red sandstones and conglomerates; 15. metapsamites and metadiabasites; 16. acidic metavoclanites, metapelites and metapsamites; 17. metabasites and filitoids; 18. quartzites and quartz conglomerates; 19. sericite schists; 20. exploration area of the Kaona quartzites; 21. location of the geological column Kaona-Turija; 22. location of the geological column Sena-Turija, and 23. location of the geological column Sena-Mišljenovac

The metamorphic complex in the area Kaona has been insufficiently studied from the aspect of quartzite research as a quartz mineral resource. In the period 1988 - 1990 (Bugarin), a quartzite prospectus was carried out in the area of Kaona, a narrow locality of the "Kornjica" (a detailed geological map 1:2.500, the surface area of 2 km^2 and 200 ha, was made, covering the area where the quartzite outcrops were observed.) In the same proportions, a structural map of the locality of Kornjica was made. Systematic research of the regional character included: recognition and geological mapping of the terrain for development a geological map of 1:10.000. In geological mapping, the samples were taken for mineralogical-petrological tests as well as for laboratory tests of chemical composition of quartzite. It is determined by the geological researches that it is a quartzite series of thickness up to 150 m, in the form of packages (layers), whose quality differs macroscopically by compactness, thickness, grain size distribution, etc. The scope and type, as well as the density of applied exploration works was not satisfactory to talk about the reserves of higher categories on which the future exploitation is based.

2.1 Geological Characteristics of the Quartzite Deposit Kaona

The area of field of the quartz raw material, Kaona, was built mainly of crystalline shales, within which quartzites, quartz metaconglomerates and quartz metasands are located (Figure 3). The southeastern and southwestern parts of this terrain are formed by the sedimentary structures of the Miocene age.

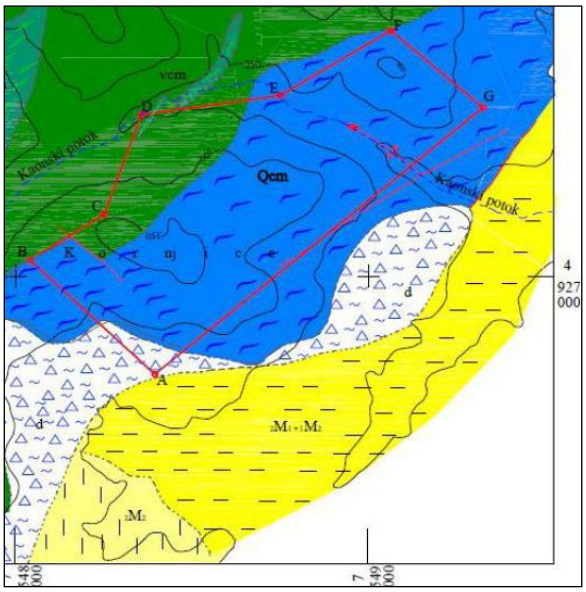

Figure 3 *Geological map of the explored area Kaona 1:10 000 (a part of the leaf Kladurovo 2-L-34-128-Ca 1:25 000)*

Legend: ***1.*** *Delluvium;* ***2.*** *conglomerates, sandstones, sandy clays and coal;* ***3.*** *conglomerates, sandstones, marls, exfoliated schist, clay and coal;* ***4.*** *quartzites with metaconglomerates and quartz conglomerates;* ***5.*** *metamorphosed gabbro;* ***6.*** *metamorphosed diabase and gabrodiabase;* ***7.*** *quartz-sericite-chlorite schists and graphitic schists;* ***8.*** *anticline;* ***9.*** *fault;* ***10.*** *exploration area*

The deposit Kaona is located at the forehead of putting on the proterozoic and old paleozoic complexes of the Moravian zone, over the Mesozoic structures of the Golubac-Gornjak structural unit. If the Mesozoic sediments east of Kaona are excluded, and in our case they represent only the ground on which the Vend-Cambrian formation is drawn, then the geological situation is quite simple.

By studying quartzite, quartz metaconlomerates and quartz metasandstones of Kaona, it was observed that, in the vertical column, three identical zones can be separated, thickness of about 80 m. From the existing three horizons of quartzite, disintegrated quartzite, and quartz metaconglomerates and quartz metasandstones, the oldest one occurs near Kaona that denotes the passage of proterozoic (venda) into the cambium (Kalenić, Hadži-Vuković, 1974).

Quartzites are the metamorphic structures that originate from quartz sands, quartz sandstones and quartz conglo-merates, which underwent changes in both methane and cement binder due to the regional metamorphism, both the base mass and cement binder. In spite of the fact that the proportion of cement masses in the higher horizons is not large, however, quartzites of Kaone are a better quality mineral raw material as cleaner.

3 MATERIAL AND METHODS OF QUARTZITE TESTING AS THE MINERAL RAW MATERIAL

Within testing the quality of quartz mineral raw material, the earlier results of systematic testing of regional character (period from 1988 to the end of 1989) were used, by reconnaissance and geological mapping of the terrain surface, as well as development of shallow trenches. Sampling of trenches was carried out by outbreaking a rough furrow (in total 23 samples were taken, which were analyzed on: SiO_2, Al_2O_3, Fe_2O_3, Fe_2O_3 and CaO).

The basic method of detailed geological exploration the deposit of quartz raw material Kaon was the exploration depth drilling with coring. The Kaona deposit at Kucevo was explored by vertical cross-sections (Figure 4), exploration drilling from the terrain surface (9 vertical exploration drillholes). Total of 419.0 meters was drilled.

Geological works followed the exploration drilling; they were performed simultaneously and continued after them.

The applied test methods are reduced to sampling the exploration drillholes. Tests were taken for laboratory (chemical), petrological, and physico-mechanical tests. Testing of the exploration drillholes cores was carried out in parallel with the geological mapping the core of drillhole. For laboratory test (chemical) tests, individual samples were taken along the entire length of the drillholes (except the humus cover interval). The lengths of sampling the cores from drillholes were 2 m (exceptionally, 1.8 m or 2.5 m when, due to the lack of core, the two-meter interval could not be accurately determined). Total of 198 individual samples were taken. Total of 19 samples was taken for petrological testing of samples from exploratory drillholes (Table 6) of which 11 preparations were made. For laboratory tests of physical-mechanical properties, total of 104 samples was taken. The taken samples were analyzed in the MMI Bor laboratories (chemical tests, mineralogical-petrological, geomechanical tests and targeted technological tests).

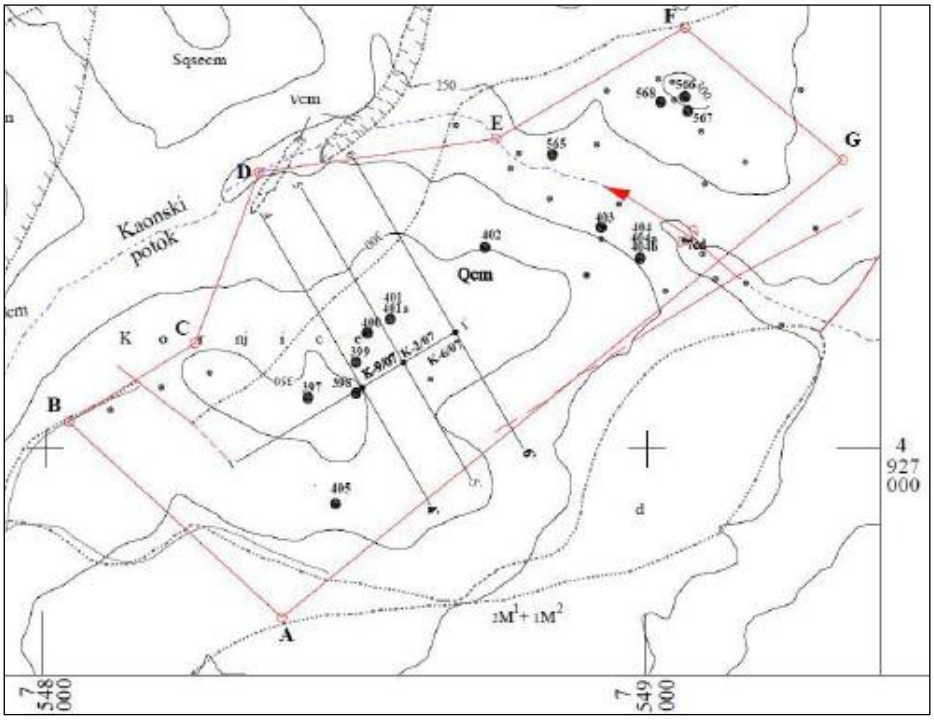

Figure 4 *Map of sampling the site Kornjice, 1:10 000 (a part of the leaf Kladurovo 2 L-34-128-Ca)*

Legend: ● ABCDEFG - Breakpoints of the exploration area of quartz mineral resources; ● 404 – petrological prospecting point; ● - chemical test outcrops in 1988; ● K-9/07 - petrological tests of exploration drillholes; 5-5' – Exploratory cross section

4 RESULTS OF TESTING THE QUALITY OF MINERAL RAW MATERIAL

4. 1 Chemical Characteristics of the Kaona Quartzite

The basic criterion for contouring the productive interval, i.e. determining the internal contour of the deposit, was a minimum content of SiO_2 of 85% and a maximum content of harmful substances: Al_2O_3 to 5.0%, Fe_2O_3 to 5.0% and CaO to 5.0%.

Based on the demands of certain branches of the quartz raw material industry, the existence of parts of deposits with different SiO_2 medium contents, which had to be taken into account in designing the model, were identified, so that three quality classes (Table 1) were separated within the base.

Table 1 *Quality classes of the deposit Kaona*

Quality class	Content of useful and harmful components (%)			
	Useful components	Harmful components		
	SiO_2	Fe_2O_3	Al_2O_3	CaO
QI	> 93.00	mah 5.00	mah 5.00	mah 5.00
QII	90.00 – 93.00	mah 5.00	mah 5.00	mah 5.00
QIII	85.00 – 90.00	mah 5.00	mah 5.00	mah 5.00

Witin testing the quality of quartz mineral raw material, the previous results of systematic testing of a regional character were also used. Sampling of a trench was done by outbreaking a rough furrow. The so-formed individual test sample was analyzed on: SiO_2, Al_2O_3, FeO, Fe_2O_3 and CaO (total of 23 samples were taken). The SiO_2 content ranges from a minimum of 93.82% to a maximum of 98.22%, and a mean content of 96.32 %. The Al_2O_3 content varies from a minimum of 0.10 % to a maximum of 1.63%, and a mean content of 0.68%. The Fe_2O_3 content varies from a minimum of 0.34% to a maximum of 2.12%, and a mean content of 0.96%. The FeO content varies from a minimum of 0.37% to a maximum of 1.01%, and a mean content of 0.64%. The content of CaO from the taken samples is in traces. Three composite samples were formed from the same samples. Composite samples were analyzed on: TiO_2, Cr_2O_3, MgO, K_2O, Na_2O, and loss by ignition. The results of chemical analyses of composite samples are shown in Table 2.

In the laboratory conditions, the chemical analyses of individual samples from drillholes were carried out on useful and harmful components: SiO_2, Al_2O_3, Fe_2O_3, CaO. From the individual samples, the composite samples (total of 41) were formed, which were tested for SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, S-total, SO_3, TiO_2, K_2O, Na_2O, Cr_2O_3 and loss by ignition.

A composite sample was obtained combining the material with five consecutive, individual samples p (ten-meter interval). The mean content of useful and harmful components in the drillholes, calculated on the basis of chemical analyses of individual samples, were obtained as weighted values by the length of testing interval, while the mean content was calculated for the whole deposit as the weighted value of the entire sampling interval (Table 3). The mean content of useful and harmful components, calculated by the MINEX 5.2.1 program package, from the composite samples by the selected quality classes, depending on the require-ments of application the mineral raw material, are shown in Table 4 for the whole deposit.

Table 2 *Results of outcrops sampling (composite test)*

Sample designation	Medium content (%)					
	TiO_2	Cr_2O_3	MgO	K_2O	Na_2O	G.Ž.
1-13 AB	0.033	0.000	0.027	0.172	0.033	0.390
10-20/ CD	0.033	0.027	0.015	0.183	0.031	0.140
17-A; 17-B; 17-C	0.080	0.000	0.029	0.251	0.037	0.280

Table 3 *Medium content of useful and harmful components (by drillholes, from individual tests)*

Drillhole designation	Medium content (%)			
	SiO_2	Fe_2O_3	Al_2O_3,	CaO
K-1/07	96.222	1.766	1.433	0.230
K-2/07	93.405	1.601	3.051	0.118
K-6/07	92.900	1.268	3.126	0.229
K-5/07	94.848	1.686	1.852	0.451
K-17/07	95.293	1.433	1.663	0.113
K-11/07	92.831	1.926	2.485	0.107
K-20/07	95.582	1.272	1.293	0.220
K-7/07	94.213	1.691	1.845	0.271
K-9/07	94.929	1.618	1.361	0.147
Whole deposit	94.442	1.569	2.013	0.215

Table 4 *Medium contents from composite tests by the quality classes, calculated by the software package MINEX 5.2.1.*

Quality class	Medium content (%)										
	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	Na_2O	K_2O	S	TiO_2	SO_3	Cr_2O_3
QI (> 93% SiO_2)	95.19	1.45	1.63	0.23	0.12	0.09	0.33	0.16	0.13	0.42	0.08
QII (90-93% SiO_2)	91.30	2.06	2.88	0.33	0.16	0.16	0.62	0.26	0.17	0.65	0.03
QIII (85-90% $SiO_{2)}$	88.72	2.42	5.26	0.07	0.20	0.16	0.88	0.14	0.18	0.35	0.04
Whole deposit	94.84	1.76	1.76	0.23	0.13	0.10	0.35	0.17	0.13	0.43	0.08

4.2 Petrographic Quartzite Characteristics

By a detailed observation and measuring on the outcropsa of rocks, the way of quartzite occurrence was determined, i.e. the exture properties of the same. Each outcrop is described, determined by coordinates and documented by the photographs on appearance and way of occurrence of these rocks (Figure 4). The samples of quartzite and quartz metaconglomerates were taken from the same outcrops for petrochemical testing (determining the mineral composition and rock structure and chemical testing.). Total of 14 samples were taken by the petrological prospecting the site Kornjica along the routes, parallel profiles, at a distance of 50 meters. Mineralogical - petrographic testing was carried out on selected samples from the drillholes (total of 11 samples) Total of 25 petrographic preparations were made. The examination of preparations was carried out on the Carl Zeiss/Jena polarization microscope, magnification up to 1200 x.

Based on the mineral composition, structure and texture, the Kaona quartztes are divided into: quartz metachonglomerates, massive quartzites, quartzite with sericity, cataclastic quartzite and quartzite with chloritide. Quartz metaconlomerates are dominant rocks in the researched area. They are of shrunken texture, build the banks of thickness up to a dozen meters (Figure 5). Macroscopic, on the ground, they

are recognized by quartz pebbles, size of 2 to 5 cm, which are deposited in a fine-grained quartz mass. The rock is mono-mineral, built of quartz, granoblastic structure withof elements of blastopsamitic and porphyroblastic. Quartz occurs in grains of size from the tenth part up to several millimeters. Bigger quartz grains make for the most part the pebbles, size up to several millimeters, when the wall gets blastopsamitic and porphyroblastic structure.

Figure 5 *Banks of quartz metaconglomerates on the north-eastern part of Kornjica, above left a detail of the rock*

4.3 Physical - Mechanical Characteristics of Quarcite

Physical-mechanical testing of samples from the exploratory drillholes (104 pcs.) was carried out on prepared test samples according to the valid standards for each type of test or according to the recommendations of the International Society for Rock Mechanics (ISRM). The following physical properties were determined on quartzite and quartz sand samples: humidity v = 11.40%, specific gravity or bulk density of solid particles γ_s = 18.84 kN/m^3, volume weight γ = 16.83 kN/m^3, porosity n = 3.58%, velocity of longitudinal wave propagation VL = 4.123.43 m/s. From the mechanical parameters, the following were tested: uniform pressure strength σp = 93.89 Mpa, and shear resistance parameters (cohesion C=25.57 MPa, and angle of internal friction φ = 27.88°).

4.4 Granulometric Characteristics of Quarcite

Testing the granulometric composition of the quartz mineral raw material from the Kaona deposit at Kučevo was carried out by

two methods. The first method is to test the grain size distribution of the composite samples. Composite samples were formed according to the quality classes for each individual drillhole (Figure 6). The second method of testing consisted in testing the grain size distribution of each individual sample from all drillholes. The grain size distribution the samples of the quartz mineral raw material of the Kaona deposit is characterized Kaon deposit that fine classes (-0.212 + 0 mm) and coarse classes (+4 mm) participate with about 10-30%. Classes -4 + 0,212 mm prevail, with a share of 70-90%.

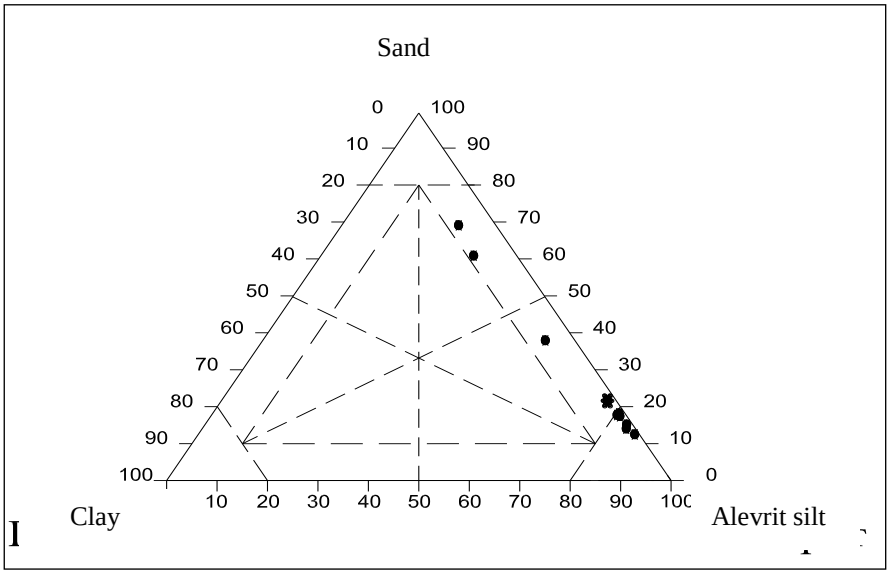

Figure 6 *Three-component diagram of particle size distribution of composite samples*

4.5 Results of direct technological quarcite testing

The direct technological tests (in order to determine the adequate technology to enable the cheapest production of commercial products through laboratory testing of disintegration, screening and atry sand washing), have resulted in a technological scheme for processing the quartz mineral raw materials in the Kaona deposit. A technological sample was formed of materials of all quality classes (run-of-mine raw material = minimal content of SiO_2 85% and maximum content of harmful substances: Al_2O_3 to 5.0%, Fe_2O_3 to 5.0% and CaO to 5.0%) and the results of these direct technological tests are shown in Tables 5 and 6. The proposed technological scheme for processing the quartz mineral raw materials for the Kaona deposit (Milanović et al., 2009, 2010) contains the primary disintegration into a washing drum, and the secondary disintegration in the atry washing equipment is omitted (based on the achieved laboratory results by simulation the process of atry washing).

Table 5 *Content of useful and harmful components in the useful fractions of deposit*

Particle size distribution	SiO_2	Al_2O_3	Fe_{-uk}	K_2O	Na_2O	TiO_2	Cr_2O_3	G.Ž
(mm)	%							
-30+2.362	96.33	1.62	0.93	0.49	0.052	0.19	0.10	0.053
-2.362+0.63	97.60	0.95	0.67	0.18	0.034	0.068	0.050	0.35
-0.63+0.106	96.13	1.39	0.90	0.26	0.057	0.15	0.11	0.98
-0.106+0.000	88.45	5.46	1.60	0.66	0.17	1.23	0.39	1.95

Table 6 *Physical-chemical characteristics of the run-of mine raw material, Kaona*

PHYSICAL - CHEMICAL CHARACTERISTICS		
Bond's index - balls	Wi (kWh/t)	12.71
Bulk density of dry sample	γ_s (kg/m^3)	1,102.6
Bulk density of wet sample	γ_v (kg/m^3)	1,363.83
Rough moisture content	v_g (%)	9.53
Density of sample	ρ (kg/m^3)	2,720
ELEMENT	**CONTENT (%)**	**ANALYTICAL METHOD**
SiO_2	95.22	G
Al_2O_3	1.53	AAS
Fe_2O_3	0.35	AAS
K_2O	0.069	AAS
Na_2O	0.37	AAS
TiO_2	0.13	ICP-AAS
Cr_2O_3	0.035	ICP-AAS
Fe	1.01	AAS
G.Ž.	0.88	G
pH	8.25	

5 DISCUSSION OF DIRECT TECHNOLOGICAL QUARTZITE TESTING

Quartz raw materials are used in: refractory industry, glass and ceramics industry, plastics industry, chemical industry (to obtain acid resistant materials, enamel for dishes), metallurgy (as fluxes, granulate production for metallurgical processing of ferro alloys), in casting industry (for molds and cores), construction, for production of silicate fillers, as well as the production of ferrosilicon (Table 7). The use of quartz raw materials depends on the quality (chemical composition) and physical-mechanical properties of the same.

The plan of mining exploitation of mineral resources (open pit mining) foresees the annual mining capacity of 150,000 t/year, commercial fractions or commercial products with application shown in Table 7, and

the expected annual production balance mass of the annual production is shown in Table 8. The proposed technology and technological solutions have achieved the primary goal: to obtain several commercial products for use in various industrial branches by a relatively small investment (simpler technology).

Table 7 *Fields of application the commercial size classes of quartz mineral resources*

Size class (mm)	Fields of application
-30.00+2.362	Construction, filter fillings, oil industry, air sand blasting
-2.326+0.630	Construction, filter fillings, oil industry, air sand blasting
-0.630+0.106	Casting industry (very good), glass industry (VIII class), ceramic industry (II class)
-0.106+0.053	Construction industry (gas, concrete), chemical industry, extractive metallurgy, casting industry, construction
-0.053+0.000	Building ceramics

Table 8 *Commercial products - expected balance of weight at the annual level, deposit Kaona*

Product	Size class (mm)	Production (t/h)	Mass (%)	Annual production (t/year)
P1	-30+15	3.24	9.08	13,617.60
P2	-15+2.362	5.23	14.65	21,976.66
P3	-2.36+0.63	16.29	45.61	68,418.75
P4	-0.63+0.106	9.54	26.70	40,041.56
Waste	-0.106+0.000	1.41	3.96	5,945.43
Capacity (Qyear)	150,000 t/year (35,712 t/h)			

CONCLUSION

Based on the results of detailed geological explorations (chemical, mineralogical - petrological and geomechanical tests) and direct technological testing (in the laboratory conditions), the deposit of quartzite Kaona is included in the first groupof the "Quartzite and quartz sand deposits of uniform thicknesses and chemical - mineral composition with the reserves amounts to over 1,000,000 tons of mineral raw materials". The exploration works include a small part of the deposit, an area of about 0.57 km^2, which indicates that the geological explo-rations of the deposit itself should be continued.

Due to the uneven quality of mineral raw materials of the Kaona deposit (chemical composition and physical - mechanical properties), the same can have limited application in the refractory industry, glass and ceramics industry, plastics indu-stry, chemical industry (to obtain acid resistant materials, enamel dishes), metallurgy (as fluxes, production of granules for metallurgical processing of ferro alloys), casting industry (for molds and cores), construction, for the production of silicate fillers, as well as the production of ferrosilicon.

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IMPORTANCE OF PLANNING THE OPEN PITS IN THE CONDITIONS OF CONTEMPORARY MINING - A CASE STUDY: THE OPEN PIT SOUTH MINING DISTRICT MAJDANPEK[***]

Abstract

In today's financial and environmental climate, it is imperative to develop the robust projects with good economics. Successful business in conditions of limited resources is impossible without analyzing all the technical and economic parameters and scenarios of sustainable operation. In this sense, it requires the application of mathematical algorithms implemented in the contemporary software tools able to efficiently provide the effective troubleshooting of design in complex conditions of modern mining.

This paper, an example of the open pit South Mining District Majdanpek, shows the importance of planning and design the ore exploitation in achieving the maximum net present value (NPV).

Keywords: *planning, optimization, net present value, open pit South Mining District Majdanpek*

INTRODUCTION

Mine planning is aimed at one goal: maximizing the value to be realized from extracting the mineral resources. This goal achievements depends primarily on the ability of an engineer to realize the all issues related to the production process in terms of the number of alternatives related to the investment and exploitation factors. The decisions are updated through time, usually annually, as a new information becomes available.

The size, location and final shape of an open pit are important in planning the location of waste dumps, stockpiles, processing plant, access roads and other surface facilities, and for development the production program. The pit design also defines the minable reserves and associated amount of waste to be removed during the operation life. Over the past 50 years, determining the optimum open pits has been in the areas of operational research in the mining industry.y and many algorithms have been published.

The design and scheduling of open pit mines is a significant and complex problem in the mine planning. The principal aim of mining operation is to ensure that an ore body is exploited in a way such that the value realized from the mine is maximum. A well-known early contribution to this field was made by Lerchs and Grossmann [8], who presented a graph-theoretic algorithm for determining the final con

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tour of the open pit, known as the *ultimate pit*, such that the total profit from the mine is maximized.

Some optimization methods for solving problems of mine scheduling are the heuristics (Gershon [1]), dynamic programming (Onur and Dowd [2], Wang [3], parametric methods (Whittle [4]), Tolwinski and Underwood [5], Tolwinski i Golosinski [6]), integer linear programming (Gershon [7], Smith [8], Caccetta and Hill [9]) and Mixed Integer Linear Programming – MILP (Vahid Rafiee i Omid Asghari [10]).

METHODOLOGY

Mining processes are complex and complicated, with many different economic, technical, environmental and other parameters that must be planned before the project gets its practical value. Many of these parameters are evaluated independently of the other, due to the expediency and difficulty in predicting the values of variables under consideration. Costs, prices, reserves, ore mining and processing, as well as many aspects of society, such as the issuance for implementation of works are absolutely essential for the project evaluation.

Each ore body is different, but the main steps in the open pit planning, when the main objective is the maximization of NPV, take place on the same principle. These steps are for simplicity represented as linear. The actual planning process is an iterative process in which some steps or combination of steps are repeated many times with the sensitivity analysis.

Achieving the maximum NPV is realized by the procedure which comprises first the optimization of open pit and defining the phase of open pit development (pushbacks) with calculation the ore amount and mineral content in each phase. The next step is to optimize the mining dynamics.

Blok model of deposit, created by the method of geostatistical modeling, with separate areas of useful mineral blocks and non-profit blocks of waste, allows engineers to select the appropriate mining methods and plan the necessary equipment and infrastructure that are essential for development the process of ore mining. Blok model of deposit is a major input in the optimization process of the open pit.

Optimization of the open pit comprises obtaining a possible contour of the open pit, based on a block model of deposit, which has an economic value, and which can be calculated. The term a possible contour of the open pit means an open pit contour with maximum inclination of general slope, formed after mapping the transport routes and safety berms, and which meets the stability criteria.

To calculate the economic value, the sequence of excavation has to be firstly defined, and then, progressively with excavation, to accumulate the income and expenses. Application the principle of the time value of money, or that a dollar that is obtained today, is more valuable than the one that will (maybe) be obtained next year, means that discounting of revenue and costs is done by a factor that increases over the life of the mine.

Another thing to note is that the calculation of values is made for each block in the block model, or each block has its economic value. Calculation the economic value of the block (EVB) requires a detailed knowledge of a large number of parameters, such as the content of useful component in a block, the selling price of useful component, the costs of mining and processing, cut-off grade in mining and processing, recoveries in mining and processing.

Today's the open pit optimization techniques, which are implemented in specialized software, finding the optimal contour of the open pit are based on maximizing the NPV. This ensures that there is no independent block or combination of blocks that can be added or subtracted within the contour of the pit, which would lead to an increase in the NPV.

Optimization the open pit limit and mining dynamics was carried out in this work using Whittle software. Whittle process is based on a rapid implementation the series of the Lerchs-Grossmann (LG) algorithm. This algorithm provides the mathematically optimal ultimate open pit limit when the criterion for optimization is the maximum undiscounted cash flows. The process is used for selection the optimum final pit limit for the best and worst case of the mining excavation plans for which the NPV curves are obtained. A wide range of possible open pits is generated by this way including an engineer selecting the optimum open pit, which once again confirms that an engineer still has an irreplaceable role in design despite the a strong software development and computer equipment.

In the process of optimization of mining dynamics, a simulation and discounted cash flow analysis (DCF) are done to obtain the most favorable solution, that is, to determine the number of phases which affects maximization of the net present value in a long - term planning of the open pits.

The analysis is based on the Milawa algorithm, which is specifically designed to optimize the mining dynamics in the long-term planning strategy of mining.

The Net Present Value is calculated by discounting the estimated annual cash flows at the current time using the discount rate, which represents the risk of investment.

$$Net\ Present\ Value\ (NPV) = \sum_{t=0}^{N} \frac{Cash\ Flow\ (CF)}{(1+k)^t} \quad (1)$$

where:

k - discount rate

t - number of years.

The importance of planning the open pits is seen in the case of the open pit South Mining District Majdanpek in which the copper ore is mined. The analysis of mining dynamics for current real indicators of mining conditions at the open pit and designed mining dynamics, and within the framework of the project defined the optimal contours of the open pit, has shown how the business operations of a mining company is sensitive to the changes in mining production.

CASE STUDY

The open pit South Mining District of the Copper Mine Majdanpek is located in the south of the town of Majdanpek in its immediate vicinity. Mining of copper ore at the open pit South Mining District is carried out using a discontinuous technology of excavation, using the drilling - blasting works and loading - transport machines.

The open pit South Mining District operates within the company Copper Mine Majdanpek, which is part of the company Mining and Smelting Basin Bor Group (RTB Bor Group).

In 2013, the project was developed that reviewed the long-term development of the open pit South Mining District Majdanpek [11]. Input data for defining the final limits of the open pit and mining dynamics in the software Whittle are provided in the following Table 1.

Table 1 *Techno-economic data for analysis [11]*

Parameter	Unit	Value
Base metal prices		
- Copper	$/t	6,000
- Gold	$/kg	35,000
- Silver	$/kg	650
Costs of ore mining	$/t	1.50
Costs of waste mining	$/t	2.50
Costs of flotation ore processing		
- Up to 2014	$/t	4.00
- Period after 2014	$/t	3.20
Costs of metallurgical treatment of concentrates		
- Costs of copper production from concentrates		
- 2013	$/t Cu cathode	850
- Period after 2013	$/t Cu cathode	600
- Costs of gold refining	$/kg	150
- Costs of silver refining	**$/kg**	15
Flotation copper recovery from ore		
- Up to 2014	%	80
- Period after 2014	**%**	86
Metallurgical copper recovery from ores		
- Up to 2014	%	94
- period after 2014	%	98
Total recovery of gold	%	50
Total recovery of silver	t/year	50
Annual processing capacity of ore	t/year	8,500,000
Discount rate	t/year	10

The basic problem of production system at the open pit, in the period from 2013 to the present day, is related to a delay in relocation the major infrastructure facilities, located in a newlydefined contour of the open pit (the route of the state road M22 I B series, a part of the route of the existing 35 kV transmission line, the riverbed of the river Mali Pek, the urban waste water collector), as well as pumping of the mine water, whose starting level was at a height of k+221, and these are amounts of 15,136,286 m^3. This caused a delay in the ore stripping and therefore deviation from the designed solutions and parameters that guarantee the maximum NPV, which is verified by the techno-economic analysis of the project.

The conducted analysis is aimed to determine the resulting implications in the company business, which is reflected primarily in the lost profit due to deviations from the optimal mining dynamics defined by the mining project.

The amount of ore and overburden in the early years, from the first to the fifth year, represent the real amounts, excavated at the open pit South Mining District Majdanpek [12].

Geological reserves of the copper deposit South Mining District Majdanpek are calculated by the method of mini blocks, sizes 15x15x15 m. The basis for calculation the geological reserves is a digital block model of the deposit which was formed in the software Gems [13, 14]. Geostatistical

method that, used to assess the content of metals in the process of deposit modeling is a method of real kriging.

Figure 1 shows a three-dimensional block model of Cu in the deposit South Mining District.

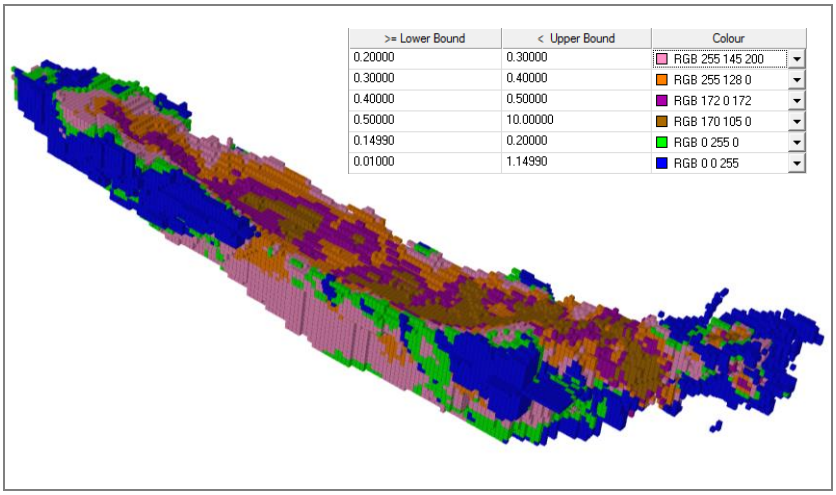

Figure 1 *View the 3D block model of the deposit South Mining District Majdanpek*

On the basis of a defined block model of the deposit, the optimization of the final contour of the open pit was done in the software Whittle and defined development phases of the open pit; six pjases are defined, wherein the sixth phase is the final contour of the open pit, Figure 2.

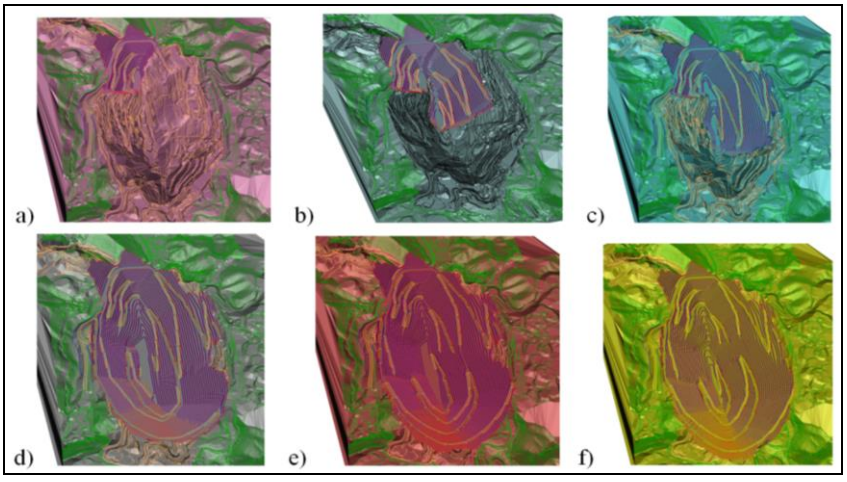

Figure 2 *View of the final contour of the open pit mining South Mining District Majdanpek (3D) [15]*

a) Phase 1; b) Phase 2; c) Phase 3; d) Phase 4; e) Phase 5; f) Phase 6 (final contour of the open pit)

RESULTS AND DISCUSSION

Maximization of the NPV of the project in the life time of the mine was carried out by optimization the mining dynamics.

The results of carried out analysis are shown in the following graphs in Figures 3 and 4.

Figure 3 *Mining dynamics for the project design and conducted analysis*

The following can be concluded from the graph in Figure 3:

1) During the period from the first to the sixth year, significantly lower amounts of ore and overburden were mined relative to the designed amounts.

2) The amounts of overburden are-balanced by the project, which in the period up to 13th year have a uniform value, and then decline steadily until the end of mining life.

3) The conducted analysis shows that it is necessary to significantly increase the annual amounts of overburden to achieve the required capacity of ore mining.

4) The lifetime of the mine was increased by 4 years, while the amounts of ore and overburden are the same.

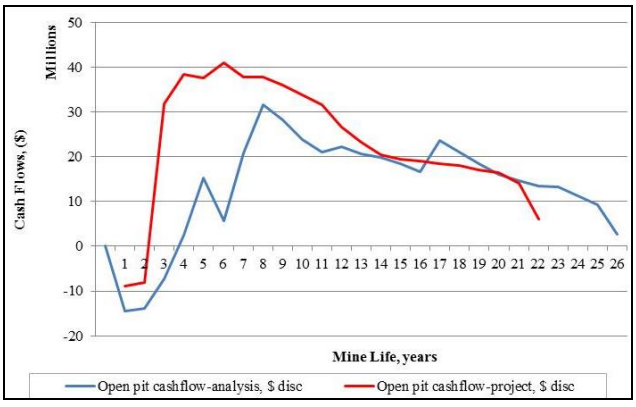

Figure 4 *Cash flows for the project design and conducted analysis*

Graph in Figure 4 indicates the following:

1) Cash flows in the period up to 3rd year of mining are negative for the conducted analysis and total to – 35,771,590 $. In the project design, the negative values of cash flows are up to 2nd year of mining and amount to $ -16,912,075.
2) The curve of cash flows for the conducted analysis, after reaching a positive value grows much slower and has less value compared to the curve of cash flows for the solution provided in the project.

Based on the generated cash flows, the maximum NPV are calculated and to be achieved in the following cases:

- NPV obtained by the project design is 507,621,108 $,
- NPV obtained by the conducted analysis is 354,763,334 $.

Due to a deviation from the given solution in the project, or the planned mining dynamics, there was a realization of smaller cash flows in the initial years of operation and longer mining life of the open pit, what have also increased the discounting time that has a significant reduction in the NPV in the amount of 152,857,774 $ in the end result.

CONCLUSION

Planning every mining operation has the main goal to achieve the best economic effects of business in the life time of the mine. Also, the mining company may want to simultaneously maximize the NPV, the life time of the mine and metal content in the ore, and on the other hand to minimize the capital expenditures, which is difficult to achieve. The most common case is that the main objective of the company is to maximize the NPV, and that the life time, reserves and capital costs are in certain acceptable limits.

The main value of the conducted analysis is that the real case shows how important it is the planning in the mining system in terms of achieving the best business results. Analysis indicates that any deviation from the planned solutions in a project can lead the business to be affected, not only mine, but also the entire company of RTB Bor Group.

Analysis has showed that the deviation from the planned mining dynamics, within the project defined optimal contour of the mine, resulting in a reduction the projected values of the NPV for 30%, or 152,857,774 $.

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SELECTION THE RATIONAL MODEL OF TRANSPORT TRUCK BY THE SELECTIVE COAL MINING AT THE OPEN PIT GACKO[**]

Abstract

This paper gives the selection of the optimal model of trucks for transport of coal, and seam waste at the OP Gacko in terms of selective exploitation. Mining of coal and seam waste is carried out in two exploitation zones, the central and roof zone, and the coal and waste transport and disposal is carried out to the different crushing plants and landfills. Using the software package Talpak, the capacity of a truck for transport of coal, and seam waste was calculated for different transport routes and types of trucks. The analysis was done for three types of trucks: Belaz 7555, Belaz 75491 and Belaz 75135. The results analysis were used for evaluation, ranking and selection the optimal type of truck.

Keywords: *truck transport, OP Gacko, transportation costs*

INTRODUCTION

Works on coal mining at the open pit Gacko currently performed by the Main mining project of the open pit Gacko - Central field capacity of $2.3 \cdot 10^6$ t/year of run-of-mine coal. Mining takes place in two zones, the roof and central exploitation zone.

Excavation the overburden and interseam waste in the central zone of the open pit (the zone of exploitation the main and the first and the second floor of coal seam), is carried out within the second continuous BTO system and within the DTO the combined system. Overburden excavated by the bucket wheel excavator type ER 1250 17/1.5 within the first BTO system is transported by conveyor belts with a belt width of 1200 mm and disposed on the West outer landfill by a spreader Ars 1200 (20 + 50) * 21. In the case of the second BTO system, the base of excavation equipment includes a bucket-wheel excavator ER 1250*16/1, which operates in tandem with a selfpropelled transporter P of 1600*21/50. Disposal is done in the excavated space of the Field B. In addition to a continuous system in the excavation of overburden, the hydraulic shovel excavators Komatsu PC 2000, Terex RH 90C, D 475 bulldozer Comatsu in tandem with a loader Komatsu WA 700 and a combine Wirtgen 2500SM. Transport of overburden is carried out by trucks, capacity of 110 t (trucks BELAZ 75135) to the crusher SB are 1525 (DTO system).

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Coal mining is done applying the technology of selective mining. The following hydraulic shower excavators are engaged on these activities are engaged: Komatsu PC 800, Hyundai R800, and CAT 385B. Removed quantities of coal are transported by truck 55 t (BELAZ 7555) to the primary crusher for coal SB 1315, and SB 1515 (DTD system).

TRANSPORTATION SYSTEMS OF COAL AND SEAM WASTE

Transportation of coal and waste excavated in the process of selective coal mining is divided into internal and external. Having in mind, the coal excavation and seam waste takes place in two spatially separate exploitation wholes, the central zone and roof zone. In each zone and for different periods of development work, there are the appropriate schemes of coal and seam waste transport, given in Figures 1 and 2.

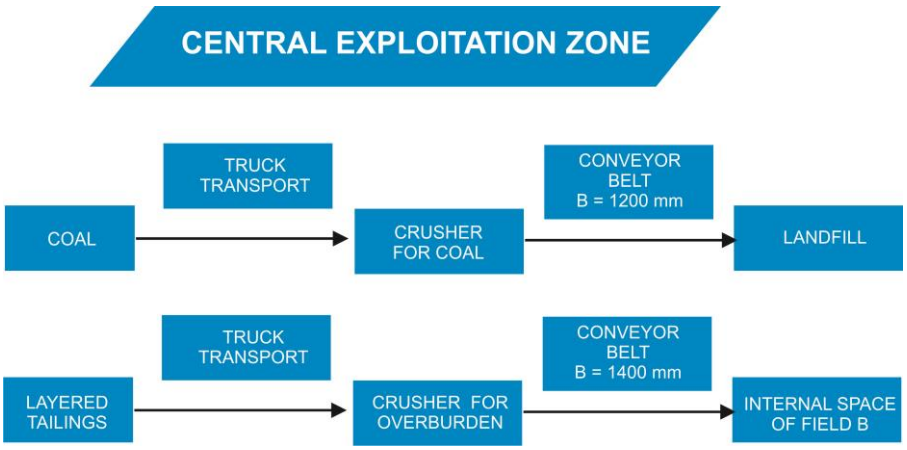


Figure 1 *Scheme of coal and waste transport in the central zone of exploitation*

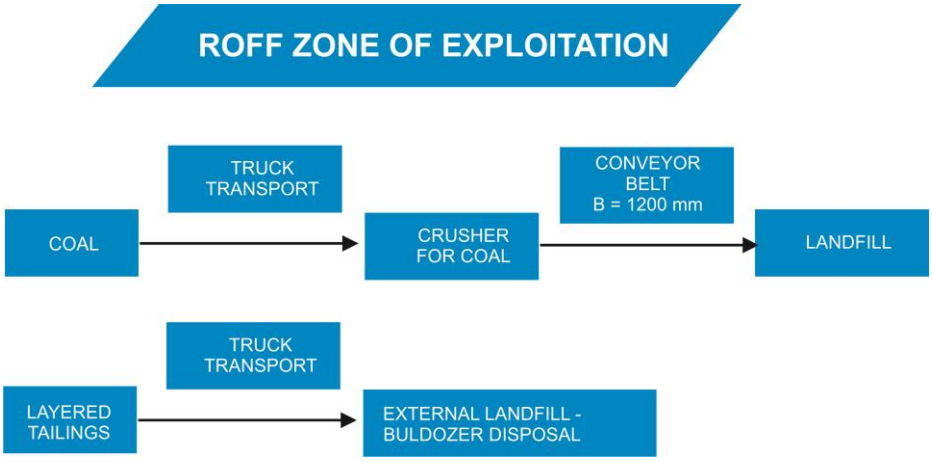


Figure 2 *Scheme of coal and waste in the roof zone of exploitation*

Internal transport of coal is by trucks and takes place from the excavation site to the crushing plants for coal.

Internal transport of waste is by truck in the central zone of exploitation and takes place from the excavation site to the crushing plant for waste, or DTO crusher system. Transport of waste in the roof zone of exploitation is by truck from the excavation site to a place of disposal on the external landfill.

External transport of coal takes place from the crushing plants to the landfill of the power plant by belt conveyors, belt width 1200 mm. The external transport of waste from the central coal series takes place from the crushing plant for waste to the site of disposal in ther excavated area of the Field B. Disposal of waste tailings is carried out within a disposal of overburden from the central zone of the open pit, or by a combined system (DTO, crusher-conveyor belt-stacker). Disposal is done by a stacker type OS 1600.

CALCULATION THE TRUCK TRANSPORT

Computer program Talpac was used for calculation the system excavator - truck used a computer program Talpac. Based on the input parameters, a hourly capacity of the truck was calculated for a particular relation.

Software package Talpak is a simulation of the loading and transport process at the open pits. The software optimizes the transport fleet budget, calculation the technical and economic parameters of equipment operation such as a cycle length, capacity, etc. In the present case, this program was used to determine the parameters in transport of various materials (coal and waste) and from different sites (the central zone and roof zone of exploitation). The calculation results are used as the base for the operating costs of transport.

The organization of work at the open pit Gacko is 365 days a year, 7 days a week in 3 shifts. Total effective time during the year amounted to 3,500. Based on these organizations, following the planned working time was used for calculation the loading and transport:

- Total possible number of shifts per year:	1,095 shift/year
- Duration of a shift:	8 h
- Operating hours per year:	8,760 hours
- Effective working hours per shift	5.5 h
- Effective working hours per year	3,500 hours

Presented planned and effective working hours at the open pit was used in the software Talpac for calculation the loading and transport system. Table 1 shows the input parameters and loading mechanization used for calculation. Table 2 shows the input parameters for the transport mechanization required for calculation.

Table 1 *Characteristics of loading machinery*

Komatsu PC 800				
	Parameters			
	Showel volume (m^3)	6	Motor power (kW)	363
	Speed (km/h)	4.2	No. of revolutions (rpm)	1800
	Excavation depth (m)	8.45	Weight (kg)	75200
	Medium ground pressure (N/cm^2)	12.2	Length of rig (mm)	7500
	Caterpillar width (mm)	610	Total length (mm)	14405
	Width of caterpillar base (mm)	4110	Height of branch	4690
	Length of caterpillar base (mm)	5810	Cabin height	3670
	Shovel width (mm)	2200	Total width	4110

Table 2 *Characteristics of transport mechanization*

Truck Belaz 7555-55 tons		
	Hopper capacity (m^3)	37.5
	Engine power (kW)	522
	Capacity (t)	55
	Max. speed (km / h)	55
	Dump angle (^{o})	47
	Weight (kg)	41000
	Total height (mm)	4610
	Total width (mm)	5240
	Total length (mm)	8890
	Price (KM)	800 000
Truck Belaz 75491-80 tons		
	Hopper capacity (m^3)	46
	Engine power (kW)	630
	Capacity (t)	80
	Max. speed (km / h)	50
	Dump angle (^{o})	46
	Weight (kg)	72500
	Total height (mm)	5350
	Total width (mm)	5420
	Total length (mm)	10300
	Price (KM)	1 300 000
Truck Belaz 75135-110 tons		
	Hopper capacity (m^3)	71.2
	Engine power (kW)	895
	Capacity (t)	110
	Max. speed (km / h)	50
	Dump angle (^{o})	47
	Weight (kg)	100100
	Total height (mm)	5900
	Total width (mm)	6400
	Total length (mm)	11500
	Price (KM)	1 800 000

Based on the entered data, the hourly capacities of the truck were calculated for the certain relation expressed in čm^3/h when operating in conjunction with the loading equipment. Based on the amounts that should be transported into a specific route and hours of operation, for each zone of work implementation in the considered period of exploitation, the number of required trucks was calculated. Number of trucks needed in the corresponding period was calculated based on the total time required for truck engagement for the amounts of coal and seam waste from the individual work sites, and for the specific transport lengths. Tables 3, 4 and 5 are give the parameters of loading and transport system, calculated in the software package Talpac. Calculations are made according to the annual periods for the three types of trucks (Belaz 7555, Belaz 75491, Belaz 55135), depending on the zone of exploitation (roof and central zone) and the type of materials (coal and seam waste).

Table 3 *Parameters of transport by the trucks type Belaz 7555*

Year	Place	Central Zone - Coal	Central Zone – seam waste	Roof zone - coal	Roof zone – seam waste	Required number of trucks	Reserve in capacity (%)
2017	Quantities (čm^3)	703,125	175,732	1,077,000	357,712	10	24.50%
	Capacity of transp. truck (čm^3/h)	98.8	89.4	69.9	47.8		
	Required time of engagement (h)	7,114	1,965	15,401	7,484		
2018	Quantities (čm^3)	703,125	155,418	1,077,000	521,436	11	19.64%
	Capacity of transp. truck (čm^3/h)	92.5	84.9	66.5	46.7		
	Required time of engagement (h)	7,601	1,831	16,203	11,156		
2019	Quantities (čm^3)	703,125	94,935	1,077,000	769,835	13	17.72%
	Capacity of transp. truck (čm^3/h)	78.3	68.4	55.54	46		
	Required time of engagement (h)	8,978	1,389	19,392	16,735		
2020	Quantities (cm^3)	703,125	208,438	1,077,000	589,884	14	21.51%
	Capacity of transp. truck (čm^3/h)	70.29	62.86	56.16	39.67		
	Required time of engagement (h)	10,003	3,316	19,177	14,870		

Table 4 *Parameters of transport by trucks type Belaz 75491*

Year	Place	Central Zone - Coal	Central Zone – seam waste	Roof zone - coal	Roof zone – seam waste	Required number of trucks	Reserve in capacity (%)
2017	Quantities (čm^3)	703,125	175,732	1,077,000	357,712	9	12.00%
	Capacity of transp. truck (čm^3/h)	109.32	99.25	77.32	59.81		
	Required time of engagement (h)	6,430	1,771	13,929	5,981		
2018	Quantities (čm^3)	703,125	155,418	1,077,000	521,436	10	9.00%
	Capacity of transp. truck (čm^3/h)	96.22	97.03	72.23	51.99		
	Required time of engagement (h)	7,309	1,602	14,912	10,030		
2019	Quantities (čm^3)	703,125	94,935	1,077,000	769,835	11	8.40%
	Capacity of transp. truck (čm^3/h)	92.84	89.08	70.53	58.36		
	Required time of engagement (h)	7,572	1066	15,270	13,192		
2020	Quantities (cm^3)	703,125	208,438	1,077,000	589,884	12	7.80%
	Capacity of transp. truck (čm^3/h)	77.5	58.08	70.34	49.37		
	Required time of engagement (h)	9,072	3,581	15,312	11,949		

Table 5 *Parameters of transport by trucks type Belaz 75135*

Year	Place	Central Zone - Coal	Central Zone – seam waste	Roof zone - coal	Roof zone – seam waste	Required number of trucks	Reserve in capacity (%)
2017	Quantities (čm^3)	703,125	175,732	1,077,000	357,712	6	21.25%
	Capacity of transp. truck (čm^3/h)	120.3	142.3	120.1	96.1		
	Required time of engagement (h)	5,844	1,235	8,964	3,721		
2018	Quantities (čm^3)	703,125	155,418	1,077,000	521,436	7	27.48%
	Capacity of transp. truck (čm^3/h)	120.3	109.8	120.2	93.8		
	Required time of engagement (h)	5,843	1,415	8,964	5,559		
2019	Quantities (čm^3)	703,125	94,935	1,077,000	769,835	7	16.16%
	Capacity of transp. truck (čm^3/h)	120.2	109.1	119.9	90.4		
	Required time of engagement (h)	5,848	870	8,986	8,515		
2020	Quantities (cm^3)	703,125	208,438	1,077,000	589,884	7	18.52%
	Capacity of transp. truck (čm^3/h)	120	108.9	118.9	86.3		
	Required time of engagement (h)	5,858	1,915	9,058	6,835		

Based on the determined parameters of transportation the masses of coal and waste, the costs of standardized material were calculated. The standardized materials included: fuel (kg/čm^3), lubricant (kg/čm^3), an oil (kg/čm^3), tires (pcs.) and spare parts (kg/čm^3), Table 6 gives a summary of the standardized material costs per year for three types of trucks. Based on the calculated standardized costs, the calculation was made of the total operating costs, and they are shown in Table 7.

Table 6 *Costs of standardized material per year*

Normative costs per year									
Type of truck	**Years**	**Unit costs (KM/čm^3)**	**Unit costs (KM/t)**	**Unit costs (KM/čm^3)**	**Unit costs (KM/t)**	**Unit costs (KM/čm^3)**	**Unit costs (KM/t)**	**Unit costs (KM/čm^3)**	**Unit costs (KM/t)**
		CZ-U*	**CZ-U**	**CZ-SJ†**	**CZ-SJ**	**KZ-U‡**	**KZ-U**	**KZ-SJ§**	**KZ-SJ**
Belaz 7555	2017	1.574	0.984	1.721	1.076	2.151	1.344	3.062	1.914
	2018	1.669	1.043	1.803	1.127	2.251	1.407	3.130	1.956
	2019	1.939	1.212	2.194	1.371	2.660	1.663	3.175	1.984
	2020	2.140	1.337	2.371	1.482	2.633	1.646	3.652	2.283
Belaz 75491	2017	1.685	1.053	1.838	1.148	2.308	1.442	2.931	1.832
	2018	1.890	1.181	1.875	1.172	2.458	1.536	3.344	2.090
	2019	1.952	1.220	2.027	1.267	2.513	1.570	2.999	1.874
	2020	2.303	1.439	3.013	1.883	2.519	1.574	3.512	2.195
Belaz 75135	2017	2.381	1.349	2.041	1.156	2.384	1.351	2.935	1.663
	2018	2.381	1.349	2.591	1.468	2.383	1.350	3.003	1.701
	2019	2.383	1.350	2.607	1.477	2.388	1.353	3.109	1.761
	2020	2.386	1.352	2.611	1.479	2.407	1.364	3.248	1.840

Table 7 *Operating costs of the different types of trucks*

			CZ-U	**CZ-SJ**	**KZ-U**	**KZ-SJ**
Truck Belaz 7555	2017	The required quantities (čm^3)	**703,125**	**175,732**	**1,077,000**	**357,712**
		Total (KM)	1,106,892	302,408	2,316,299	1,095,254
	2018	The required quantities (čm^3)	**703,125**	**155,418**	**1,077,000**	**521,436**
		Total (KM)	1,173,661	280,143	2,424,814	1,631,945
	2019	The required quantities (čm^3)	**703,125**	**94,935**	**1,077,000**	**769,835**
		Total (KM)	1,363,556	208,279	2,865,060	2,443,918
	2020	The required quantities (čm^3)	**703,125**	**208,438**	**1,077,000**	**589,884**
		Total (KM)	1,504,519	494,291	2,835,571	2,154,515
Truck Belaz 75491	2017	The required quantities (čm^3)	**703,125**	**175,732**	**1,077,000**	**357,712**
		Total (KM)	1,184,685	322,920	2,485,396	1,048,314
	2018	The required quantities (čm^3)	**703,125**	**155,418**	**1,077,000**	**521,436**
		Total (KM)	1,328,744	291,486	2,646,879	1,743,859
	2019	The required quantities (čm^3)	**703,125**	**94,935**	**1,077,000**	**769,835**
		Total (KM)	1,372,512	192,415	2,706,005	2,308,698
	2020	The required quantities (čm^3)	**703,125**	**208,438**	**1,077,000**	**589,884**
		Total (KM)	1,619,129	627,928	2,712,791	2,071,830
Truck Belaz 75135	2017	The required quantities (čm^3)	**703,125**	**175,732**	**1,077,000**	**357,712**
		Total (KM)	1,673,999	358,590	2,568,067	1,049,887
	2018	The required quantities (čm^3)	**703,125**	**155,418**	**1,077,000**	**521,436**
		Total (KM)	1,673,999	402,728	2,566,091	1,565,642
	2019	The required quantities (čm^3)	**703,125**	**94,935**	**1,077,000**	**769,835**
		Total (KM)	1,675,286	247,470	2,572,027	2,393,199
	2020	The required quantities (čm^3)	**703,125**	**208,438**	**1,077,000**	**589,884**
		Total (KM)	1,677,867	544,270	2,592,028	1,915,858

* *Central Zone - coal,*
† *Central Zone – seam waste*
‡ *Roof zone - coal,*
§ *Roof zone – seam waste*

CAPITAL AND OPERATING COSTS OF VARIANT SOLUTIONS

In order to gain a clearer status on the costs of variant solutions, the calculation of the capital costs was made. Capital expenditure (capex) were calculated as annuity loans for the purchase of a truck loan. The loan was calculated for the following conditions: the return period 10 years, interest rate of 6%. The operating costs (opex) included the total standardized costs per year in the areas of exploitation. Table 8 gives the total values of capital and operating costs. Figure 3 and Figure 4 shows a graph of movement the capital and operating costs for three types of trucks.

Table 8 *Capital and operating costs (KM)*

Type of truck	costs	2017	2018	2019	2020	Σ
Belaz 7555	opex	4,820,853	5,510,564	6,880,814	6,988,895	24,201,126
	capex	1,280,000	1,360,000	1,563,200	1,628,800	5,832,000
Belaz 75491	opex	5,041,315	6,010,968	6,579,629	7,031,678	24,663,590
	capex	2,402,000	2,009,800	2,139,800	2,262,000	8,813,600
Belaz 75135	opex	5,650,541	6,208,460	6,887,982	6,730,024	25,477,007
	capex	1,728,000	1,951,200	1,875,600	2,008,000	7,562,800

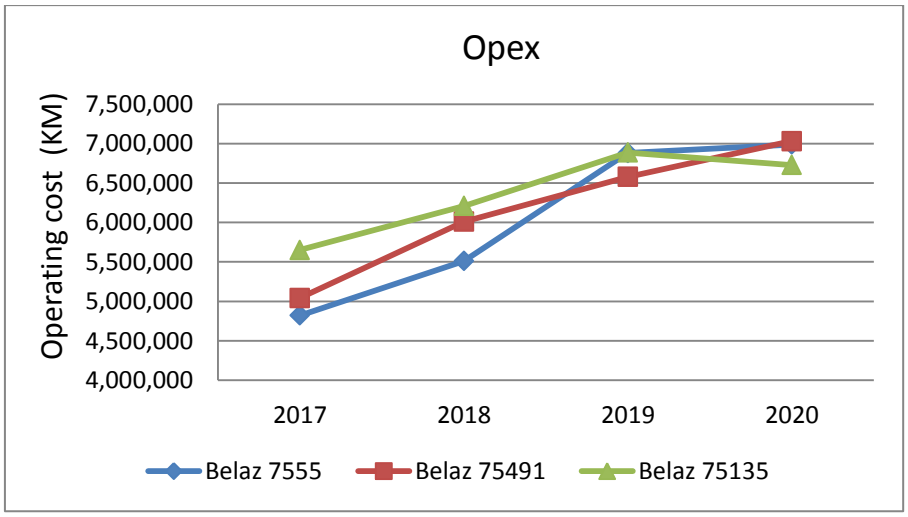


Figure 3 *Operating costs by type of truck*

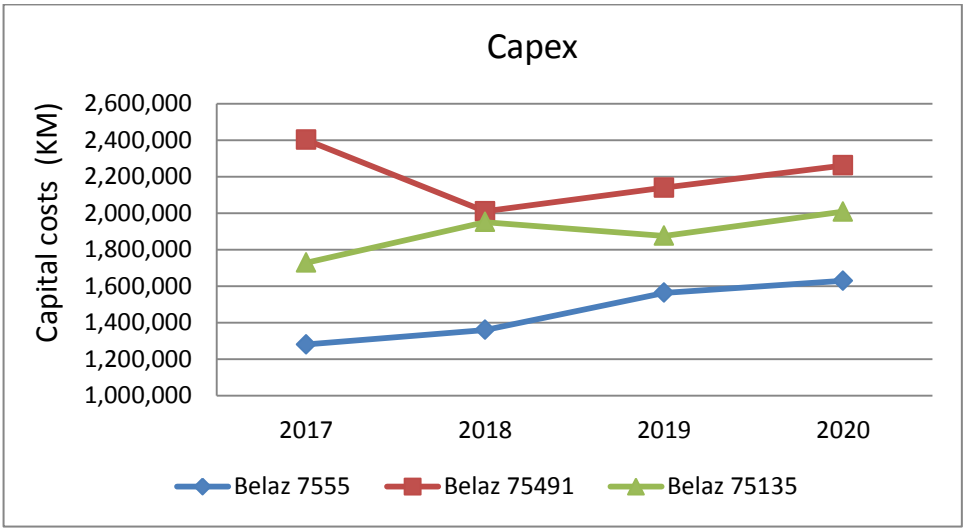
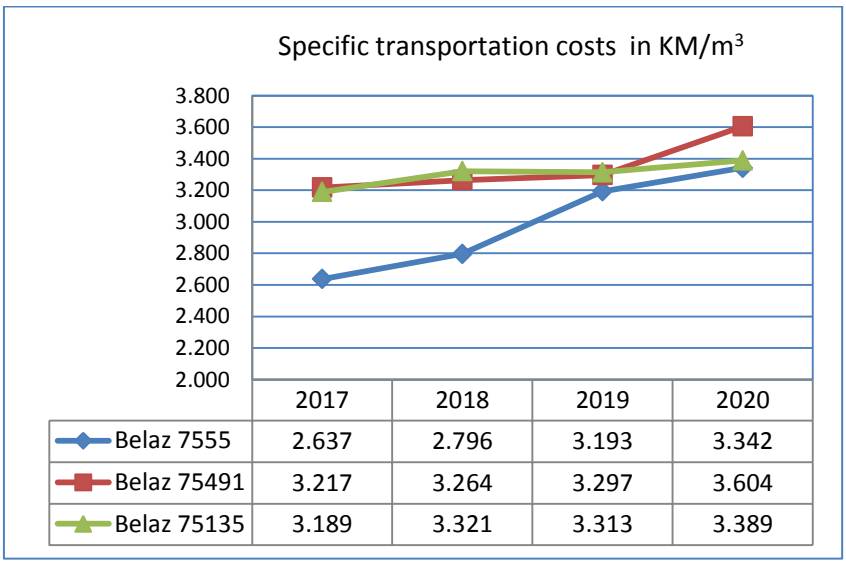


Figure 4 *Capital costs by type of truck*

TRANSPORT COSTS PER VARIANT SOLUTIONS

Specific costs of transport according to the variant embodiments given as a ratio of the total cost and weight needed to conduct necessary transported per year periods, and the values are shown in the diagram in Fi-gure 5. Cost unit quantity of material is provided in the HP/m^3.



	2017	2018	2019	2020
Belaz 7555	2.637	2.796	3.193	3.342
Belaz 75491	3.217	3.264	3.297	3.604
Belaz 75135	3.189	3.321	3.313	3.389

Figure 5 *Specific transportation costs KM/m^3*

Figure 6 shows the specific transport costs, expressed per meter of transport. These specific costs are given for the medium annual transport lengths. A medium transport length per some years is calculated as a weighted mean of length of transport route by the amount of material that is transported.

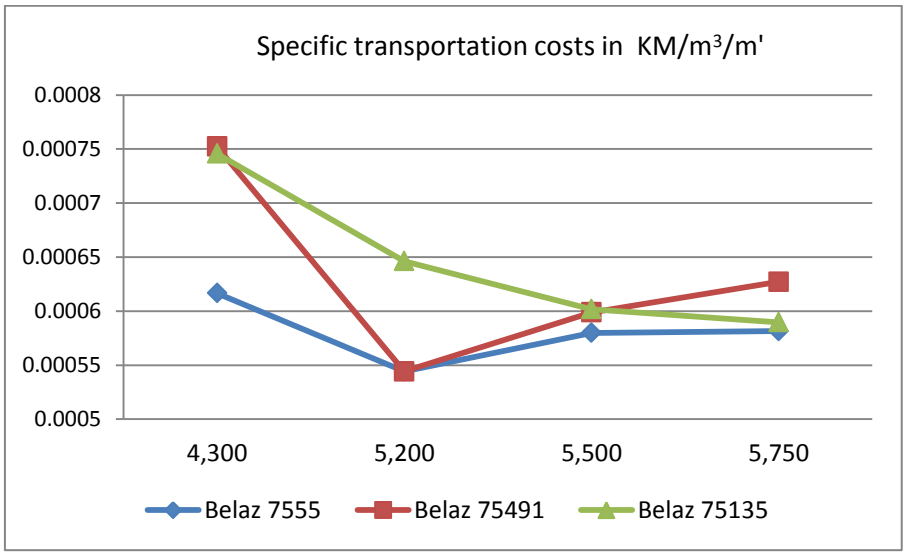


Figure 6 *Costs per meter of transport route*

CONCLUSION

Based on the calculated values of the technical and economic parameters of transport, as the most type of truck is allocated a truck Belaz 7555 capacity 55 t. The optimal type of truck can be determined through the present procedure of analysis, which has to satisfy the relevant require-ments.

The analysis was required on:

- specific ratio the amount of coal and seam waste in the deposit and defined level of selection in exploitation;
- specific physical and mechanical properties of coal and seam waste;
- specific transport lengths of coal and seam waste;
- specific site within the open pit, if there are more.

All listed parameters significantly affect the efficiency of operation the specific truck model, and a good knowledge of physical mechanical and structural characteristics of the work environment and technological characteristics of excavation equipment must be to make the final assessment on the best model of vehicle. When considering different models of trucks in addition to the technical operating parameters, such as the hourly capacity, capacity utilization factor, time utilization, etc. must be analyzed as well as the economic parameters of material transport for a specific model of truck that would cover both operating and capital costs.

In this case, the most favorable model truck is a truck Belaz 7555, which has the

smallest capacity and the volume of the crate. This conclusion can be drawn only for the period under consideration, or for consideration the weighted average duration of transport. The presented analysis shows that the increase of transport length, the parameters on the basis of which the asse-ssment of the transportation economy change in favor of the vehicles with a higher load-carrying capacity and volume of crates. The limit of application in relation to the other model of vehicle, in this particular case is the model 7555 Belaz up to 6 kilometers, while in the longer distances better para-meters can be expected in the application a truck Belaz 75135.

The question of selecting the optimal type of truck in selective exploitation must be solved through a complex analysis for each specific case. This derives from the specificity of transport in selective exploittation considering that the same type of truck is used for transport of waste and transport of useful minerals. Also, the analysis must include a longer period of time in order to take into account the changeable conditions of exploitation in the real space of the open pit and real-time of exploitation.

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IMPACT OF DRILLING IN THE OPEN PIT MINING ON THE ENVIRONMENT[**]

Abstract

In order to provide better and easier loading of useful component and overburden, the drilling and blasting belong to the important work operations at the open pits. Borehole drilling represents a source of harmful respirable mineral dust beside the applied measures for its prevention at the place of creation. Dust emissions during borehole drilling depends on a method and speed of drilling, borehole diameter, mechanical rock properties and applied method to capture dust in order to suppress the dust concentration in the working and living environment of the open pit.

Keywords: *drilling, dust, environment*

1 INTRODUCTION

Air is a very important part for the existence of human and other living orga-nisms. The main sources of air pollution can be broadly categorized in natural as well as in anthropogenic emissions (Tofan Kumar Rout et al., 2014). Natural emissions are not yet under human control, with the air pollution control technologies being implemented to suppress the human emissions (Tofan Kumar Rout et al., 2014). The main anthropogenic sources of the air pollution are industry (thermal power plants, refineries, open pits, etc.), traffic and home (domestic) emissions. Between these various sources of the air pollution, mining is the main source of dust pollution (Ghose and Majee, 2000).

The coal open pits use a large-scale mechanization and in their work a large amount of dust and gases is realized, which negatively affect the human health (Dhar, 1994). Various mining processes that release a large amount of dust, especially at the open pits, are: removal of overburden, removal of waste, mining and drilling operations, coal mining, transport of useful components or waste on transport routes, operating of crushing plants, etc. The rate of dust drop and its chemical composition are needed in quantitative and qualitative frameworks to the dust pollution in a particular region. Managing dust from the mine is important because it can affect local and regional air quality and negatively affects the local community and present a risk to public health (Pandey et al., 2008).

2 DRILLING

Drilling of boreholes in a useful component or accompanying rocks represents the main and permanent source of very stable and highly dispersed systems of floating,

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respirable, mineral dust (M. Miljković, 1998).

The empirical formula (S.F. Sepelen, G.A. Radcenko) for determining the dust emission in drilling of boreholes is presented in the form:

$$E = i\, V_o d_o^2\, \rho\, f\, K_1 K_2 K_3, \text{(mg/s)} \qquad (1)$$

where:

- E - dust emission in drilling, mg/s
- i - coefficient taking the drilling and cleaning method of the borehole (i = $155 \cdot 10^{-8}$ in normal drilling and borehole washing with water, i = $90 \cdot 10^{-8}$ when the water softeners are added, i = $16 \cdot 10^{-8}$ at optional drilling and borehole washing with water),
- V_o - drilling speed, mm/s,
- d_o - diameter of borehole, mm,
- r - rock density,
- f - strength coefficient according to Protodjakon,
- K_1 - coefficient of simultaneous operation for multiple drilling hammers (K_1=1 for one drilling hammer, K_1=1.7 for two drill hammers, K_1=2.7 for three drilling hammers, for drillers in the open pit exploitation K_1=1),
- K_2 is the coefficient of inclination angle of borehole (K_2=1 for horizontal, K_2=1.3 for inclined and vertical upwards, K_2=0.7 for inclined and vertical downwards),
- K_3 - coefficient taking into account the impact of the type of hammer drill or drill (K_3=1.3 for working with manual drilling hammer, K_3=1 for drilling hammer or chisel on rack, K_3=0.5 for pivot drill hammer or hydraulic pushing drilling accessories).

Drilling of boreholes for the primary massive blasting at pits open is carried out most often by drilling rigs which can drill boreholes 200-300 mm in diameter and depths up to 20-30 m.

Having in mind the use of this type of equipment, where the boreholes of large diameter are drilled, as a result, a large amount of dust is created that endangers the working and living environment in the area of the surface mine. For this reason, the manufacturers of drilling rigs install the special systems - devices for suppressing the formation of dust by means of water or decking devices, hermetization of the mouth of boreholes and dust aspiration of from the borehole and capture of dust, using the dry cyclones or sleeves and other dust filters for dust capture by the airborne air. The purified air is evacuated into the atmosphere through a pipe.

The drilling rig is a point source of dust, and the emission of dust depends on the efficiency of filter for cleaning the exhaust air, that is, the concentration of dust in the air of the outlet pipe and its quantity:

$$E = Q_v\,(N_{izl} - N_p), \text{ mg/s} \qquad (2)$$

where:

- Q - capacity of the air aspiration device, m^3/s,
- $N_{izl} - N_p$ - dust concentration on the outlet pipe and in the outer air, mg/m^3.

3 DUST CONTROL

The dust control created by the air compressor during drilling is necessarily an evil.

There are two systems for the acceptance and suppression of dust:

1. Dry dust collection system
2. Dust water suppression (wet method)

For dust control, the area surrounding the hole is closed by so called hood dust. "Hoods for dust" are closed by the side with curtains. The dust control system on the drill must be used in combination with dust hood and curtain. The two most common types of dust control are dry dust collectors (dry method), and water injection (wet method). Dust collectors are essentially large vacuum cleaners that pull - take dust from the dust hood and lead it through a system of elemental filters. Water injection system injects water in the form of fog in the air current. This system represents a more efficient solution for providing a minimum amount of

dust, but the introduction of water into the borehole may slow down the drilling process by increasing the cutting density (broken material at drilling) at the bottom of the hole, which compressed air should start and lift. Also, such a system requires a constant water supply, that is, frequent replenishment of the water reservoir, and in winter conditions, the worn-out developed heating systems must be used.

3.1 Dust suppression systems, cleaning of sucked air and dust emission

Within the drill rig, there is a dust suppression system, cleaning the sucked air.

Dry drilling is done without the use of water for dust control. Dust control is achieved by a dust extraction system mounted on a drill. These systems have the ability to function in different climatic conditions, that is, they are not susceptible to freezing at lower temperatures, unlike the water systems, and can be up to 99 percent effective if properly are maintained. There are different types of dry dust collection systems that are used depending on the drill size. Medium to large diameter drills have a system shown in Figure 1.

Dust is generated by the outlet air from the borehole, which in fact represents the compressed air that is inserted through a drill rod and comes out through the crown, and has the role of cleaning and ejecting the sections through the borehole. In a system with adequate function, these sections are collected in the aspiration chamber and on a deposited heap of fine material around the mouth of borehole. This dust, obtained by drilling, located in a chamber, is removed by a dust collector system. This system (dust collector) consists of the exhaust fans and filters that purify air from the chamber. This is mainly a self-cleaning system, in which the compressed air is used which pulses through the filters at certain time intervals to clean them and prevent blockage. The fine-filtered fine material then falls through the bottom of collector to the dust dump.

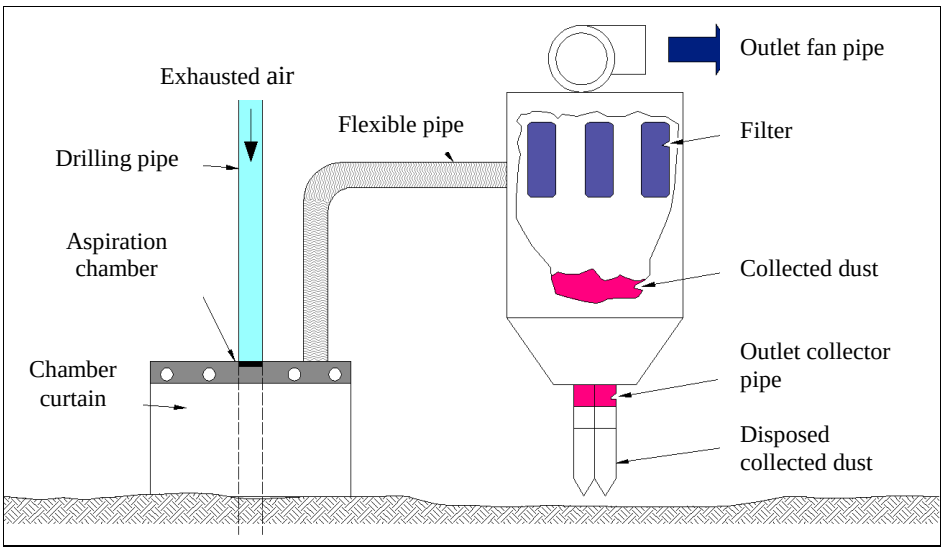

Figure 1 *Dry system for dust collecting*

Drills with a smaller diameter of drilling have the system shown in Figure 2. Schematic shows the operation of this type of system. The difference in a system with a

larger diameter drill is that this system collects the all materials in the cutting-drilling, then sends it to a large separation cyclone located on a drill bit to remove the large diameter (large granulation) cuts and then sends the residue to the dust collector on the back of drill, where dust and fine cuts are released (small granulation material). Maintenance a dust collection system is important for maintenance the effective dust control on these systems. The two most important things in maintenance are: the filters should be replaced before they become clogged, and the dust release can be significant if drilling rods and crowns are not properly maintained.

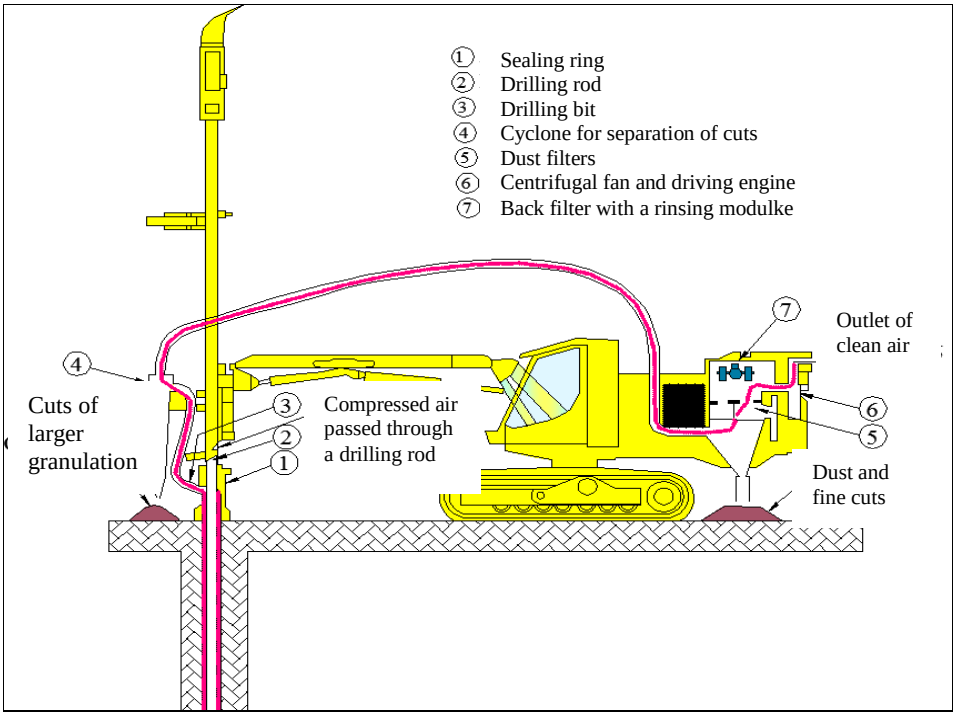

Figure 2 *Dry system for dust collecting in drills with smaller drilling diameter*

The system for dust suppression with water (wet method) is shown in Figure 3.

The best method for dust control in drilling at the open pits is to use the wet drilling techniques. Wet drilling injects water together with air to wash the cuts from the borehole as shown in Figure 3. Testing has shown that this technique can provide dust control with an efficiency of up to 96 percent [USBM 1987]. Water injection requires monitoring by the operator for effective dust control. The required amount of water for dust control is not great. Typical water flow in wet drilling systems is generally in the range of 0.37 to 7.5 l/min, but this va-ries depending on the type of drill, geology, and the humidity level of drilling material. Too little water leads to a reduction the efficiency of dust control while too much water leads to the operational problems with the drill. It is concluded that the amount of water required for dust control depends on the type of drill and drilling material.

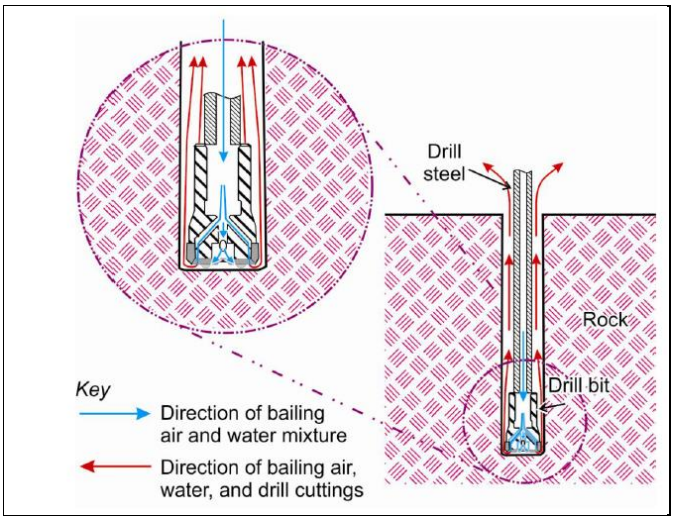

Figure 3 *Wet drilling method*

4 EFFICIENCY OF THE WET METHOD AND DUST ELIMINATION DURING DRILLING AT THE OPEN PITS

In order to reduce dust when drilling on a drill rig, it is mandatory that the dust extraction and purification device of the suctionned dust air is in the proper state. A rubber seal should be installed on the borehole open for dust suction, which, after filtering the purified air, is released into atmosphere with a concentration less than 50 mg/m^3.

During the borehole drilling, dust may fall into the environment if the dusting system is not in a function. Borehole drilling rigs have the installed devices for cleaning the boreholes from fragments by compressed air through which the water is added by the injector.

The scattered water in the form of fog and fine droplets with dust from the borehole creates agglomerates that compressed air takes and deposits under a hood with which the borehole is isolated from the environment. The reduction efficiency is reduced by reduction the amount of water, and completely is absent if the boreholes are cleaned only by compressed air (dry drilling).

The efficiency (η_i) of dust wetting with water added to the compressed air is 60% ($\eta_i = 0.6$).

At the drilling machine beside the wet process, an additional air cleaning method of dust of less than 10 μm diameter is applied. The efficiency of controlling the dust emission of less than 10 μm diameter is about 80% if the device for dust aspiration is in the correct state.

The efficiency coefficient of aspiration and cleaning of air on drilling in the proper operation of device is:

$$\eta_i = \left[1-(1-\mu_1)(1-\mu_2)\right] = 0{,}92 \qquad (3)$$

Dust reduction effect is:

$$N = \frac{1}{(1-\mu_1)(1-\mu_2)} = 12{,}5\ times \qquad (4)$$

where:

μ_1 and μ_2 - coefficients

5 CONCLUSION

Drilling as a technological phase of exploitation the mineral raw materials at the open pits causes the formation of large quantities and concentration of dust. Such a negative effect on the working and living environment should be controlled by the efficient dust suppression and dust cleaning systems. As the efficiency of these systems is shown as over 90%, and more importan-tly, the total dust concentrations generated by drilling can be reduced by 12.5 times.

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THE EXTRACTION OF AGGREGATES IN SERBIA, 1973 - 2015, A STATISTICAL EXPLORATION[***]

Abstract

We contribute to the fields of mineral economics, environmental and economic history in two respects: first, we construct a novel time series data set for the levels of aggregates extraction in Serbia between 1973 and 2015; the second, we estimate a change point ordinary least squares regression to model the dynamics of aggregates extraction in the aforementioned period. Our cliometric estimates are in great accordance with the major business cycle facts of the Serbian economy in the last 40 years. The most important policy implication of our results pertains to the potential slowdown of aggregates extraction from the onset of the Great Recession.

Keywords: *aggregates, mineral economics, Serbia, cliometrics, change point regression*

1 INTRODUCTION

Aggregates (crushed stone, sand and gravel) are high bulk, low unit value granular materials used primarily in the construction industry. The use of aggregates in construction industry is primarily in the form of cement, asphalt, mixed and pre-cast concrete. They can also represent the end-products in the form of railroad ballast, armour stones, filter beds or flux materials. Transportation costs, i.e., the market location, is the most important factor in determining the value of aggregates.

Aggregates, as documented by Menegaki and Kaliampakos [15], represent the biggest branch of mining by production volume, and the second biggest branch of mining by production value, just after the sector of fossil fuels. They, hence, represent the most valuable non-fuel mineral commodity in the world. In addition, as Menegaki and Kaliampakos [15] note, their close conection with the construction industry places them among the most used materials worldwide, second only to water. Krausmann et al. [14] document how the total aggregates extraction in the XXth century has increased by a factor of 34.

Aggregates, apart from their importance for the construction industry, are also important from the standpoint of sustainable resource management. Bleischwitz and Bahn-Walkowiak [11] emphasize the environmental importance of aggregates extraction from two perspectives: 1) material intensity perspective-the relevance of aggregates for increasing resource productivity in the Euro

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pean Union (EU) as a part of the Lisbon strategy; 2) environmental intensity perspective-the relevance of aggregates for increasing the eco-efficiency and lowering the environmental impacts in the EU.

This paper is concerned with the analysis of aggregates extraction dynamics in Serbia between 1973 and 2015. T hecliometric estimates are in great accordance with the major business cycle facts of the Serbian economy in the last 40 years. The most important policy implication of our results pertains to the potential slowdown of aggregates extraction from the onset of the Great Recession.

We contribute to the fields of mineral economics, environmental and economic history in two ways. First, we construct a novel time series data set for the aggregates extraction in Serbia between 1973 and 2015. Bleischwitz and Bahn-Walkowiak [11], as well as Behrens et al. [9], acknowledge how the present data are fragmentary, incomplete and in most instances based on different definitions and classifications. Second, we estimate a change point ordinary least squares regression to capture the dynamics of aggregates extraction in the aforementioned period. Menegaki and Kaliampakos [15] analyse the extraction of aggregates in 26 European economies between 1997 and 2006. Their data set mainly deals with the advanced European economies, while their empirical estimates are mostly concerned in detecting the most important explanatory factors of aggregates extraction, such as population size, gross domestic product (GDP) and construction sector value added. Our approach is somewhat different, since we present a detailed single country study from emerging Europe with an emphasis on a much longer sample span.

The rest of the paper is organized as follows. Section II provides theoretical background for our subsequent cliometric estimates. Section III presents our novel time series data set, as well as the results of our change point regression model. Section IV concludes by providing some policy pre scriptions for the revival of aggregates extraction industry in Serbia.

2 CHANGE POINT REGRESSION MODEL

We base our cliometric estimates on the following change point ordinary least squares (OLS) regression model with m potential structural breaks $(T_1, T_2, \dots T_m)$:

$$Level_t = c_j + t_j + \varepsilon_t, \quad t = T\_(j-1) + 1, \dots T\_j \qquad \text{(II.1)}$$

in which $j = 1, 2, \dots m+1$, $T_0 = 0$ and $T_{m+1} = T$, c_j refers to the intercept coefficients with property $c_i \neq c_{i+1}$ $(1 \leq i \leq m)$, t_j refers to the linear time trend coefficients with property $t_i \neq t_{i+1}$ $(1 \leq i \leq m)$ and ε_t corresponds to the error term. $Level_t$ is a dependent variable, and refers to the levels of aggregates extraction measured in 000 of cubic meters (m^3).

Bai [5] was the first to derive the consistency, rate of convergence and asymptotic distribution of the OLS estimates of a change point regression model from equation (II.1). Building on the work of Bai (1997), Bai and Perron [6, 7, 8] have proposed two tests of the null hypothesis of no structural break against an unknown number of breaks given some upper bound *M*. The upper bound *M* for the number of breaks is inversely proportional to the size of trimming percentage ϵ, $\epsilon = h/T$, in which h represents the minimal length of each subregime. The OLS estimates are consistent even if the disturbances are heterogeneous across regimes. If the disturbances are autocorrelated, Bai and Perron [7] specify a quadratic spectral kernel based heteroscedasticity and autocorrelation consistent (HAC) covariance matrix using the pre-whitened disturbances. The kernel bandwidth is determined automatically using the Andrews AR (1) method.

In summary, Bai and Perron [6, 7, 8] propose the following algorithm for estima-

ting the change point OLS regression model: 1) prespecify the upper bound for the number of breaks M by setting the value of trimming percentage ϵ; 2) test the null hypothesis of no structural break against the alternative of a prespecified number of breaks defined in step 1) using the double maximum tests of Bai and Perron [6, 7, 8]; 3) estimate the change point regression model via OLS method.

3 EMPIRICAL EVIDENCE

This section consists of two subsections. Subsection III.1 introduces a novel time series data set for the levels of aggregates extraction in Serbia between 1973 and 2015. It also discusses themajor stylised facts regarding the dynamics of aggregates extraction. Subsection III.2 presents the change point OLS regression model which captures stylized facts from Subsection III.1.

3.1 Data & Stylized Facts

Our study analyses the dynamics of aggregates extraction in Serbia between 1973 and 2015. The availability of official data determines both the beginning and the end of our sample span. Our data come from the Statistical Yearbooks of the Republic of Serbia between 1978 and 2016 published by the Statistical Office of the Republic of Serbia (*The Statistical Yearbooks of the Republic of Serbia for the indicated period can be downloaded in PDF format from the electronic library of the Statistical Office of the Republic of Serbia available at http://www.stat.gov.rs/WebSite/ Public/PageView.aspx?pKey=452)*. Data for Kosovo are not included from 1999. We focus on the levels of domestic aggregates extraction as in Behrens et al. [9]. We do not make distinction between used and unused domestic extraction due to data unavailability. [9] We express the levels of aggregates extraction in 000 of cubic meters (m^3). The conversion from cubic meters to metric tonnes is impossible, since we do not know the exact proportions of particular types of aggregates in the total of aggregates extraction. More precisely, from 1973-2002, aggregates encompass broken stone from silicate rocks, sand and gravel. From 2003-2015, aggregates encompass crushed and broken stone, round pebbles, natural sand and gravel. Table 1 reports our data set. The first column of the table refers to the levels of aggregates extraction, while the second column represents the annual percentage change in aggregates extraction.

Table 1 *The extraction of aggregates in Serbia, 1973-2015*

Year	Levels (000 of m^3)	Growth rates (%)
1973	9044	NA
1974	10091	11.58
1975	12183	20.73
1976	12421	1.95
1977	12909	3.93
1978	15649	21.22
1979	18268	16.74
1980	15623	-14.48
1981	13781	-11.79
1982	13808	0.20
1983	14043	1.70
1984	11984	-14.66
1985	12619	5.30
1986	11778	-6.66
1987	9580	-18.66

Continuation Table 1

1988	11209	17.00
1989	10702	-4.52
1990	9068	-15.27
1991	7473	-17.59
1992	5593	-25.16
1993	1783	-68.12
1994	1945	9.09
1995	2230	14.65
1996	3467	55.47
1997	2647	-23.65
1998	3302	24.74
1999	2020	-38.82
2000	2684	32.87
2001	1982	-26.15
2002	2088	5.35
2003	6260	199.81
2004	7058	12.75
2005	7556	7.06
2006	8633	14.25
2007	8734	1.17
2008	8667	-0.78
2009	5789	-33.21
2010	6951	20.07
2011	6533	-6.01
2012	6166	-5.62
2013	4590	-25.56
2014	5307	15.62
2015	6142	15.73

Sources: Authors' calculations and Statistical Yearbooks of the Republic of Serbia 1978-2016.

Table 2 shows the basic descriptive statistics for the levels and growth rates of aggregates extraction presented in Table 1. The mean and median represent the measures of central tendency of the respective empirical probability distributions, while the standard deviation quantifies how much, on average, the data points deviate from the mean. Maximum refers to the largest data point, while minimum refers to the lowest data point within our sample. Skewness measures the asymmetry of the empirical probability distribution from normal probability distribution, while kurtosis is the descriptor of the shape of empirical probability distribution which measures the combined weight of distributions' tails relative to the rest of the distribution. JB statistics combines the values of skewness and kurtosis to test whether a particular empirical probability distribution is normally distributed. While the null hypothesis of normal probability distribution is accepted in the case of levels of aggregates extraction (p=0.42), the opposite is true for the time series of growth rates (p=0.00).

Table 2 *Descriptive statistics for aggregates, 1973-2015*

	Levels	**Growth rates**
Mean	8147.91	4.10
Median	7556.00	1.83
Maximum	18268.00	199.81
Minimum	1783.00	-68.12
Standard Deviation	4430.89	37.81
Skewness	0.24	3.21
Kurtosis	2.14	18.47
JB statistics with p-values	1.75 (0.42)	491.04 (0.00)
Number of observations	43	42

Source: Authors' calculations. Levels-000 of m^3; growth rates-%. p-values are given in ().

Figure 1 presents the facts outlined in Table 2 graphically. The upper panel of Figure 1 depicts a time series for the levels of aggregates extraction, while the bottom panel of Figure 1 depicts a time series for the growth rates of aggregates extraction. The upper panel of Figure 1 displays 6 distinctive sub-periods in the dynamics of aggregates extraction between 1973 and 2015: the first sub-period spans from 1973 to 1979, the second sub-period spans from 1980 to 1988, the third sub-period spans from 1989 to 1994, the fourth sub-period spans from 1995 to 2002, the fifth sub-period spans from 2003 to 2008 and the sixth sub-period spans from 2009 to 2015.

The *first sub-period* from 1973 to 1979 witnessed sharp increase in the levels of aggregates extraction. The average annual growth rate of aggregates extraction was 12.7%. In 1979, the aggregates extraction reached its maximum level of around 18.3 million m^3. The upward trend in aggregates extraction is consistent with rapid economic growth in Serbia in the sub-period under consideration. In particular, Bićanić et al. [10] report the average annual growth rate of Serbian GDP of around 6.5% between 1952 and 1979. (*Bićanić et al. [10] explain in great length how they convert the values of social product into the long-run time series of GDP for Yugoslavia and its successor states. This discussion is beyond the scope of this paper. For details, see Bićanić et al. [10])*

In great contrast with respect to the first sub-period, the *second sub-period* between 1980 and 1988 witnessed sharp decrease in levels of aggregates extraction. The average annual level of extraction of approximately 12.7 million m^3 was far below the 1979 maximum value of around 18.3 million m^3. The average annual growth rate of aggregates extraction entered negative territory in 1980, and hovered around -4.7% throughout the whole decade. The outlined patterns are again consistent with the overall political and macroeconomic developments in Serbia between 1980 and 1988. In particular, Bićanić et al. [10] report the average annual growth rate of Serbian economy of only 0.4% between 1980 and 1989. Moreover, they also identify the year 1980 as a structural break in the dynamics of GDP per capita in Yugoslavia, Serbia as well as all others successor states [10].

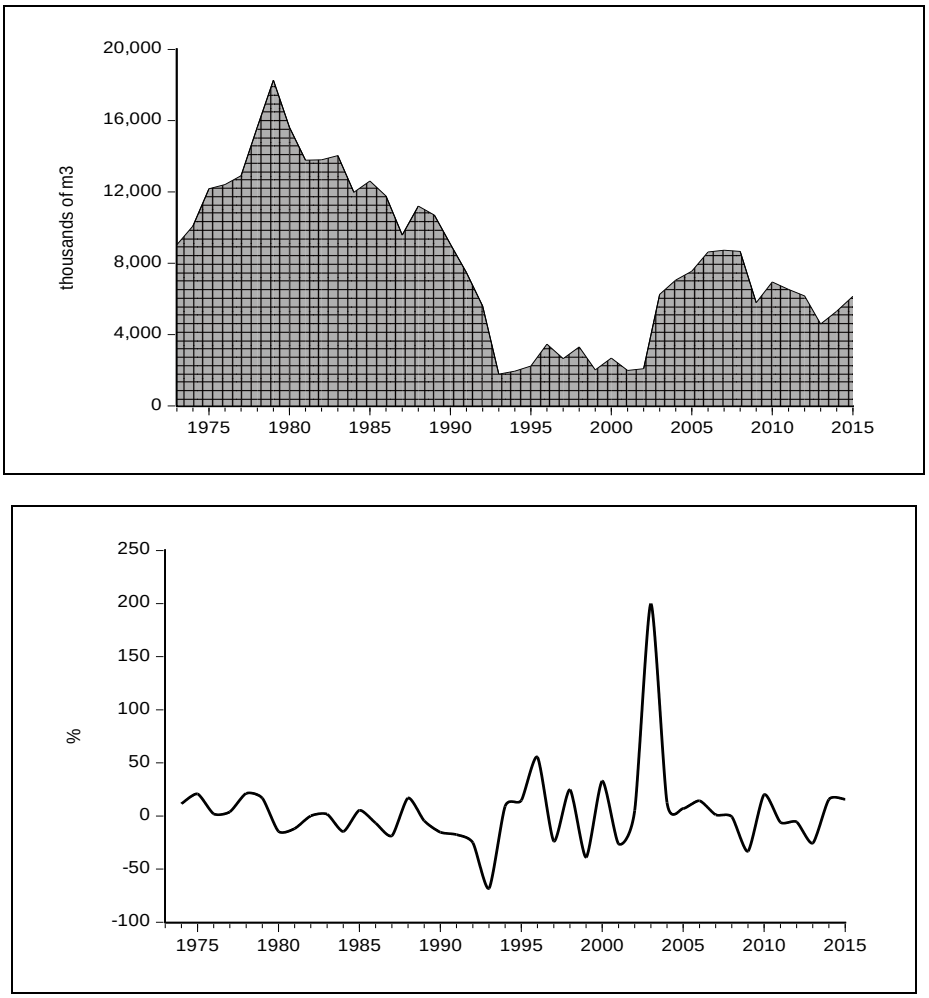

Figure 1 *Levels (upper panel) and Growth Rates (bottom panel) of Aggregates Extraction in Serbia, 1973-2015*

The most important political shock was the institutional power vacuum which emerged after the death of Josip Broz Tito, the first and only president of Socialist Federal Republic of Yugoslavia (SFRY). The Collective Presidency, which took the control over SFRY after Tito's death was unable to cope with the internal and external imbalances Yugoslav and Serbian economy were facing at the beginning of the 1980s.

The most important internal imbalance between 1980 and 1989 was the high cost-push inflation, which accelerated into a hyperinflation in the last quarter of 1989. Petrović and Vujošević [21] identify the public sector wage hikes as the main culprit behind the inflationary pressures in Yugoslav economy in the analyzed sub-period. The demands for higher public-sector wages stemmed from the labour-managed public

enterprises which were primarily concerned with the wage maximization and employment protection (*The roots of the labour-managed, i.e. self-managed, economy lie in the 1965 economic and social reform. For details about this reform, and the evaluation of its impact on overall macroeconomic performance in Yugoslavia, see Bićanić et al.* [10]). The government then, in order to prevent potential social unrest, pressed the state banking system to extend highly subsidized loans at negative real interest rates to self-managed enterprises. The state banking sector, hence, monetized a quasi-fiscal deficit of the public enterprise sector violating the soft-budget constraint of the government.

The most important external imbalance between 1980 and 1989 was the balance of payments and external debt crisis which actually exacerbated already present internal imbalances. Petrović and Vujošević [21] show how the real devaluation of dinar led to a significant pass-through effect to prices, as well as to a decrease in real wages. The drop in real wages, consequently, gave an additional impetus to the demands for higher public-sector wages. The real devaluation of the dinar stemmed from chronic trade balance deficit which emerged in Yugo-slavia after the World War II. The trade balance deficit was a consequence of high absorption gap, since domestic absorption grew more rapidly than domestic production. Higher demand for consumer goods from abroad was the main determinant of absorption gap, since social planners in Yugoslavia were primarily concerned with the production of machinery and investment equipment. Higher demand from abroad was primarily financed with foreign loans and remittances. When the 1979 oil price shock hit the global economy, the supply of foreign loans dried up due to a world-wide global recession. In addition, central banks from all over the world started pursuing restrictive monetary policies in order to combat oil-induced price increases. Contradictionary monetary policies all around the world led to interest rates hikes, which pushed the costs of foreign borrowing even further. The maturity structure of foreign loans changed, since investors from abroad were willing to borrow only temporary due to high global economic uncertainty. Since the global borrowing conditions for SFRJ changed, the government, under the stand-by arrangement with the IMF, devalued the dinar and introduced import quotas to reduce the trade deficit as the main culprit behind high external debt. The stabilization program was unsuccessful in eliminating the external imbalances and led to an even deeper recession which spilled over to the construction and aggregates extraction industry.

The *third sub-period* between 1989 and 1994 witnessed even further deterioration in the levels of aggregates extraction. The average annual level of extraction dropped to only 6 million m^3. In 1993, the annual level of aggregates extraction reached historical minimum of only 1.8 million m^3. The average annual growth rate of aggregates extraction fluctuated around -20%, reaching the historical minimum in 1993 of staggering -68%. The devastating developments in the aggregates extraction industry were primarily a consequence of Yugoslav wars and international economic embargo. In addition, between 1992 and 1994, Yugoslavia experienced the second-highest and the second-longest hyperinflation in economic history, as documented by Petrović et al. [20]. Petrović et al. [20] state that, as the inflation gained pace, output in Yugoslavia halved leaving no room for any industrial and growth recovery.

The *fourth sub-period* between 1995 and 2002 witnessed a mild revival of aggregates extraction in Serbia. The average annual level of extraction increased above historical minimum attained in 1993, and oscillated around 2.6 million m^3. The average annual growth rate of aggregates extraction also recovered and levelled off around 5%. Unfortunately, political and macroeconomic developments curtailed a more robust recovery of Serbian aggregates extraction industry between 1995 and 2002.

The Kosovo War and the overthrown of Milošević regime were the main political shocks that destabilized the economy in 1999 and 2001, respectively. For instance, the growth rate of aggregates extraction dropped sharply in 1999 to the second lowest historical value of -39%, while in 2001 it equalled -26%.

Petrović [19] documents th emajor macroeconomic imbalances between 1994 and 2002 which stifled the overall industrial progress, and, hence, the progress of aggregates extraction industry. In particular, all nominal magnitudes (M1, base money, wages, inflation and the exchange rate) grew at the average rate between 40-50%. The real money demand, measured as the share of M1 in GDP, was only 6%, indicating how public at large perceived economic policies of the Serbian government. The estimated fiscal deficit was around 10% of GDP, while the tax system was highly distorted with 7 different retail sales tax rates. Approximately 40% of all retail goods and services were kept under direct price control. As a consequence of all aforementioned political and macroeconomic developments, the living standard during the 1990s decreased by over 50%. The unemployment rate in 2000 was around 30%, while the average net monthly wage was less than 45 euros. Arsić et al. [3] document how 35% of population lived below regional poverty line, and another 35% just above the poverty line. Petrović [19] finally reports how GDP per capita at the outset of democratic political reforms in 2001 only slightly exceeded GDP per capita from the second half of the 1980s.

The *fifth sub-period* between 2003 and 2008 witnessed a sharp recovery of aggregates extraction industry in Serbia. The average annual level of extraction jumped to 7.8 million m^3. The average annual growth rate of aggregates extraction increased from its previous sub-period value of 5% to approximately 39% between 2003 and 2008. In 2003, the average annual growth rate of aggregates extraction reached its historical maximum of 200%, which was related to the acquisition of three large cement plants by foreign investors. The sharp revival of Serbian aggregates extraction industry is a direct consequence of macroeconomic reforms after the year 2000. The backbone of macroeconomic stabilization program was the exchange rate based stabilization which led to adisinflation and stable currency (*For details see Arsić et al.* [3] *and Petrović* (2004) [19]). The government also, under the IMF surveillance, carried out a fiscal consolidation package of around 5% of GDP between 2002 and 2005, recording a fiscal surplus in 2005, as described in Andrić et al. [1, 2].

The *sixth sub-period* between 2009 and 2015 witnessed again another decrease in the levels of aggregates extracted. In particular, the average annual level of extraction returned to approximately 6 million m^3, the average level recorded between 1989 and 1994. The average annual growth rate of aggregates extraction again turned negative and floated around -2.7%, a drop of around 40 percentage points from the average growth rate between 2003 and 2008. In 2009, a year in which the Great Recession hit the Serbian economy, the average annual growth rate of aggregates extraction equalled -33%. After the arrival of the Great Recession to Serbia, the overall economic slowdown affected construction industry and, consequently, spilled over to aggregates extraction industry.

3.2 Results

The time variable in equation (II.1) serves as a proxy for the combined influence of all relevant economic factors on aggregates extraction in Serbia between 1973 and 2015. Moore et al. [16] follow a similar approach when they use linear time trend to capture the influence of intrasectoral shifts, material substitution and resource saving technologies in their study on economic growth and the demand for construction materials in the UK and the US between 1960 and 1992 [16]. Nelson and Kang [17]

explore, however, the errors in regression models in which time is included as an explanatory variable under the deterministic trend assumption when in fact the time series belongs to the class of stochastic trend processes (*If the time series under question exhibits deterministic time trend, then we can forecast its value in period t given the information available in period t-1. On the other hand, if the time series under question exhibits stochastic time trend, then we cannot forecast its value in period t given the information available in period t-1.*) In addition to inspecting the graph of the series along with its autocorrelation function, Nelson and Kang [17] recommend the use of formal statistical tests for the nature of particular time trend (deterministic vs. stochastic).

Following the advice of Nelson and Kang [17], we first visually inspect the graph of the series along with its autocorrelation function, and then turn to formal statistical tests. First, the visual inspection of Figure 1 points to deterministic segmented time trend for aggregates extraction in Serbia between 1973 and 2015. Second, the inspection of autocorrelation function points to highly persistent temporal dependence, since the first lag autocorrelation coefficient equals 0.93. The positive autocorrelation, however, drops to zero after only 10 years when it becomes mildly negative. Finally, Table 3, which summarizes the results of our formal statistical tests, gives overall support to the deterministic trend hypothesis. The table, in particular, shows the results from tests proposed in Elliott et al. [12], as well as the results from tests proposed in Ng and Perron [18]. We detrend the data by the generalized least squares (GLS), since Eliott et al. [12] show how GLS detrending yields power gains for these tests by allowing for a more precise autoregressive spectral density estimate that is invariant to the parameters of the trend function. In addition, we determine the number of lags in testing regressions in accordance with the modified Akaike criterion (MAIC) in which we set the maximum number of lags to 8. (*The results are robust for different values of the maximum number of lags. They are also robust if we exclude the time trend from testing regression. All these findings are available from the authors upon request).* Ng and Perron [18] show how MAIC leads to size improvements over standard information criteria since it adapts to the analyzed sample even if the number of deterministic components increases.

Table 3 *Stochastic trend tests for aggregates, 1973-2015*

Tests	Statistics	Specification	Lags	Criterion
ERS	22.94***	Intercept & Trend	0	MAIC
MZ_α	-4.02	Intercept & Trend	0	MAIC
MZ_t	-1.40	Intercept & Trend	0	MAIC
MP_T	22.40***	Intercept & Trend	0	MAIC
MSB	0.35***	Intercept & Trend	0	MAIC

Notes: *** 1% level significance, ** 5% level significance, * 10% level significance.

Table 4 presents our estimates of the change point regression model for the period 1973-2015. The model estimates are in great accordance with major business cycle facts of the Serbian economy discussed in previous subsection. The breaks occurred in 1980, 1989, 1995, 2003 and 2009. The corresponding trend estimates across breaks have appropriate size, sign and statistical significance. The most important policy implication of our results pertains to the potential slowdown of aggregates extraction

from the onset of the Great Recession, a result also obtained by Herrero et al. [13] in the case of Spain.

In obtaining the estimates from Table 4, we first specify the upper bound for the potential number of breaks by setting the value of trimming percentage ϵ to 15%. The chosen trimming percentage value of 15% corresponds to a maximum of 5 potential structural breaks. Second, we implement double maximum tests UDmax and WDmax to determine the actual number of structural breaks, given the ϵ - prespecified upper bound for the potential number of breaks. Both test statistics are statistically significant at 1% level and date breaks, as already stated, in 1980, 1989, 1995, 2003 and 2009. Finally, given the presence of breaks in aforementioned years, we estimate a change point regression models via OLS by allowing disturbances to differ across estimated breakpoints. We model the auto-co-rrelation in disturbances by specifying a quadratic spectral kernel with the Andrews automatic bandwidth and AR (1) pre-whitened residuals, as in Bai and Perron [7].

Table 4 *Change point ols regression for aggregates, 1973-2015*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
1973 - 1979 -- 7 obs				
Intercept	8704.21	291.05	29.91	0.00
Time trend	1411.21	197.37	7.15	0.00
1980 - 1988 -- 9 obs				
Intercept	19266.77	546.36	35.26	0.00
Time trend	-595.72	51.10	-11.66	0.00
1989 - 1994 -- 6 obs				
Intercept	41783.14	1337.66	31.24	0.00
Time trend	-1929.14	77.25	-24.97	0.00
1995 - 2002 -- 8 obs				
Intercept	5463.75	1035.95	5.27	0.00
Time trend	-114.17	37.68	-3.03	0.005
2003 - 2008 -- 6 obs				
Intercept	-9026.29	2441.38	-3.70	0.001
Time trend	518.29	79.49	6.52	0.00
2009 - 2015 -- 7 obs				
Intercept	11736.43	4490.31	2.61	0.01
Time trend	-149.00	119.12	-1.25	0.22
Number of Observations	43	**Standard Error of Regression**		746.43

Notes: *dependent variable*-levels of aggregates (000 of m^3); *estimation method*-OLS with heterogeneous errors across breaks as in Bai and Perron [7]; *break type*-UDmax/WDmax double maximum tests with 15% sample trimming percentage; *co-variance matrix specification*: HAC standard errors with quadratic-spectral kernel and Andrews automatic bandwidth with single pre-whitening lag.

Figure 2 confirms the appropriateness of our change point regression model. The left axis of the Figure 2 traces the actual and model estimated values of aggregates extraction, while the right axis traces the residual values of aggregates extraction, i.e., the values equal to the difference between actual and model fitted estimates. The actual and model fitted values are almost identical producing normally distributed residual values

.

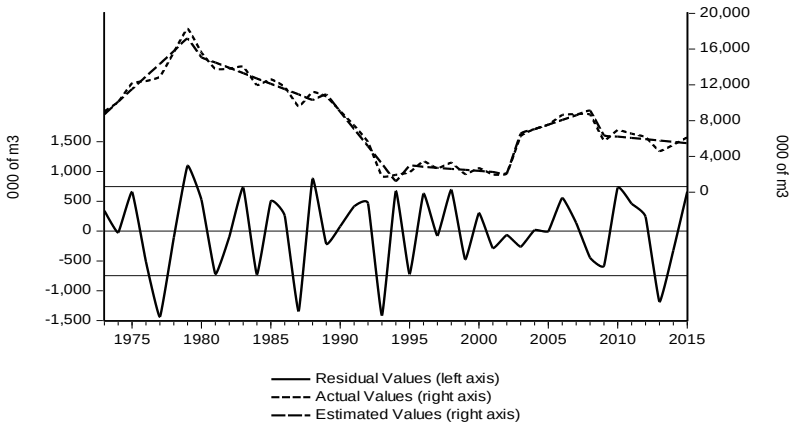

Figure 2 *The Actual, Estimated and Residual Values of Aggregates Extraction in Serbia, 1973-2015*

4 CONCLUSION

We have analyzed the dynamics of aggregates extraction in Serbia between 1973 and 2015. Our results are consistent with major business cycle fluctuations of the Serbian economy in the last 40 years. Although this paper bears a historical conno-tation, its results can, however, be of some assistance to policy makers in Serbia today, since the most relevant policy implication of our research refers to the potential slowdown of aggregates extraction from the onset of the Great Recession.

The question for policy makers, hence, becomes how to stimulate the revival of aggregates extraction industry in Serbia. The potential answer lies in increasing the share of infrastructure investment in GDP, especially if we take into account the relatively lower share of public infrastructure spending in Serbian GDP with respect to other emerging European economies. Bleischwitz and Bahn-Walkowiak [11], for example, report how the world-wide de-mand for aggregates rose approximately by 4.7% annually through 2007, driven primarily by infrastructure construction in countries such as China, India, Poland, Russia, Taiwan, Thailand and Turkey. Menegaki and Kaliampakos [15] support these findings in the case of 26 European economies between 1997 and 2006. On the other hand, since the seminal paper of Aschauer [4], the numerous empirical studies show how "core" infrastructure projects-streets, highways, airports, mass transit, sewers and water systems-have the greatest explanatory power for the overall growth rate of the national economy. The increase in infrastructure public spending, hence, can also have an indirect effect on the aggregates extraction industry via higher growth demand channel, if policy makers in Serbia succeed in minimizing political economy frictions in the realization of infrastructure projects.

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THE USE OF DATABASE ON INJURY AT WORK RECORDS IN SERBIA

Abstract

The risk of an injury at work, occupational disease or damage to the health of employees due to danger is, lately, the common subject of numerous studies. The appropriate identification of the risks is the starting point for development the safety and health of the employees in a company. In order to adequately anticipate the risk based on the statistical data on incidents, e.g. injuries at work, it is necessary to identify the critical points in the enterprise. It is impossible to start in motion a risk-management plan without the serious statistics with the elaborately processed data on an injury. Most companies, conditioned by a strict legal framework in the field of safety and health at work, keep their records on injuries. However, with development in this domain, the need for a uniform database for all injuries that occur on the territory of the Republic of Serbia is created. This paper proposes the form, use and further development of the unified database for injuries at work. The base is modeled after the existing form of the report on injuries at work, and its possibilities are shown through the example of injuries that have occurred in the coal mine Bogovina in 2016.

Keywords: *database, records, injuries at work*

INTRODUCTION

The direct consequences of the inadequate risk management methods in the industry are: the increased number of injuries and accidents at work, disabilities and employees' sickness and their absence from work. The injury occurs as a result of an uncontrolled event or dangerous situation that a worker has found himself in. The injury can be qualified as any mechanical, physical or chemical damage on the employee resulting in a disability and causes physical and mental trauma. [1] The safety and health protection at work, OH&S, refers to the control, review of the safety systems at work and a set of measures aimed at improving the safety of employees. The analysis of the results of an injury can lead to certain conclusions on the injury cause.

Studying the injuries at work in any area of industry depends on the quality of input data from the statistics on injuries at work that have already occurred. It is important that this information is processed in a unique way. A record allowing monitoring the different aspects of injury, such as the number, type and severity of injury, the injured part of the body and many more, offers many possibilities for research. It is necessary to connect this information to several other parameters in order to come to a conclusion. Such an analysis of information is the best achieved through a database. SQL Server Management Studio is a free application from Microsoft, and this software has been precisely used in this paper to create a database of injuries at work.

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The obtained data processing through the questionnaires provides conclusions related to the security of a company, business or municipality. The obtained conclusions are essential for improvement the safety and health of the employees in the company, as well as for evaluation the safety measures at the state level. By investment in such statistics, which would be updated by the companies, the state would create the conditions for monitoring the implementation of the law and regulations, application the standards and the safety inspection work in the companies which are essential to the process. A review of the system by the competent and responsible persons would enable OH&S to make decisions, based on the output data that would level Serbia with the global trends.

Database structure is a complete match to the Report on the injury at work or Form No. 1, which is filled out by the employer in the case of an accident. As such, it should be available to every employer on the Agency for the Safety and Health at Work website. These data should be also available to the researchers who monitor injuries and risks within the framework of certain activities.

Form No. 1 consists of seven chapters, each for a different kind of data collected. If the form is filled out electronically, it is necessary to have a drop-down list for each of the seven factors. This should be done in order to prevent the person responsible for the safety and health at work to fill in the data randomly and avoid having non-uniform information due to using a capital letter, spacing or using letters like č, đ, š, ž and ć. Of course, the data such as the name of the injured, the names of the witnesses, a unique personal identification number and the name of the person responsible cannot be uniform. Only the database with data collected this way can be used for further research.

LEGAL REGULATIONS WHICH REGULATE THE RECORDING OF INJURIES AT WORK IN SERBIA

Legal basis for keeping the records is already established by the Act on Safety and Health at Work (Official Gazette RS, Nos.101/05 and 91/15), Article 51 says:

"The report on injuries at work, occupational disease or damage to the health of employees due to danger which happens at the place of work, is to be delivered, by the employer, to the injured or affected by the disease employee, and to the organizations responsible for health and pension insurance. The content and method for filling out the report form, mentioned in paragraph 1 of this Article, is determined by the Minister of Labour, Employment, and Social Issues of the Republic of Serbia.

The employer shall, at the request of a labor inspector or a representative of the employees, submit a safety report, stating the health of employee and measures which have been taken."[3]

The Act on Safety and Health at Work clearly defines the way of processing the injury. The Minister of Labor, Employment, and Social Issues of the Republic of Serbia issued the Regulations on the content and methods for filling out and issuing a form on the injury at work and occupational disease (Official Gazette RS, No.72/2006 and 84/2006 - correction) which states the following forms (Act 5, Paragraph 1):

- Form No. 1 THE REPORT OF AN INJURY AT WORK
- Form No. 2 THE REPORT OF AN OCCUPATIONAL DISEASE.

The employer is obligated to fill in the form within twenty-four hours of learning that the injury occurred. [3]

The Regulations stipulates that there should be five (5) copies of the form printed/filled out, two copies for the Republic Health Insurance Fund and three copies for the employer. [4] The employer is to keep one copy of the authenticated form, one

copy is given to the employee, and the third copy of the form is delivered to the organization responsible for pension and disability insurance through the Ministry of Labor, Employment, and Social Issues- Department for Safety and Health at Work.

The main issue is that the most of the employers do not deliver the form to the Department for Safety and Health at Work, instead, it is directly sent to the organization responsible for pension and disability insurance, thus, the processing of the data and drawing of the conclusions about the safety in the field of injuries are prevented. The Department for Safety and Health at Work has initiated a project to form The Registry of the injuries at work, but the data are still unavailable.

Presently, the Republic Health Insurance Fund has recorded and has access to the information related to the total number of injuries and gender of the injured employees, which is unusable from the point of studying the safety for the most of activities.

CREATING A DATABASE ACCORDING TO THE REPORT ON INJURY AT WORK IN THE REPUBLIC OF SERBIA

The form THE REPORT OF AN INJURY AT WORK was used as a starting point for creating database because it contains data necessary for the appropriate processing of injuries. Based on the form that was formulated in the Regulations on the content and method of issuing the report of injury at work, and occupational disease forms, the database that fully matches the look of the REPORT OF AN INJURY AT WORK is created. After filling in the form by the OH&S service in the company, where the incident happened, the user can print it or send it for further processing. All data entered in the report are signed a unique ID number, and they are saved in the database for further analysis. Filling in this form is, certainly, the employer's obligation in order to fulfill the legal procedure, and cannot be considered as an additional requirement regarding the database. The database has an option for further data processing in the category- injuries at work are not adequate for the injuries occurring outside this category, e.g. transport or agriculture. Such injuries should be processed in the Registry of injuries.

In order to ease the data entry, an application with the appropriate user interface should be created. The overall idea is to create the so called drop-down columns wherever that is possible, so the user could choose only one indicator, e.g. a code, registry number, street or a city. All the injury data would be uniformed by that way.

This is particularly applied to the portion of the form which contains the prescribed codes for identifying the causes and sources of injuries given in the Records and notifications of occupational injuries and occupational diseases determined by the International Labor Organization (aka. The ILO), the part of the form which contains the Code of Practice, as well as the part of the form which is supposed to be filled by a doctor and refers to the classification of violations according to the code diseases ICD 10. [6]

It is necessary to clearly define the questionnaire so the user of database cannot, for example, mark finger or upper arm, because in the drop-down column there is only "upper extremities" as an option. The data base Injury_at_Work is designed as part of the tool for the study of the injuries in the mining industry by a person in charge of this area in an organization and it also requires an addition of queries which are not set in the Report of an injury at work. It is, especially, necessary to separate injuries of workers engaged directly in the production process from those which are not, and enable the option which clearly connects worker with the production process. However, the topic of this paper is formulation, dis

play and analysis of desired data from the existing Report of an injury at work, and the possibility of use these records for as many as possible agencies in Serbia, and the database was designed carrying such a concept in mind. Still, each industry can add its own queries for the purposes of their analysis.

Figure 1 shows the database of injuries at work diagram. There are seven entities in the database: Injured, Employer, Eyewitness, Manager, Injury, Workplace and Doctor's findings. Those entities represent the integral part of the Form No. 1, and contain columns that match the required items in a specified form. In addition to these columns, each entity or a table contains the so-called primary key, or the primary column (injured ID or employer ID) with the automatically generating unique number that identifies each row in the column or, in other words, each group of data related to the specific victim. All groups of data are related to a specific injured person, so the table Injured represents the main entity or the main column. The problem of linking the groups of data between tables is solved by introduction a column with a foreign key constraint. The foreign key can be found in all tables except in the main table. As table Injured is the main table, the primary key of table Injured – injured ID is set as a foreign key for the rest of tables.

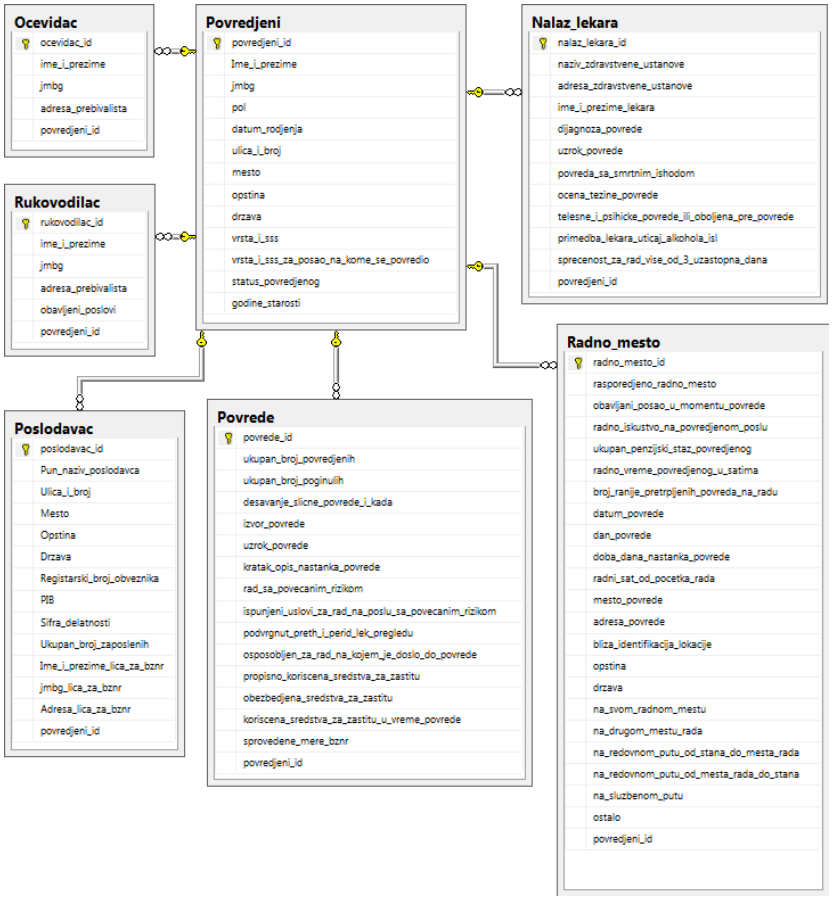

Figure 1 *Database of injuries at work - table diagram with their interrelations*

The data of injured workers are entered directly into the SQL Server Management Studio database table to the requirements of each individual column. The improvement of model will lead to development the user interface where all data on injured worker will be entered according to the Report of an injury at work.

POSSIBILITIES OF SEARCHING THE DATABASE

Injuries at Work Database was created in the way that each table represents one set of data from the form, for example, a group of data on employer is a table in the database that is linked to other tables. Figure 2 shows the basic table, Injured table which generates the ID number (injured ID) for each of the injury that occurs.

	povredjeni_id	Ime_i_prezime	jmbg	pol	datum_rodjenja	ulica_i_broj	mesto	opstina	drzava	vrsta_i_sss	vrsta_i_sss_za_posao_na_kome_se_povredio	status_povredjenog
1	1	[redacted]	[redacted]	m	[redacted]	Zlot bb	Zlot	Bor	Srbija	osnovna škola	NK jamski vozač	u radnom odnosu
2	5	[redacted]	[redacted]	m	[redacted]	Bogovina bb	Bogovina	Boljevac	Srbija	osnovna škola	NK jamski vozač	u radnom odnosu
3	6	[redacted]	[redacted]	ž	[redacted]	čupiceva br.9	Zajecar	Zaječar	Srbija	dipl.inž. geologije	Geolog	u radnom odnosu
4	7	[redacted]	[redacted]	m	[redacted]	Podgorac b.b.	Podgorac	Boljevac	Srbija	osnovna škola	NK jamski vozač	u radnom odnosu
5	8	[redacted]	[redacted]	m	[redacted]	Bogovina bb	Bogovina	Boljevac	Srbija	osnovna škola	PK kopač	u radnom odnosu
6	9	[redacted]	[redacted]	m	[redacted]	Ilino b.b.	Ilino	Boljevac	Srbija	osnovna škola	KV-kopač	u radnom odnosu
7	10	[redacted]	[redacted]	m	[redacted]	Šarbanovac b.b	Šarbanovac	Bor	Srbija	SSS -IV stepen, rudarski tehničar	SSS-palioc mina	u radnom odnosu
8	11	[redacted]	[redacted]	m	[redacted]	Podgorac b.b.	Podgorac	Boljevac	Srbija	SSS- III stepen	II smenski bravar	u radnom odnosu
9	12	[redacted]	[redacted]	m	[redacted]	Podgorac b.b.	Podgorac	Boljevac	Srbija	SSS- III stepen	KV oplemenjivac	u radnom odnosu
10	13	[redacted]	[redacted]	m	[redacted]	Podgorac b.b.	Podgorac	Boljevac	Srbija	osnovna škola	KV kopač	u radnom odnosu
11	14	[redacted]	[redacted]	m	[redacted]	Bogovina bb	Bogovina	Boljevac	Srbija	osnovna škola	PK kopač	u radnom odnosu
12	15	[redacted]	[redacted]	m	[redacted]	Bogovina bb	Bogovina	Boljevac	Srbija	osnovna škola	KV kopač	u radnom odnosu
13	16	[redacted]	[redacted]	m	[redacted]	Zlot b.b.	Zlot	Bor	Srbija	osnovna škola	Bravar u radionici	u radnom odnosu
14	17	[redacted]	[redacted]	m	[redacted]	Solunskih bor...	Boljevac	Boljevac	Srbija	SSS IV stepen-ekonom.teh	PK kopač	u radnom odnosu
15	18	[redacted]	[redacted]	m	[redacted]	Bogovina b.b.	Bogovina	Boljevac	Srbija	VS-menadžment	NK jamski vozač	u radnom odnosu
16	19	[redacted]	[redacted]	m	[redacted]	Bogovina b.b.	Bogovina	Boljevac	Srbija	KV-automehanicar	NK jamski vozač	u radnom odnosu
17	20	[redacted]	[redacted]	m	[redacted]	Bogovina bb	Bogovina	Boljevac	Srbija	osnovna škola	NK jamski vozač	u radnom odnosu
18	21	[redacted]	[redacted]	m	[redacted]	Valakonjska 29	Boljevac	Boljevac	Srbija	KV metalostrugar	PK kopač	u radnom odnosu
19	22	[redacted]	[redacted]	m	[redacted]	Šarbanovac b...	Šarbanovac	Bor	Srbija	osnovna škola	NK jamski vozač	u radnom odnosu
20	23	[redacted]	[redacted]	m	[redacted]	Valakonje b.b.	Valakonje	Boljevac	Srbija	osnovna škola	PK kopač	u radnom odnosu
21	24	[redacted]	[redacted]	m	[redacted]	Podgorac b.b.	Podgorac	Boljevac	Srbija	SSS-III elektro	II smenski elektricar	u radnom odnosu

Figure 2 *The table Injured in SQL Server Management Studio*

The table Injured contains basic information about the injured worker: name and surname, personal identity number, address, job title, gender, qualification and other.

To make a more vivid picture of possibilities for searching the database Injury at work, the Reports of an injury at work from the coal mine Bogovina in 2016 were entered into database. [8]

SQL (structured query language) is used for searching the database, i.e. relational query language which offers the possibility for different results, for example, how many injuries occurred in the coal mine Bogovina in 2016 that are specified according to:

- The qualification of the injured workers,
- Cause of the injury 21- landslides and caving of earth, rocks and stones [5],
- The severity of the injury.

Figure 3 presents the result of mentioned request that shows that ten injuries, caused by the caving of material occurred, which is a high percentage considering that in that year the total of 21 injuries happened. Only one of those injuries was described as severe injury, while the remaining nine were evaluated by doctors as the minor injuries. After studying the first column in Figure 3, it can be concluded that the production workers employed directly at the site are prone to this type of the injury.

	vrsta_i_sss_za_posao_na_kome_se_povredio	uzrok_povrede	ocena_tezine_povrede
1	NK jamski vozač	21	laka
2	Geolog	21	laka
3	NK jamski vozač	21	laka
4	KV kopač	21	laka
5	PK kopač	21	laka
6	KV kopač	21	laka
7	NK jamski vozač	21	laka
8	NK jamski vozač	21	teška
9	PK kopač	21	laka
10	PK kopač	21	laka

Figure 3 *View from database according to the query: the qualification of injured workers, cause of injury 21 and severity of injury*

If the condition that the severity of injury should be high and caused by 21 is added to the existing requirement, the results will be as shown in Figure 4. The database shows that injury occurred on 3 March 2016 (Monday) at 10.30 am at the OT4 site, Jama "East Field", Bogovina and that the injured worker was taken to ER in Zajecar where he received the S42 diagnosis - fracture of a shoulder and upper arm (Fractura regionis deltoideae et brachi). [6]

	vrsta_i_sss_za_posao_na_kome_se_povredio	uzrok_povre...	ocena_tezine_povrede	datum_povrede	dan_povrede
1	NK jamski vozač	21	teška	2016-03-14	ponedeljak

doba_dana_nastanka_povrede	mesto_povrede	adresa_povrede	naziv_zdravstvene_ustanove	dijagnoza_povrede
10:30	OT4, Jama Istocno polje	Bogovina	ZC Zaječar	S42-kamen

Figure 4 *The result of execution the query for closer determination of severe injury by criteria 21*

Overview, which is especially interesting in light of studying the injuries at work in the mining industry, is linked to description of injury and location of injury. Figure 5 shows table or query result, which shows the two above-mentioned parameters. It is clear that the majority of injuries occurred in the pit during cleaning the material and support construction at the site (nine injuries), movement of workers (four injuries) and during transport of intermediate goods (five injuries). Other injuries are located outside the pit or they are less interesting due to their frequency and response of the OS&H.

	kratak_opis_nastanka_povrede	mesto_povrede
1	prilikom prebacivanja korita grabuljastog transportera isti mu je priklještio prst	ETH 2, Jama Istocno polje
2	prilikom čišćenja materijala pao je kamen iz stropa i povredio mu prst leve ruke	OT3, Jama Istocno polje
3	okliznuo se prilikom dopreme građe	TH1, Jama Istocno polje
4	prilikom čišćenja materijal mu povredio palac leve ruke	ETH2, Jama Istocno polje
5	prikom bušenja ispitnih bušotina na ortu komad materijala povredio joj vrati i rame	ETH 2, Jama Istocno polje
6	prilikom čišcenja orta komad materijala udario ga po licu	OT3, Jama Istocno polje
7	prilikom igranja stonog tenisa na RSI polomio nogu	Hotel Zvezda
8	prilikom premeštanja grabuljara isti mu povredio nogu	OT3, Jama Istocno polje
9	prilikom silaska okliznuo se i povredio nogu	VV3, Jama Istocno polje
10	prilikom silaska u jamu okliznuo se i povredio nogu	GTN, Jama Istocno polje
11	prilikom čišćenja trase dalekovoda napeta grana povredila mu oko	Spolja, trasa dalekovoda
12	prilikom punjenja minskih bušotina materijal sa orta povredio mu lice i rame	PV2, Jama Istocno polje
13	prilikom podgrađivanja materijal mu povredio levu ruku	OT2a, Jama Istocno polje
14	prilikom podgrađivanja obrušeni materijal povredio mu vrat i levo rame	OT2a/1b, Jama Istocno polje
15	sekao transportnu traku	Spolja, Mašinska radionica
16	prilikom čišćenja materijala komad materijala udario ga po levom ramenu	OT4, Jama Istocno polje
17	prilikom dopreme delova za montažu grabuljara povredio	OT1, Jama Istocno polje
18	prilikom čišćenja materijala sa radilišta došlo je do odvajanja dela kamena iz stropa i povredio mu leda	ETH 2, Jama Istocno polje
19	prilikom dopreme repromaterijala zakacila ga je natezna koja je bila okacena na vozicak, i tom prilikom povredio je desno koleno	TH1, Jama Istocno polje
20	prilikom pravljenja mesta za stupac odvojio se kamen iz boka i povredio mu glavu, denu ruku i leda	TU2, Jama Istocno polje
21	prilikom prolaska kroz hodnik, okliznuo se i pao na leda i povredio levu stranu tela (rebro)	VU1B, Jama Istocno polje

Figure 5 *View from database according to the query relating to the description of the injury and location of the injury*

Based on the data, it can be concluded that the coal mine Bogovina must conduct the additional training and introduce better security measures that would increase the safety in movement of workers in the pit during cleaning the working site because most of injuries occur at these job positions.

Figure 6 shows an overview of the table base on the next requirements: the type and qualification of injured, the source of injury 531 and the minor injury. Source of the injury 531 is, according to the Records and notifications of injuries at work, a code for an injury that occurred due to the block caving in an underground facility (tunnel, mine and other). [5] This is the most common source of injury in the mining industry that often results in serious and fatal injuries of workers, and is a direct result of irregularities of the safety and support in corridors. The analysis shows that ten out of twenty-one injuries in the coal mine Bogovina are caused by caving (Figure 3), seven injuries are caused by block caving, and the three remaining are the consequence of caving at the work site. Caving at the work site during the construction of underground facilities is unpredictable and cannot be easily influenced.

	vrsta_i_sss_za_posao_na_kome_se_povredio	izvor_povrede	ocena_tezine_povrede
1	SSS-palioc mina	531	laka
2	II smenski bravar	531	laka
3	KV kopač	531	laka
4	PK kopač	531	laka
5	KV kopač	531	laka
6	NK jamski vozač	531	laka
7	PK kopač	531	laka

Figure 6 *View from database according to the query relating to the type and qualification of injured, source of the injury 531 and the minor injury*

The worker's age are always interesting for studying, primarily due to a decline of labor and physical abilities of worker compared to the younger workers without enough experience. By comparison of these two categories, a conclusion can be made concerning the quality of training the workers at the beginning of their career. Table in Figure 7 shows that the most of workers belong to a group older than 35 (90%), while only two workers were "young", that is to say, younger than 35.

	vrsta_i_sss_za_posao...	godine...	kratak_opis_nastanka_povrede	ocena_...
1	NK jamski vozač	42	prilikom prebacivanja korita grabuljastog transportera isti mu je priklještio prst	laka
2	NK jamski vozač	35	prilikom čišćenja materijala pao je kamen iz stropa i povredio mu prst leve ruke	laka
3	PK kopač	39	okliznuo se prilikom dopreme građe	laka
4	NK jamski vozač	28	prilikom čišćenja materijal mu povredio palac leve ruke	laka
5	Geolog	41	prikom bušenja ispitnih bušotina na ortu komad materijala povredio joj vrati i rame	laka
6	NK jamski vozač	35	prilikom čišcenja orta komad materijala udario ga po licu	laka
7	PK kopač	52	prilikom igranja stonog tenisa na RSI polomio nogu	teška
8	KV-kopač	52	prilikom premeštanja grabuljara isti mu povredio nogu	teška
9	SSS-palioc mina	41	prilikom silaska okliznuo se i povredio nogu	laka
10	II smenski bravar	43	prilikom silaska u jamu okliznuo se i povredio nogu	laka
11	KV oplemenjvac	49	prilikom čišćenja trase dalekovoda napeta grana povredila mu oko	laka
12	KV kopač	29	prilikom punjenja minskih bušotina materijal sa orta povredio mu lice i rame	laka
13	PK kopač	41	prilikom podgrađivanja materijal mu povredio levu ruku	laka
14	KV kopač	47	prilikom podgrađivanja obrušeni materijal povredio mu vrat i levo rame	laka
15	Bravar u radionici	53	sekao transportnu traku	laka
16	NK jamski vozač	34	prilikom čišćenja materijala komad materijala udario ga po levom ramenu	teška
17	NK jamski vozač	35	prilikom dopreme delova za montažu grabuljara povredio	laka
18	PK kopač	40	prilikom čišćenja materijala sa radilišta došlo je do odvajanja dela kamena iz stropa i povredio mu leda	laka
19	NK jamski vozač	42	prilikom dopreme repromaterijala zakacila ga je natezna koja je bila okacena na vozicak, i tom prilikom povredio je desno koleno	laka
20	PK kopač	45	prilikom pravljenja mesta za stupac odvojio se kamen iz boka i povredio mu glavu, denu ruku i leda	laka
21	II smenski elektricar	46	prilikom prolaska kroz hodnik, okliznuo se i pao na leda i povredio levu stranu tela (rebro)	laka

Figure 7 *View from database according to the query: the type and qualification of injured, age, description of injury and severity of injury*

However, if the following table (Figure 8) is considered as it shows the column Work experience of the injured, it can be concluded that even if the worker is experienced according to his age, his work experience suggests otherwise. Only five workers have an extensive work experience for over 20 years, two of them have over ten years, and other thirteen have five years of experience or less. This indicates that these workers are inexperienced and poorly trained for the work they perform, and due to this fact they are injured in such a large number. This phenomenon can be also explained by the prohibition of employment in the public sector, in which the Coal mine Bogovina belongs to. The workers are placed at jobs where their abilities do not match the requirements, but due to a lack of adequate personnel, they are provided with adequate re-training and internal qualification where they have to master the new skills in a relatively short period of time.

Figure 8 shows that the most of injuries occurred in the morning, 15 of them, which was expected since the mine operates in two shifts, but the biggest number of workers works the first shift, such as maintenance workers, and supervisory technical staff.

This paper provides an example of accessible database that would facilitate the job of data updating on injuries for Serbia in companies, and would support the regi-

ster creation. There are no reports from the previous period in the Safety Management Bureau. This provides an opportunity to the companies to translate the printed reports into digital reports within database, and in that way to help the Safety Management Bureau with data updating from the previous period.

	obavljani_posao_u_momentu_povrede	radno_iskustvo_na_povredjenom_poslu	mesto_povrede	doba_dana_nastanka_povrede
1	prebacivao korito transportera	21	ETH 2, Jama Istocno polje	01:00
2	čišćenje materijala	11	OT3, Jama Istocno polje	21:30
3	prisustvovala bušenju	6	ETH 2, Jama Istocno polje	10:45
4	čišćenje materijala	11	OT3, Jama Istocno polje	04:00
5	igrao stoni tenis na RSI	-	Hotel Zvezda	11:00
6	pomeranje grabuljastog transpotera	20	OT3, Jama Istocno polje	11:00
7	silazak u jamu	1	VV3, Jama Istocno polje	8:30
8	silazak u jamu	5	GTN, Jama Istocno polje	7:45
9	čišcenje trase dalekovoda	0	Spolja, trasa dalekovoda	12:30
10	pomagao je paliocu prilikom punjenja mina	3	PV2, Jama Istocno polje	18:00
11	čišćenje materijala	3	OT2a, Jama Istocno polje	11:30
12	čišćenje materijala	3	OT2a/1b, Jama Istocno polje	13:15
13	sekao transportnu traku	0,4	Spolja, Mašinska radionica	11:30
14	doprema građe	3	TH1, Jama Istocno polje	19:30
15	čišćenje materijala	5	ETH2, Jama Istocno polje	11:00
16	čišćenje materijala	4	OT4, Jama Istocno polje	10:30
17	doprema repromaterijala	11	OT1, Jama Istocno polje	10:45
18	čišćenje materijala	3	ETH 2, Jama Istocno polje	10:00
19	doprema repromaterijala	25	TH1, Jama Istocno polje	9:30
20	pravio mesta za stupac	23	TU2, Jama Istocno polje	19:30
21	kretao se hodnikom	30	VU1B, Jama Istocno polje	11:00

Figure 8 *View from database according to the query: performed work at the moment of injury, work experience at injured job, location of injury and time of the day of injury occurrence*

Combining the all data in a single database will provide a clear picture of security situation of the safety at work in Serbia. In the event that data are implemented in the Register of an injury, a clear cost of an injury at work will be available using data from the Health Fund.

CONCLUSION

Any injury that occurs, however bizarre, carries a message to the employer and management of the Safety and Health Protection Management Bureau of the Republic of Serbia. Ignoring these events, such as, for example, a frequent minor finger injury on a machine can be easy, but, in the worst case scenario, it can result in a fatal outcome, varying degrees of disability and, almost always, in disruption the production process, or in additional costs for the state or company. Although death seems like an exaggeration, in the underground mining of mineral raw materials, the miners get hurt on the drive drum conveyor belt which first pulls in a finger, than a hand, and then the whole body of a victim.

Database allows the generation a large amount of data in a very simple manner, and without additional hiring or cost to the employer. A disposal of this kind of data allows better access to the evaluation and implementation the laws, regulations and standards. Also, the advantage of this kind of data available is ability to identify the vulnerable groups of interest. Injuries are typically grouped around a certain accident situation which happened multiple times.

Any company that has a way of recording such injuries can easily study the risk factors at any time, new needs in the production process, the need for change in the act on risk assessment, new trainings, and enhanced control and so on.

Direction of further development and additions to this base would be in a direction of adjustment to certain jobs, and supplement to the database, related to the absence from work, for example, the cost of absence and treatment of workers, length of disability of the injured, course and outcome of recovery, and possible degree of disability as well as development the application for easier database manipulation on injuries at work.

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DRIVING POWER VERIFICATION OF THE APRON FEEDER FOR ORE TRANSPORTATION

Abstract

This paper gives the methodology for driving power calculation of an apron feeder for ore transportation on the example of the apron feeder DO-F in the open pit of the Copper Mine Majdanpek. The analysis was done by calculation for given operating parameters. The apron feeder layout is also presented, as well as the technical characteristics of the driving unit elements.

Keywords*: apron feeder, power calculation, layout, technical characteristics*

1 INTRODUCTION

Within the Complementary Mining Project on copper ore mining from the South Mining District deposit in the Copper Mine Majdanpek, which predicted an increase in capacity of ore mining and processing to 8.5 Mt per year, it was necessary to make the project documentation for verification the capacities of transportation systems for ore and overburden in the new operating conditions. Technical Project on reconstruction the transportation systems for ore [1] included the apron feeder DO-F, designed for ore transportation from the open orestorage for ore under the belt conveyor C1 to the loading portion of the belt conveyor F in terms of verification its driving power.

2 TECHNICAL DESCRIPTION

Technical characteristics of apron feeder:

- capacity: $Q = 1600\left[\frac{t}{h}\right]$
- type of material: copper ore
- size of material: $GGK = 200[mm]$
- bulk density of material: $\rho = 1860\left[\frac{kg}{m^3}\right]$
- transportation length: $L = 6.4[m]$
- maximum inclination angle of conveyor: $\beta = 0[°]$
- material lift on conveyor: $H = 0[m]$
- conveyor speed: $v = 0.\ 12\left[\frac{m}{s}\right]$
- height of fixed side walls: $h = 1.35[m]$
- width of conveyor-plates length: $b = 1.829[m]$

The apron feeder layout is shown in Figure 1 and Figure 2.

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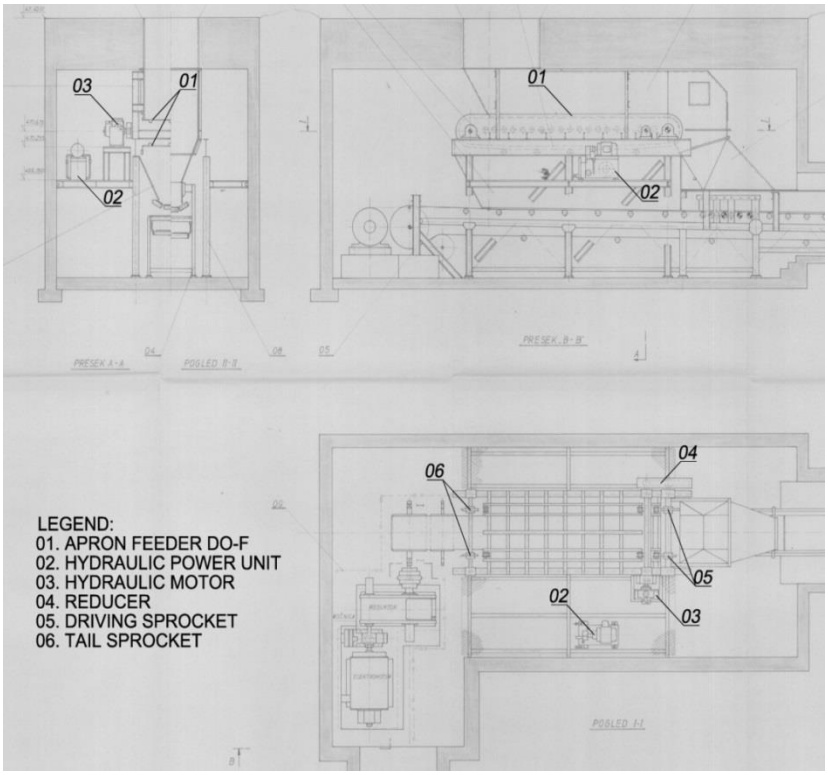

Figure 1 *Apron feeder DO-F layout in plan view and section views*

Figure 2 *View of apron feeder DO-F*

The apron feeder consists of a steel construction, driving unit, driving sprocket, tail sprocket, carrying and return rollers, chain and plates. The apron feeder is with fixed side walls.

The driving unit consists of a hydraulic power unit, hydraulic motor and single stage reducer.

The hydraulic power unit with label AF5-72M-21-40H consists of a variable displacement hydraulic pump driven by electric motor with an auxiliary charge pump, tank and pipelines with suitable fittings (pump circuit schematic is shown in Figure 3 and its view in Figure 4).

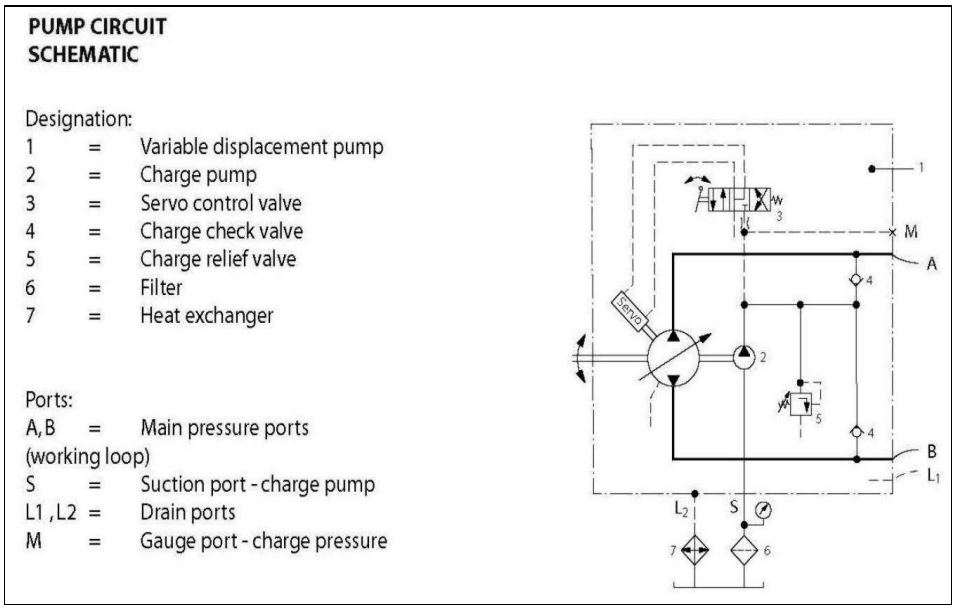

Figure 3 *Hydraulic scheme of hydro pump PV23*

The driving unit has the possibility of speed regulation thanks to the flow rate control regulation of the hydraulic pump, while the hydraulic motor has no possibility of flow rate regulation (motor circuit schematic is shown in Figure 5 and its view in Figure 6).

Technical characteristics of electric motor:

- installed power of electric motor:
  $P = 37[kW]$
- electric motor speed:
  $n = 1475[min^{-1}]$

Technical characteristics of hydraulic pump:

- label: PV23
- type: axial piston
- maximum pressure:
  $p_{max} = 200[bar]$
- maximum displacement:
  $q = 89\left[\frac{cm^3}{rev}\right]$
- speed: $n = 1475[min^{-1}]$
- working pressure:
  $p = 0 - 200[bar]$

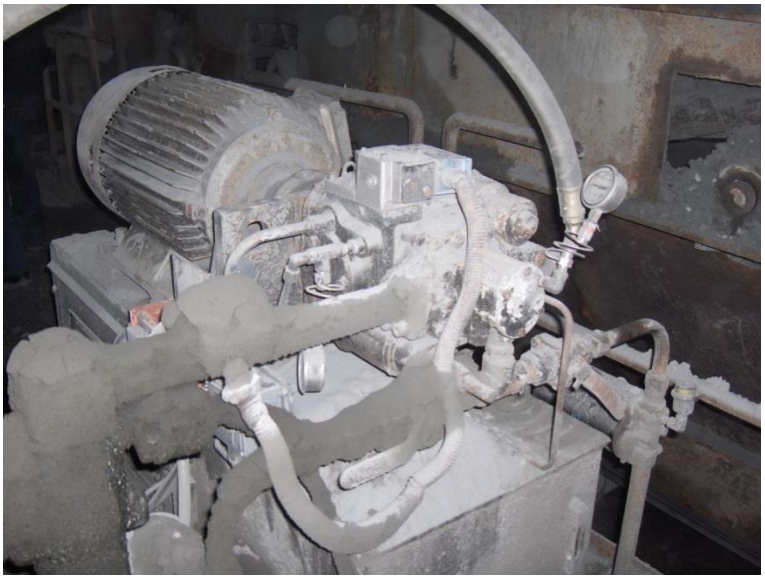

Figure 4 *View of hydraulic pump PV23*

Technical characteristics of hydraulic motor:

- label: MH187JC
- type: radial piston
- maximum pressure: $p_{max} = 200[bar]$
- displacement: $q = 3060\left[\frac{cm^3}{rev}\right]$
- nominal torque: $M = 4938[Nm]$
- maximum torque: $M = 9571[Nm]$
- speed: $n = 3 - 36[min^{-1}]$
- working pressure: $p = 0 - 200[bar]$

Technical characteristics of single stage reducer:

- number of gear teeth on hydraulic motor shaft: $z_1 = 20$
- number of gear teeth on driving sprocket shaft: $z_2 = 120$
- ratio: $i = 6$

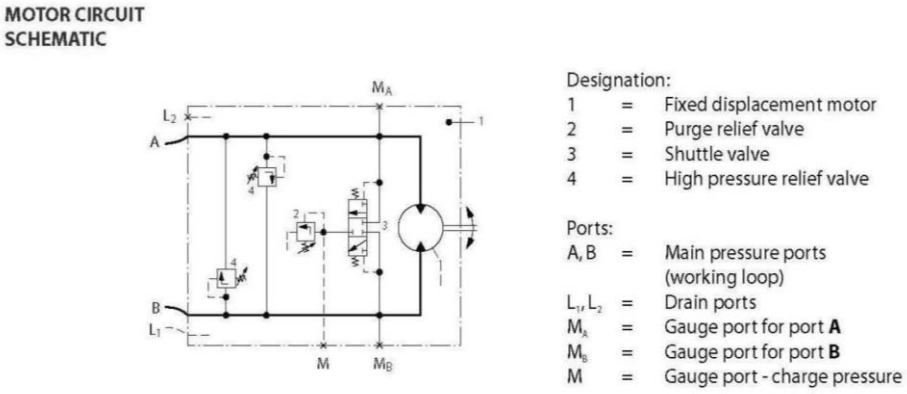

Figure 5 *Hydraulic scheme of hydro motor MH187JC*

Figure 6 *View of hydraulic motor MH187JC*

3 CALCULATION

Calculation is aimed at determining the required driving power of apron feeder and is given by [2] and [3].

- The required conveyor speed is:

$$v = \frac{Q}{3600 \cdot h \cdot \psi \cdot b \cdot \rho} =$$

$$= \frac{1600}{3600 \cdot 1.35 \cdot 0.8 \cdot 1.829 \cdot 1.86} \left[\frac{m}{s}\right]$$

$$= 0.12 \left[\frac{m}{s}\right]$$

where

$\psi = 0.8$ –coefficient of filling

- The required conveyor width with respect to the lump size of load is:

$$b \geq X_2 \cdot a + 200[mm] =$$

$$= 2.7 \cdot 200 + 200[mm] = 740[mm]$$

where:

$X_2 = 2.7$ –coefficient for sorted material

$a = 200[mm]$ –maximum lump size

The conveyor width meets the terms of lump size of load.

- The maximum static tensile force in chain is according to [3]:

$$S_{max} \approx 1{,}05 \cdot \{S_{min} + w \cdot [(q_t + q_0) \cdot L + q_0 \cdot L]\} + W_b =$$
$$= 1.05 \cdot \{2000 + 0.13 \cdot [(36333 + 2597) \cdot 6.4 + 2597 \cdot 6.4]\} + 94895 =$$
$$= 133273[N]$$

where:

$S_{min} = 2000[N]$ – minimum tensile force in chain

$w = 0.13$ – resistance coefficient of chain for sliding bearings and hard working conditions

$q_t = \frac{Q \cdot g}{3.6 \cdot v} = \frac{1600 \cdot 9.81}{3.6 \cdot 0.12}\left[\frac{N}{m}\right] = 36333\left[\frac{N}{m}\right]$ – weight of the load per length unit

$q_0 = 600 \cdot b + A = 600 \cdot 1.829 + 1500\left[\frac{N}{m}\right] = 2597\left[\frac{N}{m}\right]$ – weight of floor per length unit

$A = 1500$ –coefficient for floor length over 0.8 m and heavy floor type

- Force due to material friction with the hopper fixed sides is:

$$W_b = \mu_1 \cdot h^2 \cdot \rho \cdot g \cdot n_b \cdot l_b = 0.58 \cdot 1.35^2 \cdot 1860 \cdot 9.81 \cdot 0.82 \cdot 6[N] = 94895[N]$$

where:

$\mu_1 = 0.58$ - friction coefficient between the material and steel

$\varphi = 38°$ - angle of natural material falling

$l_b = 6{,}0[m]$ - lateral side length

$n_b = \frac{v+1.2}{1+sin\varphi} = \frac{0.12+1.2}{1+sin38°} = 0.82$ – coefficient of lateral pressure

- Pulling force on the drive sprocket is:

$$W = S_{max} - S_{min} = 133273 - 2000[N] = 131273[N]$$

- Power required to overcome the resistance forces of apron feeder motion is:

$$P_{TR} = \frac{W \cdot v}{1000 \cdot \eta} = \frac{131273 \cdot 0.12}{1000 \cdot 0.8}[kW] = 19.7[kW]$$

where:

$\eta = 0.80$-mechanical efficiency

- Cross section area of hopper opening is:

$$A = b \cdot c = 1.829 \cdot 1.6[m^2] = 2.93[m^2]$$

where:

$c = 1.6[m]$ - length of hopper opening

- Hydraulic radius of hopper opening is:

$$R = \frac{b \cdot c}{2 \cdot (b + c)} = \frac{1.829 \cdot 1.6}{2 \cdot (1.829 + 1.6)}[m] = 0.43[m]$$

- Internal friction coefficient of material is:

$$\mu = tg\varphi = tg38° = 0.78$$

- Coefficient of mobility is:

$$m = 1 + 2 \cdot \mu^2 - 2 \cdot \mu \cdot \sqrt{1 + \mu^2} = 1 + 2 \cdot 0.78^2 - 2 \cdot 0.78 \cdot \sqrt{1 + 0.78^2} = 0.24$$

- Pressure force of material column on hopper opening is:

$$T = \frac{A \cdot \rho \cdot R \cdot g}{m \cdot \mu} = \frac{2.93 \cdot 1860 \cdot 0.43 \cdot 9.81}{0.24 \cdot 0.78}[N] = 122804[N]$$

- Power required to overcome losses due to the friction force caused by pressure of material column is:

$$P_P = \frac{T \cdot v \cdot \mu_1}{1000} = \frac{122804 \cdot 0.12 \cdot 0.58}{1000}[kW] = 8.5[kW]$$

- Total required apron feeder driving power is:

$$P = P_{TR} + P_P = 19.7 + 8.5[kW] = 28.2[kW]$$

4 DISCUSSION OF CALCULATION

As can be seen from the calculation the total required apron feeder driving power consists of the power required to overcome the resistance forces of apron feeder motion, and the power required to overcome losses due to the friction force caused by pressure of material column. The motion resistance force consists of the resistance force of carrying and return strands of apron feeder, the force due to raising material which is zero in this case because it is a horizontal conveyor, and force due to material friction with the hopper fixed sides. The resistance forces depend on operating parameters of conveyor, physical properties of material, and structural characteristics of feeder. The existing electric motor $P_{EM} = 37[kW]$ is satisfactory in terms of power.

Considerable speed reduction from electric motor to drive sprocket is obtained, in this case, applying the hydrostatic transmission and one stage reducer. The application of variable displacement hydraulic pump enables the speed regulation of apron feeder so that during start of drive, the apron feeder works with a minimum speed, and nominal speed is obtained at the steady operating conditions. Using the appropriate fittings in the hydraulic installation, the system overload protection is secured, i.e. maintenance the required operating parameters of oil. The single stage reducer transmitting the motion from the shaft driven by the hydraulic motor to the shaft with drive sprocket is positioned in such a way that the hydraulic motor shaft is free from radial force. Low speed of conveyor $v < 0.2[m/s]$ ensures the relief of inertial forces that occur during operation of chain conveyors. Thus, the driveline ensures correct and reliable operation of apron feeder in given conditions.

5 CONCLUSION

The exposed methodology for power calculation of apron feeder is one of the ways to calculate the verification in selecting a driveline or driveline verification for operation in the new working conditions. The equipment manufacturers also provide their own methods for calculating the required power of apron feeder which to a lesser extent vary from manufacturer to manufacturer. Likewise, various examples of power calculation of apron feeder can be found in literature, but basically the exposed method represents the logic of calculation.

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ANALYSIS OF COAL QUALITY IN A FUNCTION OF SELECTION LEVEL FOR MINING AT THE OPEN PIT GACKO[***]

Abstract

This work analyzes the quality of coal in the function level selection for exploitation. A detailed analysis was carried out for the main coal seam, the first floor seam, the second floor seam and the overlying coal series of the coal deposit Gacko of 0.5 and 1 m. The analysis was carried out within the Strategy of mining-technological opening, development, optimization and maintenance the continuity of coal production with development the Feasibility Study of introducing a dry separation method in order to determine the amount and quality of coal for TPP Gacko. The analysis included the effects of natural and technological factors on participation the seam overburden in the run-of-mine coal as well as a degree of overburden impact on the quality of run-of-mine coal.

Keywords: *selective mining, coal quality, TPP, Gacko*

INTRODUCTION

The open pit coal mining represents a large installed capacities for the needs of energetics and is characterized by a very extensive and complex production complexes within the exploitation system.

Coal deposits, predisposed for the open pit mining, are frequently characterized by a complex structure and operating conditions. Further development of the open pit mining is also related to more complex engineering-geological, and hydrogeological characteristics of the working environment, the increased overburden coefficient, more demanding environmental conditions, which all together emphasizes a need for use the modern technological mining methods, and even selective mining that becomes more and more pronounced.

Selective coal mining in these circumstances gets more importance from the standpoint of efficiency of reserves in the deposit, and in some cases is imposed as the only possibility of mining. It is often the case that the use of selective mining allows the evaluation of those coal reserves that otherwise could not be balanced as an energy source.

In any case, whether it is a mass or selective mining, the coal excavation is carried out in a particular work environment that represents the environment of production system, with a group of specific chara-

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[***] *This work is derived from the project TR37001 "The Impact of Mining Waste from RTB Bor on the Pollution of Surrounding Water Systems with the Proposal of Measures and Procedures for Reduction Harmful Effect on the Environment", funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia*

cteristics that affect the choice of parameters for operation technology.

SELECTIVE COAL MINING AT THE OPEN PIT GACKO

Coal mining in the Gacko coal basin is carried out using the technology of selective coal mining. Orientation to the selective mining has been demonstrated in terms of efficiency and valorization the available coal reserves, then from the viewpoint of the needs and possibilities of coal homogenization, and also as the only method of coal mining with an extremely complex structure of coal bearing series.

The coal deposit Centralno Polje is more predisposed to the open pit mining, and is characterized by complex mining conditions, from the aspect of geological structure of coal bearing seams.

Within this exploration-exploitation field of the Gacko coal basin, three coal seams have been developed within the roof coal series, then the main, the first and the second floor coal seam (Figure 1).

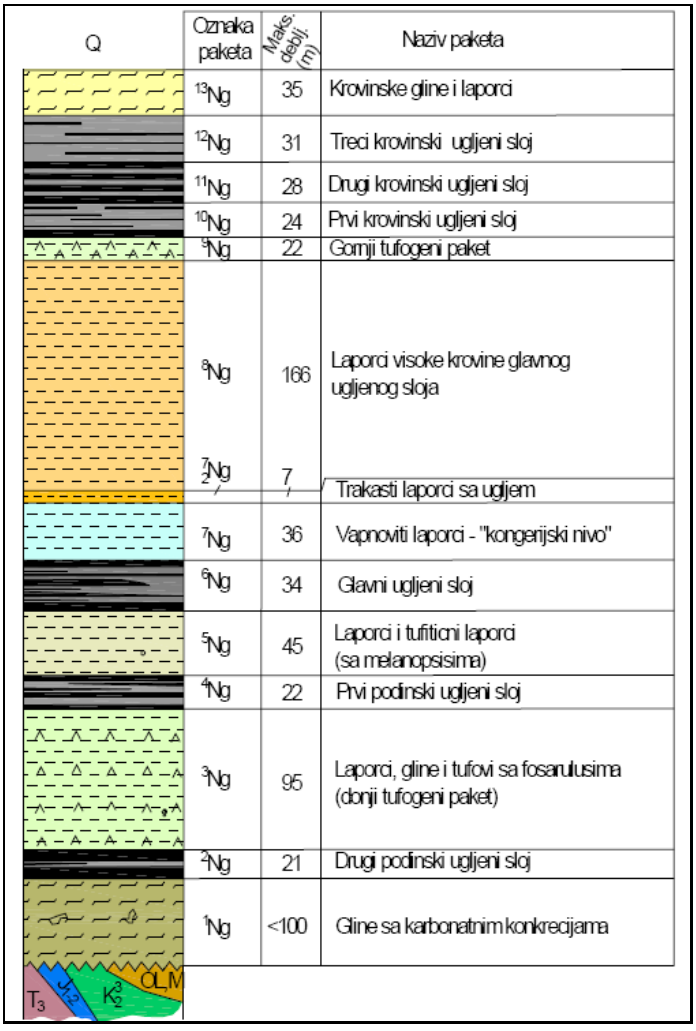


Figure 1 *Lithostratigraphic pillar of the Neogene series of the Gacko coal basin*

All coal seams are complex or stratified with greater or lesser presence of waste thin seam.

Coal, mined in this deposit, is intended to supply the thermo power plant, and the major limitation in terms of exploitability is the quality of run-of-mine coal. In the mining dynamics defining, the quality of run-off-mine coal was analyzed in the specific mining conditions. In addition to the other factors, a dilution of mineral raw material was observed as the result of the coal seam structure. Dilution occurs in mining a certain amount of waste from a contact of coal seam or thin seam.

This causes a reduction in calorific value compared to the coal calorific value determined during the deposit exploration. In a coal supply to the thermal power plants, as a condition, there is exactly a certain minimum calorific value that is a limit for the percentage presence of waste material in coal, that is, the level or degree of dilution, in this particular case the followings are analuzed, such as: the roof, the main, the first and the second floor coal seam.

Coal dilution is determined for the selection level during excavation of 0.5 and 1 m.

The selection level is minimum thickness of thin seams or a group of thin seams which are mined as the run-of-mine coal. Thins seams of coal are mined as the run-of-mine coal in two cases, as follows:

1. if their thickness is greater than the selection level, and
2. if their thickness is less than the selection level wherein the thickness of waste thin seam between two adjacent coal thin seams is less, and the sum of thicknesses of adjacent coal thin seams is greater than the selection level.

The same is also applied to the waste thin seams which are mined as the selective waste material.

If the coal thickness is less than the selection level in mining, the losses occur, while if the waste thickness is less than the selection level, a dilution occurs.

The analysis of dilution in a function of stratigraphic position interlayers of coal thin seams within the coal seams was carried out such as the pillars of drill holes were analyzed, and the presence of coal and waste thin seams of thickness less than the selected level, and their mutual position. The basis for the analysis was the basis of exploration work results (exploratory drill holes) from which the waste thin seams were firstly identified that are mined together with coal, followed by the calculation the total amount of run-of-mine coal and degree of presence the waste in the total weight of coal. Data regarding the percentage of dilution are connected to the corresponding coal seam and corresponding exploration work, and the analyzed data had its coordinates in a real space. Subsequent interpretation was carried out using a suitable software package, and the results are shown in a form of isolines of dilution percentage. In addition to the presented spatial arrangement and percentage of volume dilution, was performed and the statistical analysis of this data was performed, and the appropriate measures of tendency and dispersion were given. Further text presents the analysis results for the selection level of 0.5 and 1 m.

DILUTION FOR THE SELECTION LEVEL OF 0.5 m

Isolines of coal dilution in% by volume participation in the coal seam for the roof, main, first and second floor seam are given in Figures 2 to 5.

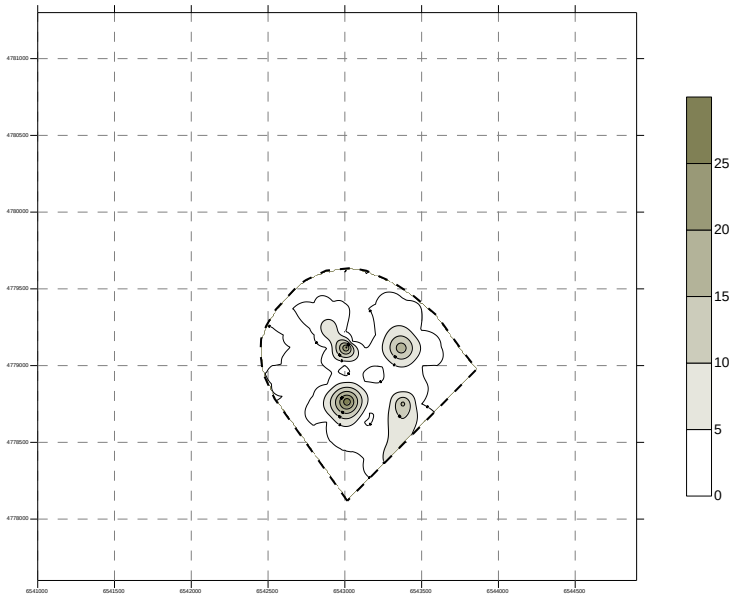


Figure 2 *Isolines of coal dilution percentage in the roof coal seam for the selection level 0.5 m*

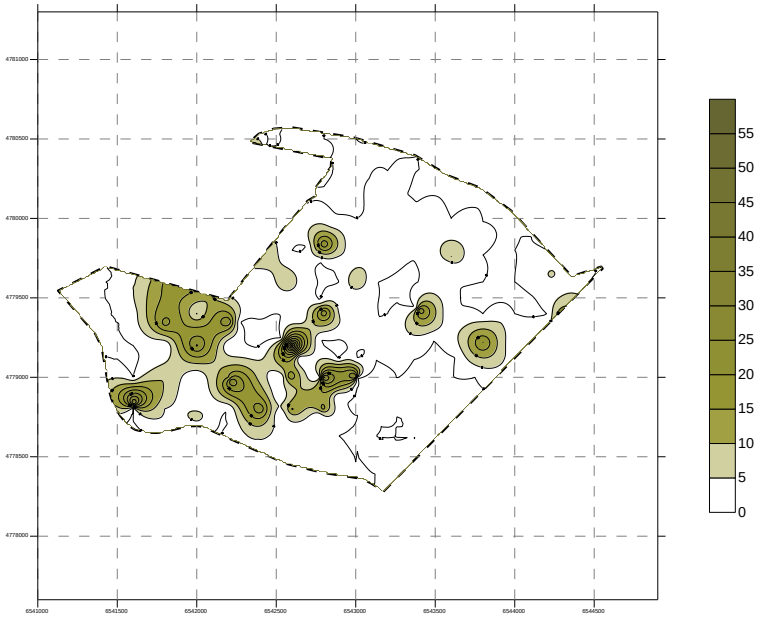


Figure 3 *Isolines of coal dilution percentage in the main coal seam for the selection level 0.5 m*

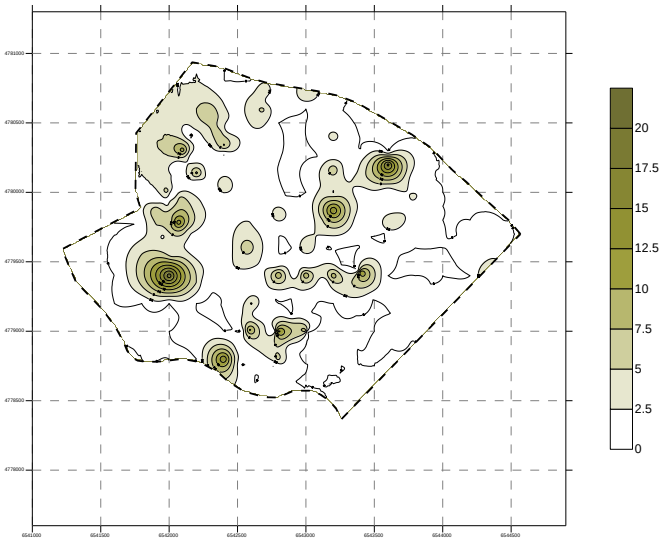


Figure 4 *Isolines of coal dilution percentage in the first floor coal seam for the selection level 0.5 m*

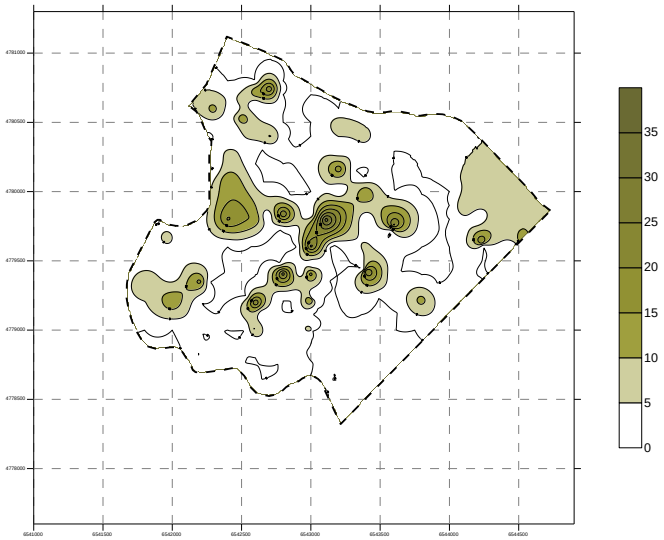
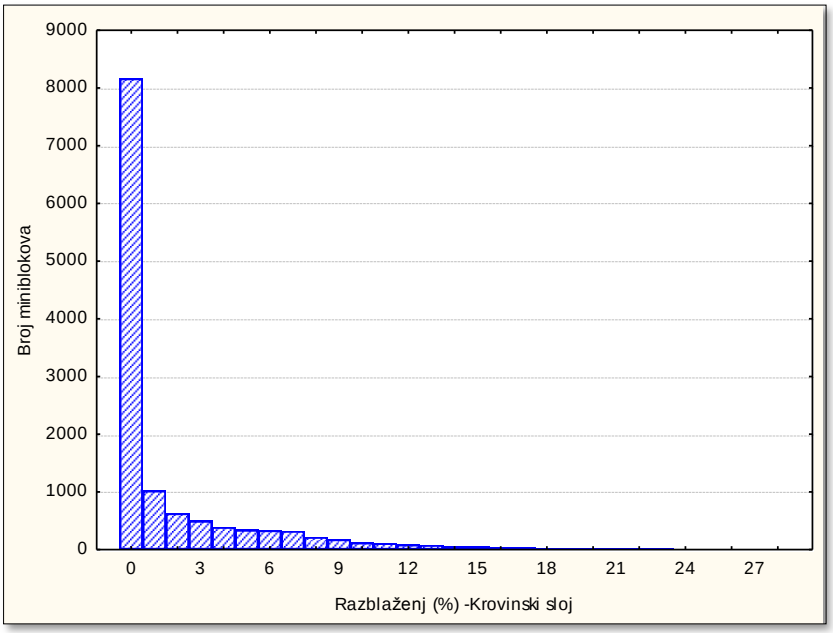


Figure 5 *Isolines of coal dilution percentage in the second floor coal seam for the selection level 0.5 m*

Histograms of dilution percentage by the coal seams are given in Figure 6.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Razblaženj (%) -Krovinski sloj

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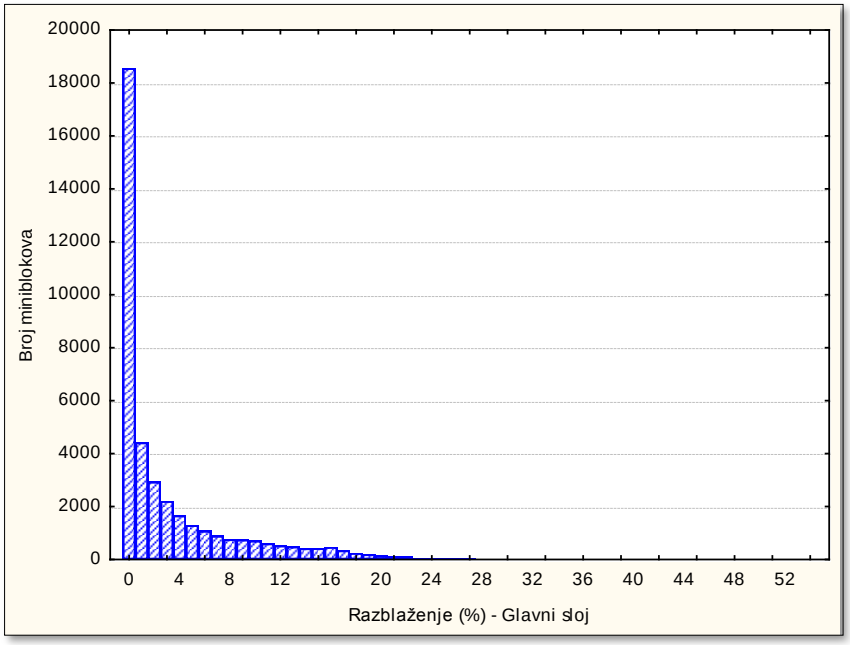
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Razblaženje (%) - Glavni sloj

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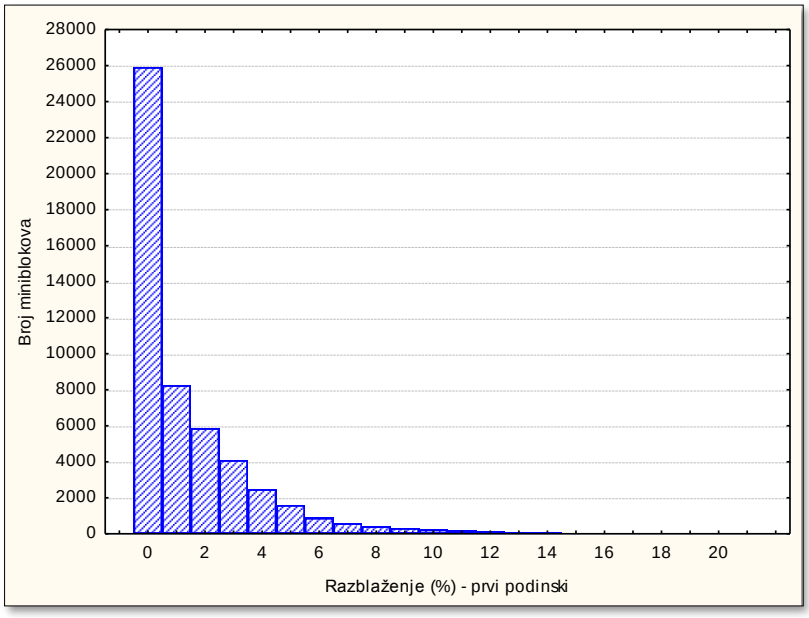

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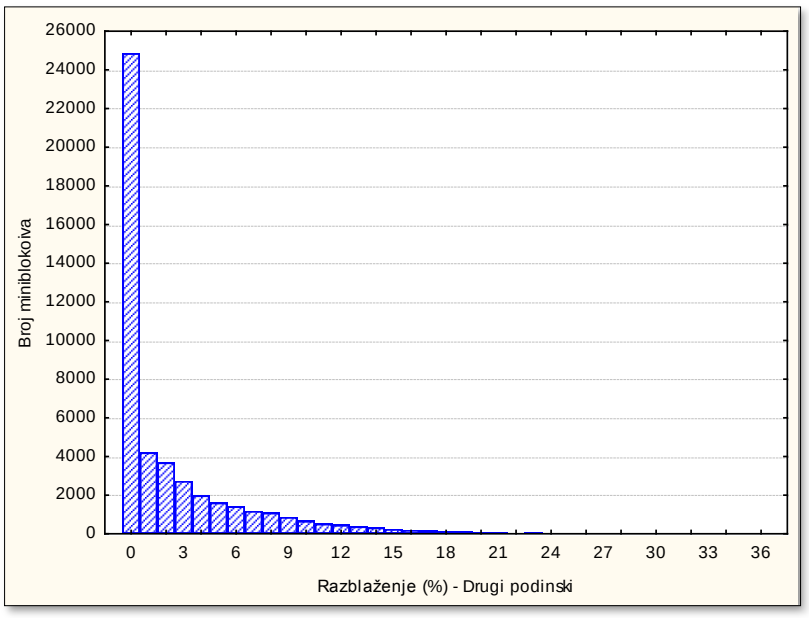


d)

Figure 6 *Histograms of the dilution percentage by coal seams (a-roof, b-main, c-first floor and d-second floor coal seam) for the level selection of 0.5 m*

Table 1 *Results of statistical analysis of dilution at the selection level of 0.5 m*

Characteristic	Roof coal seam	Main coal seam	Second floor coal seam	First floor coal seam
Arithmetic mean	2.144	3.672	1.823	2.837
Median	0.069	1.227	0.969	0.773
Standard deviation	3.883	5.418	2.405	4.345
Number of miniblocks	12779	39661	51173	47227
Minimum	0.000	0.000	0.000	0.000
Maximum	28.605	54.048	21.739	36.939
I quartile	0.000	0.000	0.048	0.000
II quartile	2.595	4.982	2.674	3.962

DILUTION FOR THE SELECTION LEVEL OF 1 m

Isolines of coal dilution in % by volume participation in the coal seam for the roof, main, first and second floor seam are given in Figures 7 to 10.

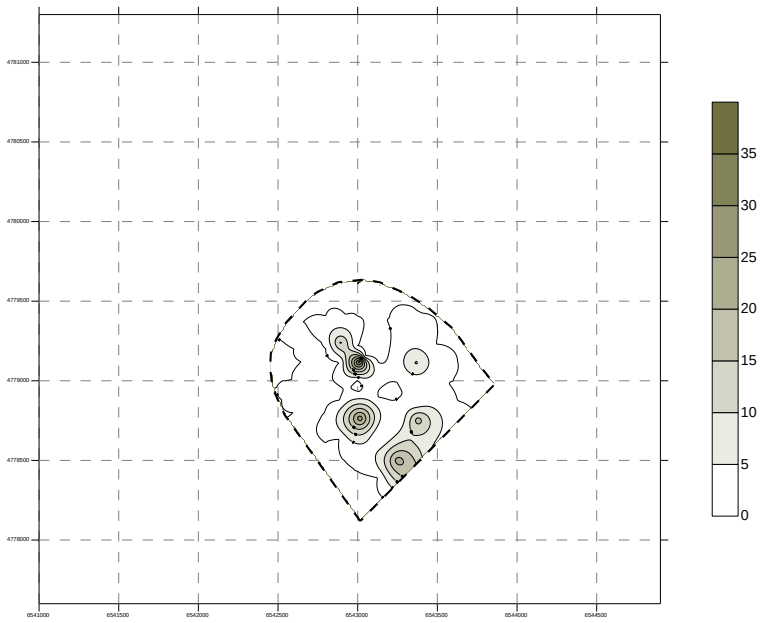


Figure 7 *Isolines of coal dilution percentage in the roof coal seam for the selection level 1 m*

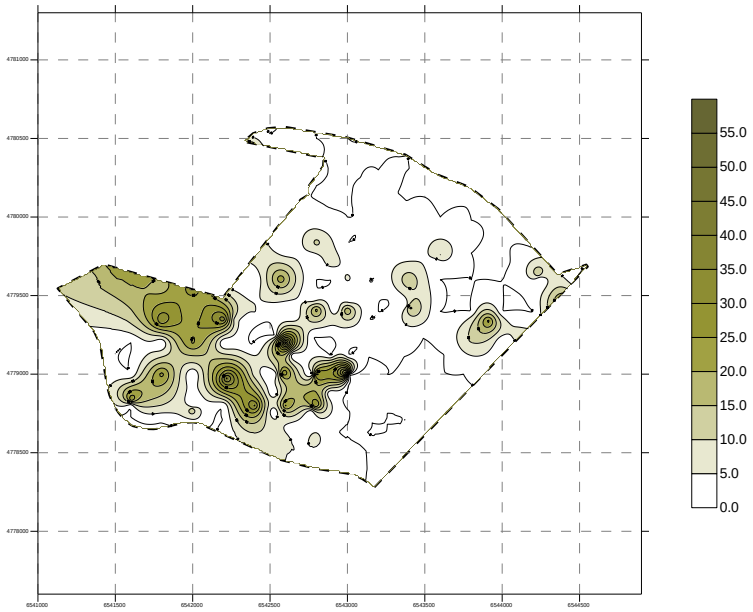


Figure 8 *Isolines of coal dilution percentage in the main coal seam for the selection level 1 m*

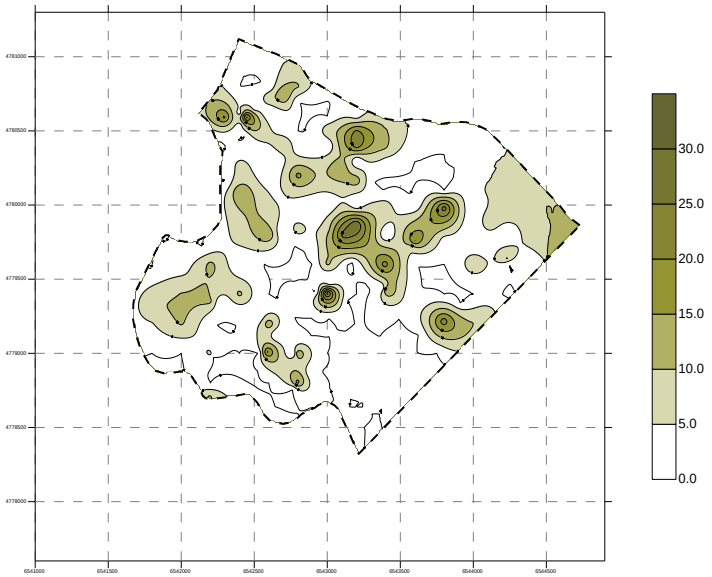


Figure 9 *Isolines of coal dilution percentage in the first floor coal seam for the selection level 1 m*

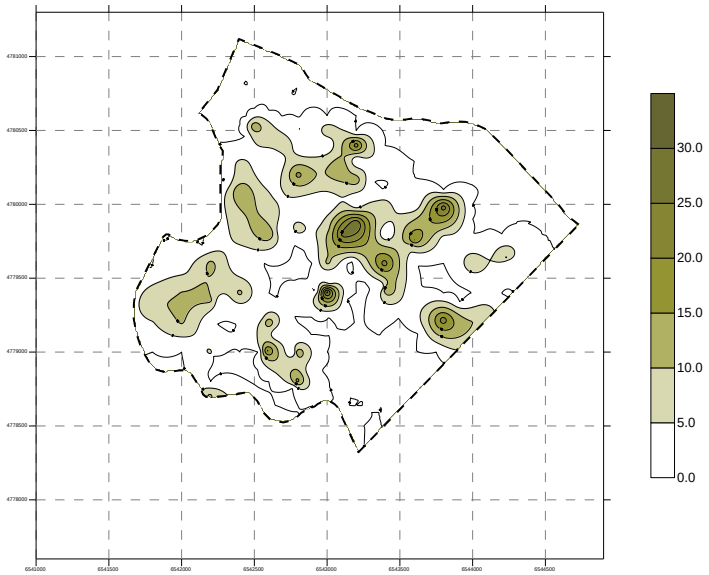
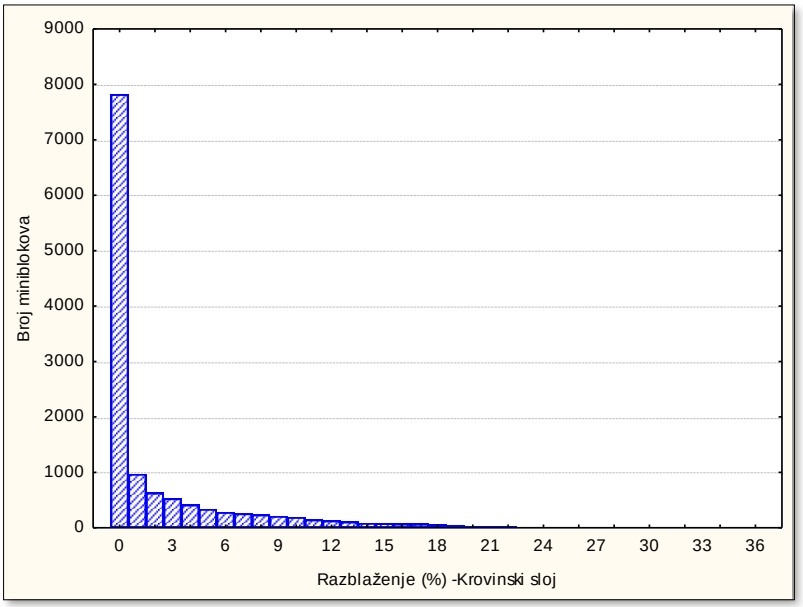


Figure 10 *Isolines of coal dilution percentage in the second floor coal seam for the selection level 1 m*

Histograms of dilution percentage by the coal seams are given in Figure 11.



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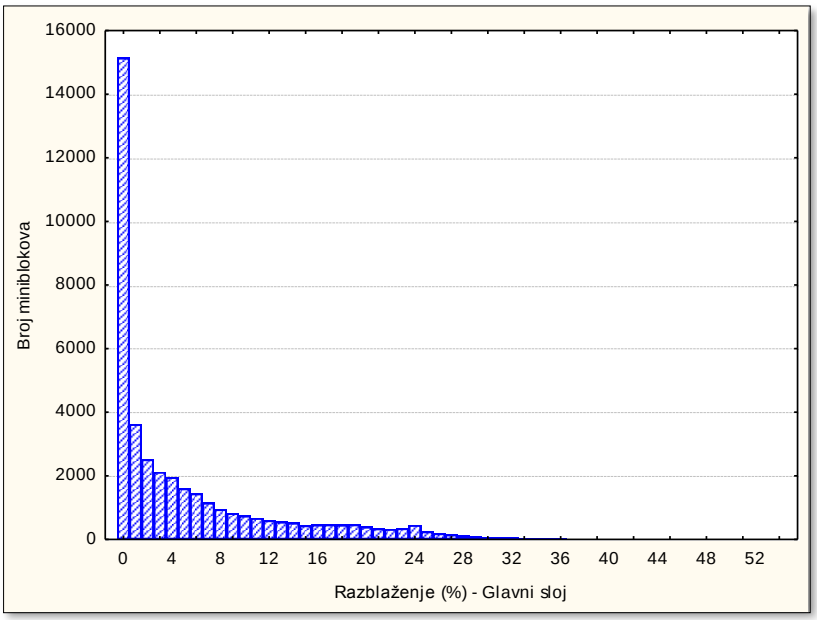
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Razblaženje (%) - Glavni sloj

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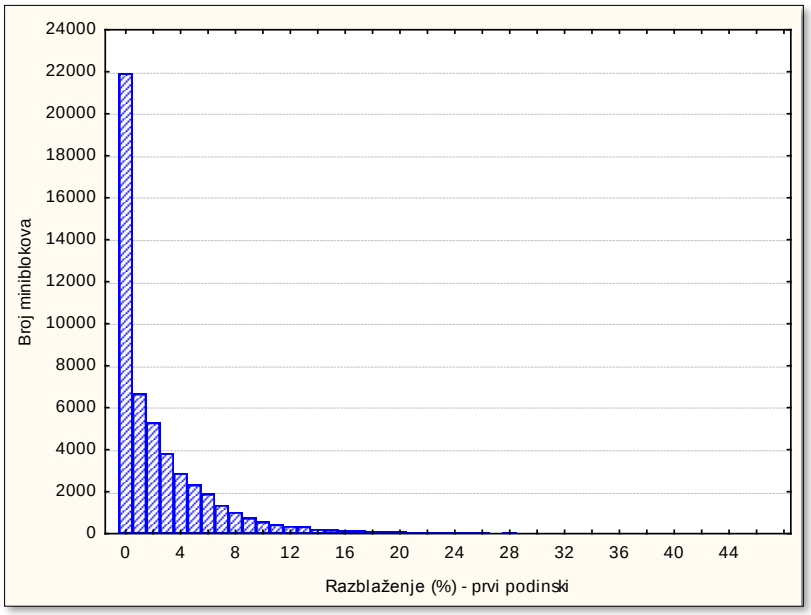
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Razblaženje (%) - prvi podinski

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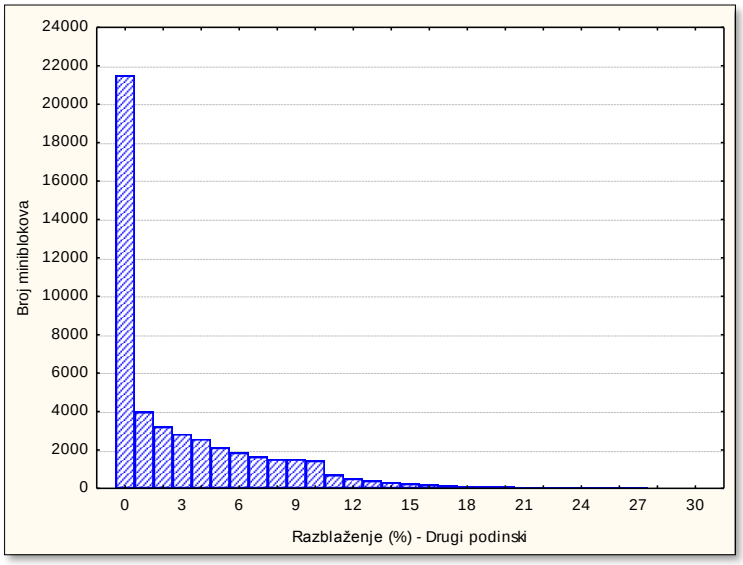

d)

Figure 11 *Histograms of dilution percentage by coal seams (a-roof, b-main, c-first floor and d-second floor coal seam) for the level selection of 1 m*

Table 2 *Results of statistical analysis of dilution (%) at the selection level of 0.5 m*

Characteristic	Roof coal seam	Main coal seam	First floor coal seam	Second floor coal seam
Arithmetic mean	2.604	5.701	3.057	3.441
Median	0.172	2.375	1.541	1.505
Standard deviation	4.556	7.535	4.457	4.470
Number of miniblocks	12779	39661	51173	47227
Minimum	0.000	0.000	0.000	0.000
Maximum	36.773	54.046	47.826	30.393
I quartile	0.000	0.094	0.011	0.000
II quartile	3.286	8.185	4.208	5.616

The quality of run-of mine coal is in a function of dilution degree, or waste percentage in run-of-mine coal. In order get to the mining coal quality, the following factors have to be taken into account leading to decrease in lower coal heating value, as follows:

- The effect of reducing the amount of clean coal in the total weight of run-of-mine coal;
- The effect of increased amounts of moisture connected to the clayey and marl components in coal, and that is increased with participation the waste material in coal;
- Reducing the heating power of coal due to the presence of carbonate component that in the endothermic process decomposes to CaO and CO_2.

Table 3 shows the quality of coal by seams (the main coal seam, the first coal seam, the second coal and for the roof coal series) in the deposit as well as for the selection level of 0.5 m and 1 m. The shown qualities are given as a function of analyzed and modeled dilution percentage.

Table 3 *Review the coal quality by seams in the deposit as well as for the selection level of 0.5 m and 1 m*

	Amounts (t)	**DTE (kJ/kg)**	**DTE (kJ/kg) for selection level 0.5 m**	**DTE (kJ/kg) for selection level 1 m**
Main coal seam	29,945,042	9,530	7,619	7,122
First floor coal seam	9,788,561	9,727	7,873	7,168
Second floor coal seam	6,030,253	9,555	7,403	7,289
Main, first and second floor seam	**45,763,856**	**9,575**	**7,645**	**7,154**
Roof coal series	20,144,899	7,741	6,188	5,456
Overall coal quality in case of application the exclusive selective exploitation			**7,199**	**6,635**

CONCLUSION

The present results of the analysis are a part of a broader study the possibilities of providing the appropriate coal quality for the needs of thermo power plant Gacko.

Having in mind the qualitative and structural characteristics of the coal deposit Centralno polje using only the selective exploitation, it was concluded that the production of minimum required coal quality cannot be expected. In order to achieve the required quality of fuel for the thermo power plant, it is necessary to apply a high selectivity during mining and restrict it to the parts of roof coal series with less pronounced stratification.

In spite of an expressed need for selective coal mining, in order to achieve the required quality of produced coal, the additional activities are required to improve the product quality. The additional improvement of coal quality is provided through a further process of processing - enrichment. Explanation the need and commitment to introduction the process of coal enrichment is given in the Strategy of Mining - Technological opening, develop-ment, optimization and maintenance a continuity of coal production with introduction the process of coal enrichment of dry separation at the open pit - Gacko (Mining and Metallurgy Institute, Bor, 2015).

In case of application the selective coal mining, regardless whether the specific conditions re provided for further processing (enrichment) of coal, it is necessary to implement those procedures in the deposit analysis as a whole and certain parts by plan and at depth.

In this way, the parts of deposit can be identified with more complex mining conditions and lower quality of run-of-mine and to predict the expected coal quality. In this way, it is possible to plan development of mining works in a function of providing the required quality or to form a basis for the quality management system of coal.

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A NEW METHOD OF COAL EXCAVATION IN THE COMPLEX NATURAL-GEOLOGICAL CONDITIONS

Abstract

In the underground coal mines in Serbia, nowadays, only the pillar methods of excavation excavations, which all affect the excavation economy.

This paper presents the solution of a new excavation method foreseen for application in the complex natural-geological conditions, which are now in all active coal deposits in the Republic of Serbia.

Keywords: *coal, excavation method, production, mechanized excavation*

1 INTRODUCTION

Complexity of the natural-geological conditions for exploitation of our coal deposits requires systematic research work aimed at improving the methods and technologies of excavation, because from this phase depends the technical, safety and economic parameters of the entire underground exploitation system in a particular ledge.

In countries with developed mining, developed underground coal mines, the basic method of excavation of coal seams is the methods of wide foreheads with complex mechanization.

In the complex and different conditions of coal deposits in the Republic of Serbia, numerous and specific technical and technological solutions of the underground coal excavation process were applied, with constant efforts to be adapted to the deposit conditions. The present conditions of the working environment influenced the selection of technological solutions for exploitation, so that in all active mines, the methods of pillar excavation in different variants are applied, which generally do not allow economic exploitation, and the risk of injuries and misconduct of employees on such types of excavation has increased.

The application of mechanized excavation technology on the principle of horizontal and vertical concentration by wide foreheads method only gave the positive technical and economic parameters in some mines and in certain excavation fields.

In order to improve the effects of application the pillar excavations in coal mines in the Republic of Serbia, the need for their rationalization is imposed, as this method of excavation will continue to dominate.

The aim of carried out research in this paper is to give a new approach to the pillar methods of excavation, and within the framework of the underground coal mines in Serbia.

The basic directions of improvement in these analyses are focused on mechani-

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zation the basic technological phases in excavation, especially in the production and loading of the excavation, which is solved by introduction the combined multifunctional machines DH L600 and DH L1200 of the German manufacturer Deilmann-Haniel Mining Systems GmbH.

2 GENERAL AND SPECIFIC CONDITIONS OF EXPLOITATION

Based on the collected and processed data, the basic natural - geological conditions in active coal mines are characterized by the following:

- most often these are thick coal seams with frequent thickness changes;
- coal seams are mostly of the complex structures with a smaller or larger share of mullock seams;
- due to intense macro and micro tectonics, the deposits are, as a rule, disrupted by several systems, which formed the excavation fields of irregular shapes and relatively small dimensions;
- in relation to the elements of laying, most of the mines, per depth, belong to the group of mines with the middle depth, and according to the fall they are about inclined and somewhat steep deposits;
- the stability of the mining access areas of excavations is directly related to the physical mechanical properties of the coal seams and associated deposits (with the pronounced participation of clay components) in which conventional sub-systems are applied;
- in terms of wateriness, all deposits, except for the coal deposit "Štavalj", belong to a group of poorly watered mines;
- self-inflammability and explosiveness of coal dust, as well as the natural tendency towards self-ignition, is the general characteristic of all mines, except for the mine Vrška Čuka;
- active deposits are not pronounced methane carriers, except for the deposit of the mine "Soko", where there are some increased methane values, and there are also phenomena of gas and material outbursts.

3 A NEW PILLAR METHOD OF EXCAVATION WITH THE APPLICATION OF A MULTI-LOADER

The novelty of a new pillar method of excavation consists in obtaining coal during the construction of the excavation corridor (I phase - excavation in progress), as well as in obtaining the roof and lateral coal in withdrawal (Phase II - excavation in withdrawal), with one of the modern and highly efficient combined machinery for working in the pit, which primarily achieves a large performance during loading.

The excavation, depending on the elevated coal production, can be planned with the use of one machine, and after the completion of the excavation hall (phase I), the same machine works in phase II - the excavation in withdrawal, and so any subsequent excavation, or can be planned using two machines, when the first machine, after completion the excavation hall (phase I), continues to the phase II, and the second machine starts production of the next excavation hall and, upon completion of its construction, works on obtaining roof and lateral coal (phase II - excavation in withdrawal). So, there is:

a) Phase I – excavation in progress, it is actually the construction of a hallway with the known technology of machine building of the corridor (cutting is done with a cutting head, and loading of material with a side spoon in a rake conveyor). It gets important in the use of maximum possible and given pit conditions applicable cross-sectional profile of the excavation hall with increase the

effects of progression. Therefore, in a shorter time interval, greater progress should be made with the maximum possible profile.

b) Phase II – excavation in withdrawal is a method of obtaining roof and side coal by cutting and mechanically loading a side spoon in a rake conveyor, where the amount of production depends on the thickness of the seam. According to the data, the coal seam is defined with a power of up to 12 m. The width of the pillar between the excavation corridors is determined according to the mine conditions (pressure, ma-nner of sub structuring, adjustment of progression or withdrawal, size of cross-section profile, etc.). Based on the experimental data it should be up to 3 m, and it will be determined in a test work.

In order to obtain roof and side coal, the multifunctional modern loader can be fully expressed with the use of a cutting head, since the coal after the construction of the excavation hall is less compact and it is easier to cut it. The test excavation method will simultaneously be another testing of this multifunctional loader for such a method of excavation. The use of construction tools is especially indicated by the fact that their use is particularly stimulated by the constructive novelty of a multi-loader, so called "click" system, or quick tool change - an average of 10 minutes.

Figure 1 shows the position of the excavation corridor in a coal seam, and Fi-gure 2 shows the principled excavation scheme with the new excavation method.

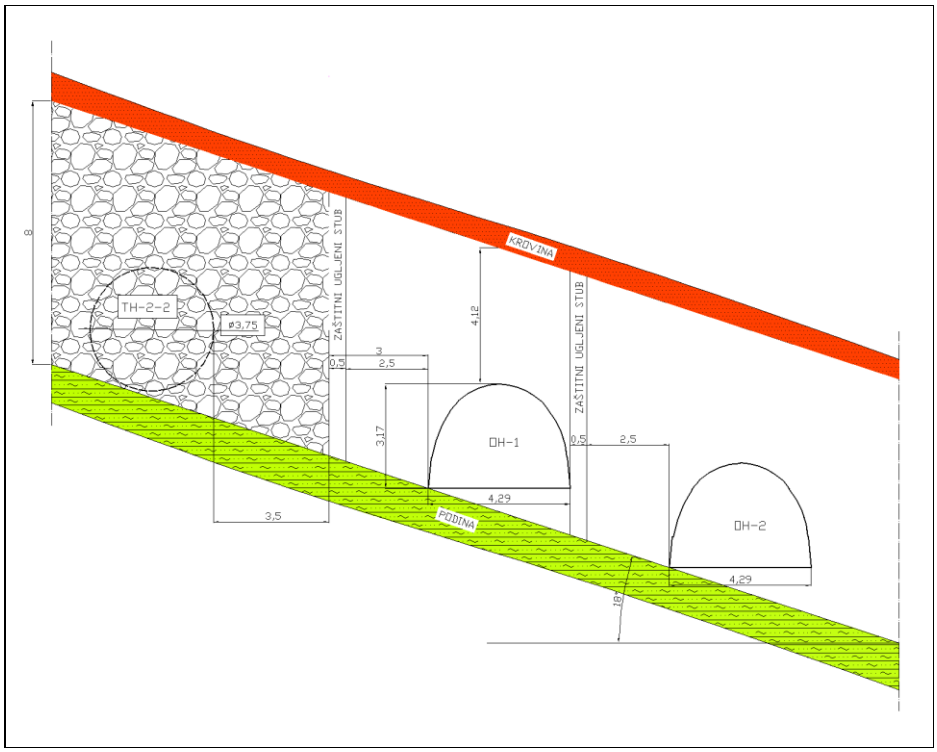

Figure 1 *Detail of possible position of the excavation hall 1 (OH-1) in a coal seam*

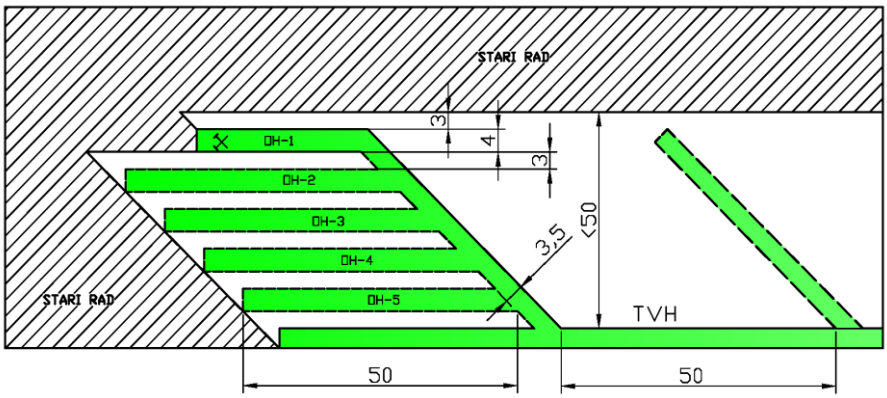

Figure 2 *Principal scheme of excavation with a new excavation method*

The advantages of the newly designed method are as follows:

- the decline, direction of providing the excavation preparation, but also its length does not significantly affect the possibility of applying of this method, and the change of these elements does not block its further work;
- the geometry of the method can be quickly adjusted to the conditions of seam (by inclination, seam thickness, etc.), and in case of sudden changes (water, methane or self-inflammation) can change;
- there are no special problems related to self-ignition due to the dynamics of excavation, and no special protection measures are foreseen except the usual ones;
- applied mechanization is easy to handle, and above all, it has the possibility of universal application (with the addition of other essential equipment according to the "click" system). The special advantage is that this mining equipment is universal for other applications in the pit, which increases its usefulness;
- the number of engaged labor force compared to the other classical methods is small, and the expected excavation effect is acceptable;
- the multi-loader compensates the lack of combine that it cannot cut below its level;
- the utilization of loading the roof coal is higher, the excavation losses are smaller. Mechanical loading left and right in excavation without input into unprotected space allows it;
- the speed of progress the excavation preparation using the loading rods is increased by more than 50% in relation to the present, which reduces the accumulation time of pit pressures and "obtaining" the used substrate material, of course, less damaged when extracting or when is under pressure;
- the excavation losses are expected to be smaller. An analysis the geometry of discovery method shows that more coal can be obtained by better excavation planning, e.g. for thicker seams, it is possible to use the method as with the damping from one floor, but also for excavation in two or more belts. With the reduction of the safety pillars between the excavation corridors, the losses are reduced.

Table 1 shows the comparative analysis of the basic parameters of the "V" methods and the new methods of excavation.

Table 1 *Comparative analysis the basic parameters of the "V" method and the new pillar method of excavation*

Basic parameters	"V" method (designed)	"V" method (real)	Improved "V" method
Phase I – Construction of an excavation corridor - Progress (m/shift)	1.00	1.00	2,00
Phase I – Construction of as excavation corridor - Progress (m/day)	3.00	3.00	6,00
Phase II – Getting coal - Deviation (m/shift)	2.00	1.50	2,00
Phase II – Getting coal - Deviation (m/day)	6.00	4.50	6,00
Height of the excavation (m)	5.00	5.00	6,00
Excavation width (m)	8.50	8.50	7,70
Surface of cross-sectional area of the excavation in progress (m^2)	8.50	8.50	16,15
Surface of cross-sectional area of the excavation in deviation (m^2)	33.97	33.97	30,05
Volume mass of coal (t/m^3)	1.33	1.33	1,33
The coefficient of utilization	0.70	0.70	0,90
The capacity of excavation in progress – phase I (t/shift)	11.31	11.31	42,96
The capacity of excavation in progress – phase I (t/day)	33.92	33.92	128,88
The capacity of excavation in deviation – phase II(t/shift)	63.25	47.44	71,94
The capacity of excavation in deviation – phase II (t/day)	189.76	142.32	215,82
The capacity of excavation in total – phase I+II (t/shift)	74.56	58.74	114,90
The capacity of excavation in total – phase I+II (t/day)	223.67	176.23	344,70
Number of workers per shift on excavation in progress – phase I (wage)	4	4	4
Daily number of workers on excavation in progress – phase I (wage)	12	12	12
Number of workers per shift on excavation in deviation – phase II (wage)	4	4	4
Daily number of workers on excavation in deviation – phase II (wage)	12	12	12
The effect on excavation in progress – phase I (t/day)	2.83	2.83	10,74
The effect on excavation in deviation – phase II (t/day)	15.81	11.86	17,98
The effect on excavation in total – phase I+II (t/day)	9.32	7.34	14,36

Figure 3 shows the DH L600 multi-purpose loader of the German manufacturer Deilmann-Haniel Mining Systems GmbH with the additional equipment, and Table 2 shows the characteristics of the DH L600 and DH L1200 machines.

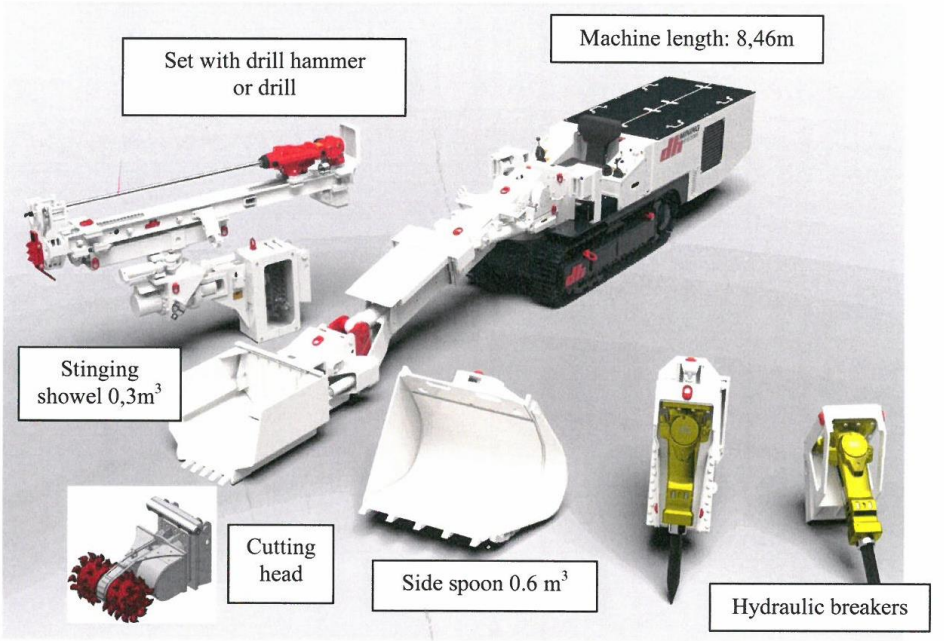

Figure 3 *DH L600 multifunctional loader with accessories*

Table 2 *Characteristics of the DH L600 and DH L1200 machines*

Parameters of the loader		dh L 1200	dh L 600
Power of the engine		75 kW	55/63 kW
Pump capacity		230 l/min	145 l/min
Volume	Box-shovel		0.3 m³ / 0.6 m³
	Side shovel	1.2 m³	0.3 m³
Driving speed		1,3 m/s	1.15 m/s
Overcoming of the rise		±20°	± 20°
Transverse inclination	Box-shovel		± 8°
	Side shovel	± 8°	± 8°
The effect of loading	Box-shovel		0.45 - 0.6 m³/min
	Side shovel	1.8 - 2.4 m³/min	0.9 - 1.2 m³/min
Length	With box-shovel		8050 mm
	With side shovel	6800 mm	7780 mm

Continuation Table 2

Width		1560 mm	1200 mm
Height	Without a protective roof	1355 mm	1200 mm
	With a protective roof	1961 mm	1994 mm
Weight approx.		14000 kg	10800 kg
Ground pressure		0,12 MPa	0,1 MPa
Free height	Machine space	350 mm	341 mm
	Track shoe	260 mm	250 mm
The angle of deflection of the working branch		2 x 20°	2 x 30°
Pace of telescopic arm		900 mm	700 mm
Unloading height	With box-shovel		2899mm
	With side shovel	2157 mm	3370mm
Excavation depth	Box-shovel		569 mm
	Side shovel	600 mm	616 mm
Penetration force	Box-shovel	–	40 kN
	Side shovel	71 kN	59 / 46 kN
Penetration force (horizontal)		150 kN	100 kN

CONCLUSION

Under the complex conditions of exploitation in coal deposits, the excavation of coal seams of medium and large thickness is carried out, mainly by the pillar excavation methods, with blasting technology, manual loading of excavation and its removal with grass conveyors.

Based on the analysis of the applied excavation systems in the mines, it is ob-vious that modernization and modernization the excavation system must be carried out in order to be more economically and safely mined. The acquired excavation experience in the current active deposits determines the continued application of pillar excavation methods, but with the wider introduction of modern equipment and mechanization of technological phases on excavations.

A detailed analysis has shown that the methods of mechanized wide foreheads can be introduced only in some parts of the coal deposits of the "Soko" and "Štavalj" mines.

The new method, which is the subject of this paper, can be applied under the conditions of most of active underground mines, which will greatly improve technical parameters and economic performances.

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BENEFITS OF APPLICATION THE MODERN TECHNOLOGY OF MECHANIZED CHARGING THE BOREHOLES AT THE OP POTRLICA PLJEVLJA[**]

Abstract

In order to improve the blasting technology, the Coal Mine Pljevlja bought a vehicle for mechanized charging of boreholes. The application of this technology has significantly improved the effects and improved the conditions of blasting at the Open Pit Potrlica. The present work describes the sa-vings of application the technology of mechanized charging the boreholes. An analysis was carried out for three variants. Variant 1 involves the use of mechanized charging of boreholes with a nonel system for initiation. Variant 2 involves the use of blasting technology with cartridge explosive and Nonel initiation system. Variant 3 involves the blasting technology with detonating cord initiation.

Keywords: *An-Fo explosives, blasting, mechanized charging, advancement of technology*

INTRODUCTION

Coal and overburden mining at the OP Potrlica is carried out in the central and north-western part of the deposit. The mining conditions are very complex and expressed through mining - geological, mining - technical and techno - economic indicators, such as:

- High dampness of deposit with the regular water inflow of around 500 l/min to 1000 l/min in the emergency situations,
- Coefficient of overburden 4 cm^3/t,
- Demanding physical - mechanical properties; blasting must be carried out to more than 80% of total weight,
- Proximity of building structures, infrastructure facilities, legal social land,
- The environmental impact, proximity of populated areas,
- Physical-mechanical characteristics of the work environment and possible application only a discontinuous mechanization for excavation.

Such complex mining conditions require studying and improvement the work technology in all technological operations.

The first working operation in the technological process is drilling and blasting.

In order to modernize this working operations, the coal mine Pljevlja has done the project documentation and, based on it, procured a vehicle for mechanized charging of boreholes. The vehicle has the ability to produce more types of explosives on the basis of ammonium nitrate.

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REVIEW THE CURRENT TECHNOLOGY OF COAL AND OVERBURDEN MINING

Technological system of overburden mining consists of the following technological processes:

- Preparation works
- Drilling and blasting
- Excavation and loading
- Internal transport
- Overburden crushing
- Outer transport
- Disposal

Excavation is carried out with the prior blasting of overburden and coal, except in the northwestern part of the open pit where, because of the proximity of town, a direct excavation is carried out. Overburden is vertically divided into floors of 15 and 10 m, which the rope shovel excavators EKG-15, EKG 12,5, EKG 5. EKG 4.6 and EŠ6/45 operate. Transport of overburden is carried by trucks from TEREX T100 to the internal landfill or to the DTO system. DTO system consists of a crusher Krupp - Fodertehnik, hour capacity of 2400 t/h, 6 belt conveyors, width B = 1500 mm and belt spreader ARS1400/25+30.

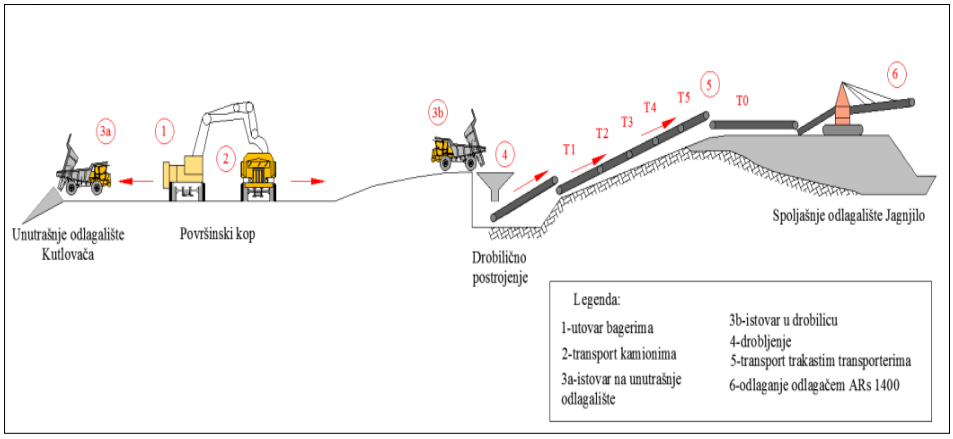

Figure 1 *Technological system of over burden mining*

Technological system of coal mining consists of the following technological processes:

- Preparation works
- Drilling and blasting
- Excavation and loading
- Truck transport
- Run-of-mine coal processing

The excavated coal is transported by the existing truck fleet to a plateau for coal disposal, with the exception of amount of 100.000 tons annually from the northwestern part of the OP Potrlica that is directly from the site transported to the facility for coal pre-paration and separation. The other amounts of coal, with transshipment on the plateau, are further transported to the plant for coal crushing and disposal of the TPP Pljevlja.

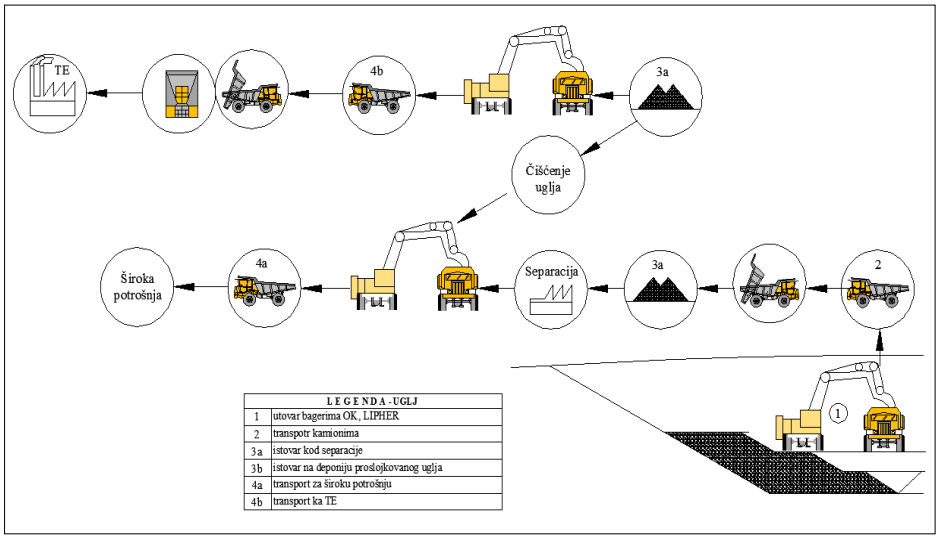

Figure 2 *Technological system of coal mining*

PHYSICAL-MECHANICAL CHARACTERISTICS OF THE FIELD

Coal and overburden mining at the open pit Potrlica are carried out in the central and northwestern part of the deposit, and the mining conditions are very complex.

Physico-mechanical characteristics of the blasting working environment are listed in Table 1 and Table 2.

Table 1 *Physical - mechanical characteristics of marl*

Marl	
Compressive strength	α_c = 182 dN/cm^2
Bulk density of marl	γ = 16.00 – 19.70 kN/m^3
Bulk density of marly clay	γ = 23.17 kN/m^3
Looseness coefficient	k_r = 1.3
Propagation speed of longitudinal waves	V_m = 2.000 m/s
Fissure degree	II i III kategorija
Cohesion	c_{sr} = 1,382.50 kN/m^2
Angle of internal friction	f_{sr} = 28.80^o

Table 2 *Physical-mechanical characteristics of coal*

Coal	
Compressive strenght	α_c = 156 dN/cm^2
Bulk density in natural state	γ = 12.30 – 14.80 kN/m^3
Clayey thin seans between the coal seams	γ = 23.05 kN/m^3
Underlaying clays	γ = 23.55 kN/m^3
Looseness coefficient	k_r = 1.3
Propagation speed of longitudinal waves	V_m = 1,290 – 1,800 m/s
Cohesion	c_{sr} = 3,100 – 4,800 kN/m^2
Angle of internal friction	f_{sr} = 33^o – 47^o

DRILLING AND BLASTING AT THE OP POTRLICA

Review the Drilling Equipment

Drilling of boreholes, diameter of 115 mm, at drilling angle of 70^o, as the slope of floor, are carried at the OP Potrlica. Length of boreholes is different depending on the height of floors or thickness of overburden and coal seam thickness.

At the OP Potrlica, taking into account the properties of the working environment, the rotary drilling system is applied.

The following hydraulic rotary drills are used for this purpose:

- BÖHLERR TCD-222
- SANDVIK Di 310
- ATLAS COPCO ROC L6-25

Types of Explosives and Blasting Equipment

At the OP Potrlica, four types of explosives are used, and the good results are achieved by thei previous applications. The An-Fo and emulsion explosives are produced in-situ in a special vehicle for production of explosives. From catridge explosives, the ammonium nitrate explosives are used of producer Poliex from Berane, as well as the cartridge waterplastic explosives, also Poliex producer. At the open pit, 80% of boreholes consist of dry boreholes, so that the An-Fo and carftridge amonium nitrate explosives have the largest use. Table 3 shows the characteristics of explosive used at the OP Potrlica.

Table 3 *Characteristics of explosive used at the OP Potrlica*

Characteristics	**Explosives– An-Fo vehicle**		**CARTRIDGE EXPLOSIVES**	
	An-Fo	Emulsion Explosives (Blendex 70/80)	Powder Explosives	Waterplastic Explosives
Density (kg/dm^3)	0.85– 0.95	1.14-1.32	1.05-1.15	1.4 – 1.5
Detonation rate (m/s)	3900	5100	4,100 ± 200	5,500 – 5,800
Gustina zapr. (kg/m^3)	920-995	1,010	940	1,020
Explosive heat (kJ/kg)	3,661-3,800	+3,000	4,160	3,474
Detonation transmission (cm)	contact	contact	contact	contact
Working capacity (cm^3) Trauzl equivalent test	290-300	370-455	360 ± 10	400

A vehicle is used at the OP Potrlica for machine charging of explosives (Figure 3).

It is a special vehicle TTT for production of explosives based on the mixtures of ammonium nitrate. The vehicle has a possibility to produce various types of explosives. The produced explosives can be divided into two groups:

1. The first group consists of explosives used in dry boreholes, i.e. emulsion explosives. These are explosives that have more than 60% An-Fo mixture, and the other part is the emulsion matrix.
2. The second group consists of explosives used for wet and dampness boreholes, i.e. pumped explosives. This group consists the explosives with the basis of ammonium nitrate emulsion (over 70%) and the other part is the An-Fo mixture.

Vehicle capacity and types of explosives are shown in Table 4.

Table 4 *Production capacities per types of explosives*

	Emulsion explosive			Pumped explosive		
Ratio emulsion /An-Fo	40/60	30/70	An-Fo	100/0	80/20	70/300
Weight (max)	10,400 kg	12,200 kg	8,600 kg	4,100 kg	5,200 kg	5,900kg

A vehicle chassis is Mercedes Benz, and vehicle superstructure is an American manufacturer Tradestar from Utah.

Technical characteristics of vehicle and reservoir capacity for raw materials are given in Tables 5 and 6.

Figure 3 *An-Fo vehicle for mechanized charging of boreholes*

Table 5 *Technical characteristics of vehicle*

Model	3341 A 6x6
Capacity	12 t
Inter-wheel base	3600 / 3900 / 4200 / 4500 mm
Engine type	V6
Engine power	300 kW /408hp
Max. torque	1850 Nm /1080 min^{-1}

Table 6 *Superstructure capacity (raw materials)*

	Volume	Filled	Density	Masses for given% filled
Emulsion tank	Cca 3.23 m^3	95 %	1250-1350 kg/m^3	4,140 kg
AN bin	10.34 m^3	95 %	800 kg/m^3	8,050 kg
Senzibilators/AL	1.00 m^3	95 %	200 kg/m^3	195 kg
Diesel fuels	700 m^3	95 %	840 kg/m3	560 kg
Additive 1	75 m^3	95 %	1000 kg/m3	>75 kg
Additive 2	75 m^3	95 %	1000 kg/m3	>75 kg
Water	300 m^3	95 %	1000 kg/m3	290 kg

BLASTING PARAMETERS

Since up to 80% of boreholes at the OP Potrlica are dry boreholes, the An-Fo explosives have have the largest use. A comparative use the An-Fo and cartridge ammonium nitrate explosives was analyzed.

The calculated blasting parameters are taken from the current Additional Mining Project of coal exploitation at the OP Potrlica - Pljevlja for the period 2015-2019, and are given in Table 7.

Table 7 *Blasting parameters taken from the AMD DRP 2015-2019.*

	An-Fo	Cartridge explosive
q	0.18 kg/m^3	0.107kg/m^3
p	8.82 kg/m'	7.08kg/m'
W	5 m	5 m
a	5 m	5 m
b	4.5 m	4.5 m
$Q_{(H\ 10)}$	45 kg	27 kg
$Q_{(H\ 15)}$	67.5 kg	40 kg

The non-electric initiation system, so-called Nonel system, is used for initiation the explosive charges in boreholed. A Dual Delay System is used from many types of such initiation. Using this type of initiators, the favorable effects of blasting are achieved. Two Nonel detonators, i.e. one for the primary and one for the secondary charging, are used to initiate the blasting charge in one borehole. In explosive initiation by Nonel system, a reactive wave extends through a Nonel tube which does not damage a part of the explosive charge pillar, what is particularly important for explosives which are not sensitive to the classic initiation means. When the ANFO, "Slurry" and other insensitive explosives are initiated by detonating cord, dead pressing of explosive charges occur and its combustion in boreholes. Thereby the effect of fragmentation is reduced. A detonating cord is also used for initiation the cartridge explosives at the OP Potrlica in addition to the Nonel system.

ANALYSIS OF THE DIRECT BLASTING COSTS

Consumption of Explosives and Explosive Means

The prices of explosives and explosive means from 2016 were used for an analysis. Table 8 presents the calculated norms of consumption, which are implemented in the process of exploitation at the open pit. In addition to the norms, specified in Table 8, the unit prices of explosives are also given. The analysis was carried out for an amount of material of 5,000,000 m^3, which generally corresponds to the annual production of overburden and coal with applied these types of explosives.

Table 8 *Norms of consumption and unit prices*

Normative material	Norms of consumption		Unit price	
Nonel	0.128	m'/m^3	0.23	€/m'
Detonating cord	0.072	m'/m^3	0.2	€/m'
Retarders	0.004	kom/m^3	1.25	€/pcs.
Safety fuse	0.000002	m'/m^3	0.2	€/m'
Mining lighter	0.000002	pcs./m^3	0.23	€/pcs.

Analysis of direct costs was carried out for three types of explosives and initiation means:

- Variant 1 - Mechanized charging of An explosives-Fo – initiation by the Nonel system
- Variant 2 – Cartridge explosives – initiation by the Nonel system
- Variant 3 - Cartridge explosives - initiation by detonating cord

Values of the specific and in annual costs of blasting are direct consequences of the calculated norms of consumption by certain variants. All relevant parameters were taken into account in calculation of norms that influence the consumption of explosive and initiation devices. First of all, those are a floor height, length of borehole, geometry of the minefield, method and diagram for connection the explosive charges within the minefield and construction of blasting charge. Taken all these factors into account, the specific costs of blasting were calculated by m^3 (Figure 4) and annual blasting costs (Figure 5) by the analyzed variants.

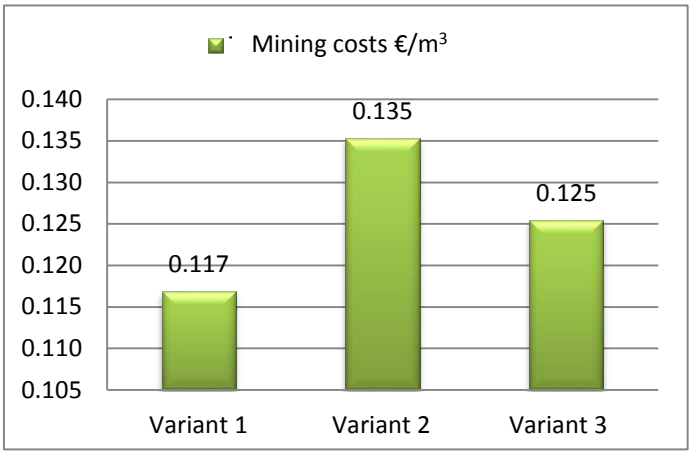

Figure 4 *Specific costs of blasting for three variant in € per m^3*

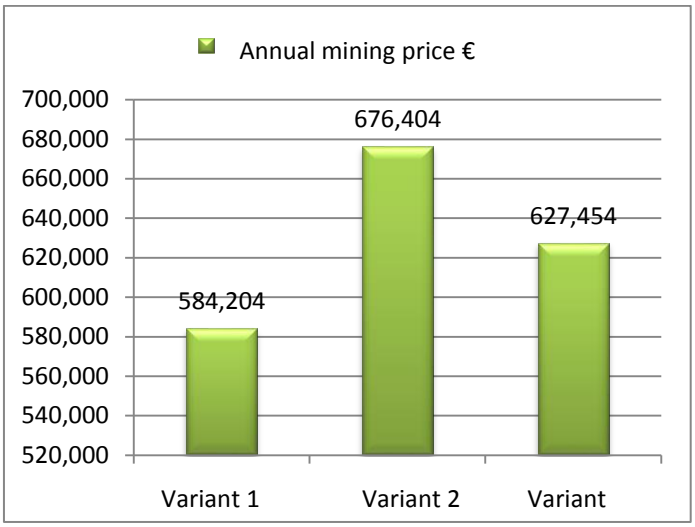

Figure 5 *Annual costs of blasting for three variants given in euros*

LABOR FORCE ENGAGED IN BLASTING

Blasting is a complex operation in the technological process of exploitation. Therefore it is the first operation in the technological process of production, the all other technological operations are dependent on its success.

According to the current systematization in the coal mine Pljevljana, 16 workers are deployed on drilling and blasting operations, out ofwhich 10 workers are deployed on blasting. The existing systematization of jobs in blasting is done in accordance with

the technology of blasting that was undertaken before purchasing a vehicle. By introduction the mechanized charging of boreholes, a necessary space is created for rationalization the labor force.

This primarily refers to the support workers engaged in heavy physical works (scheduling the packages of cartridge explosives across a minefield, etc.). It is not necessary in mechanized charging of boreholes because a complete transport of explosives from the storage to the incorpo-ration into the borehole is carried out by An-Fo vehicle. Table 9 presents the existing systematization of jobs with the number of employees and the level of income on blasting jobs.

Table 9 *Systematization of jobs on blasting*

	Job position of employee	Profess. clasif.	No. of employee	Gross monthly wage of employees	Total	Gross annual wage
Blasting	Chief engineer for drilling and blasting	Univer. degree	1	1,530	1,530	18,360
	Foreman for drilling and blasting	High school ed.	1	1,190	1,190	14,280
	Igniter of blasts	High school ed.	2	1,105	2,210	26,520
	Driver of vehicle for explosive	Highly qualified worker	1	1,020	1,020	12,240
	Operator of vehicle for An-Fo explosives	Highly qualified worker	1	1,020	1,020	12,240
	Assistant of igniter of blasts	Unqualif. worker	4	850	3400	40,800

After the analysis of three variants of blasting, the cost savings were calculated in implementation the mechanized method of blasting with explosives An-Fo (Variant 1), and they are shown in Table 10. The savings are given in relation to the blasting technology with cartridge explosives when the initiation is performed by the Nonel system (Variant 2), and when the initiation is performed by a detonating cord (Variant 3).

Table 10 *Blasting costs per analyzed variants and savings in introduction the mechanized method of charging the boreholes*

	Variant 1	Variant 2	Variant 3
Blasting costs	0.117 €/m^3	0.135 €/m^3	0.125 €/m^3
Annual price of blasting	584,204 €	676,404 €	627,454 €
Labor costs	86,700 €	131,580 €	131,580 €
Total	670,904 €	807,984 €	759,034 €
Savings by introduction of mechanized charging	/	137,080 €	88,130 €
	/	17 %	12 %

It is seen in Table 10 that the annual savings in Variant 1 as compared to Variant 22, is € 137.080, and 17% respectively, and the savings with respect to Variant 3,88,130 € or 12% compared to total costs of blasting according to Variant 1.

CONCLUSION

In addition to the benefits of application the mechanized charging relating to the direct cost savings that have been presented in the paper, there are also the indirect cost savings. Applying the An-Fo explosives achieve better results in blasting (better material granulation) what directly affects the other technological processes.

Granulation of blasted materials directly affects the process of excavation and loading, as well as the technological process of crushing, which is expressed by a higher energy efficiency. The direct impact of blasting effects is also on the extent of engagement the auxiliary mechanization.

The use of mechanized charging the boreholes enables more economical, safer, more efficient and easier operation in performing the technological process of blasting.

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ENVIRONMENTAL AND ECONOMIC ASSESSMENS THE EFFECT OF CRITICAL MINERAL OF GREEN REVOLUTION - LITHIUM

Abstract

In this paper, we wanted to explain the phenomenon of economic and environmental effect of the green mineral lithium in the world and our country. We started with an answer to the question why the mineral lithium is the future and support for the green revolution in the world. We have tried to also give a special dimension to tendencies and activities with regard to the usage of green mineral lithium in the world market. In addition, the paper presents the Jadar project and mineral lithium as economic and environmental opportunity for Serbia.

Keywords: *lithium, green revolution, Jadar project*

1 INTRODUCTION

The current world economic crisis and enormous over-exploitation of crude oil and petroleum products indicates the untenable situation in the system of environmental protection and sustainable development. Energy reserves on the planet are drastically reduced and mankind has not found yet a sufficient and adequate substitute for conventional energy generating products. It was this very fact that initiated research with the aim to find the new material and mineral resources replacing the traditional energy sources in order to preserve the environment and sustainable development. This article strives to demonstrate (taking into account that the oil was economic energy source of the 20th century) the environmental and economic assessment the effect of lithium as the green revolutionmaterial, and energy of the 21st century.

Lithium was first discovered by the Swedish chemist Johan August Arfwedson, back in 1817.

In this paper, it will be proved that the presence of lithium mineral is so great that it has been used everywhere from glass and ceramics to fat and polymer, and even in medicine. Through the paper it will be studied if there are sufficient reserves of lithium at the global level, but also in Serbia, because it is estimated that it will be used at least until the end of the 21st century up to 2100.

In the era of green revolution, a key role will be taken by the electric cars as a new green phenomenon with plenty of room in many economies in the world. This leads us to an answer to the question whether the lithium reserves today are sufficient to meet demand of electric vehicles using lithium-

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ion batteries in the era of green revolution. A special section will refer to the research of availability and usefulness of this mineral in our country.

2 MINERAL LITHIUM, THE FUTURE AND SUPPORT FOR THE GREEN REVOLUTION

Lithium with a purity of 99.5% as a chemical element in perspective will be in great demand because it is used by the smart phones, electric cars, hybrid cars, and so on. Thus, lithium is used in a wide range of products, from ceramics to the solar cells. Rechargeable batteries and electric batteries provide the most room for growth of lithium compounds. According to a recent study of BMW, depending on the model of battery, in the world, the average use is from 80 to 130 grams of metallic lithium per kilowatt [10]. Consumption of lithium batteries has increased significantly in recent years. Rechargeable lithium batteries are used in smart phones which have 2-3 grams of lithium, laptops from 30 to 40 grams, tablets 20 to 30 grams of lithium, hybrid and electric vehicles from 0.8 to 2 kg of lithium, electric cars which have 10 to 63 kilograms of lithium, Tesla model S electric car has 51 kg of lithium carbonate [12]. It is estimated that demand for lithium will be even greater, from 160,000 tons today to 570,000 tons in 2025[19].

It is an interesting data that by 2040, 50% of demand for the new batteries could be met through recycling the electric batteries for vehicles [21]. The market of electric and hybrid vehicles is growing, from 0.4% in 2012, to 0.7% in 2014, and this is only in the United States. Toyota, the Japanese automaker, has sold eight million hybrid vehicles in the past two decades. In 2015, the Japanese manufacturer Toyota has taken the lead in the lowest CO_2 emissions of 110.1 g/km. Right behind them is Renault - Nissan and Fiat Chrysler.

In the very near future, the EU plans to penalize car owners issuing a fine of 95 euros for every gram of CO_2 above the manufacturer's guideline. The new manufacturer of electric cars Tesla seeks to increase production tenfold, and it is from 50,000 electric vehicles per year presently to half a million vehicles by 2018. It is expected that the electric cars world market will increase up to 100% of the world production of cars by 2025, and these trends indicate the potential rapid growth of the market of lithium batteries for a period of 20-30 years, indicating a momentum of lithium carbonate industry, which is currently still emerging [5]. Thus the industry of electric cars will meet demand for lithium ion batteries in the 21st century (Table 1).

Plans of Norway expressed through demand for sodium batteries just confirm this. Proportionally to the number of 5 million inhabitants, this country has the largest number of electric vehicles. The Government incentives in Norway are very interesting because the all electric cars are exempt from traditional fees and taxes (VAT 25% of the vehicle price without taxes). Oslo, the capital of Norway, in addition to this, haslanes for electric vehicles, privileged parkings for electric vehicles and so on. There are also plans to ban the sale of traditional gasoline engines in Norway by 2025. This economy went a step further, and the trend is towards eco-standards of the EU, so that the vehicles that emit less than 50 g CO_2/km are exempt from the annual taxes. Up to 6,300 US dollars is being allocated for the purchase of commercial electric vehicles in the United Kingdom. Electric cars in China are exempt from excise and purchase taxes based on engine displacement. Incentives for the purchase of electric cars in China are in the range from $6,000 to $10,000 USD. In 2016, China announced its plans to build 12,000 stations for electric vehicles providing support for five million electric vehicles by 2020[20].

Table 1 *Deutsche Bank forecasts and trends of lithium supply and demand 2015-2025 [14]*

Year / Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Lithium supply (in kt)											
Chile	63	64	65	75	85	100	110	110	110	110	110
% growth	2%	2%	16%	16%	13%	18%	10%	0%	0%	0%	0%
Australia	57	69	97	112	130	159	181	186	196	206	206
% growth	40%	21%	40%	15%	16%	23%	14%	3%	5%	5%	0%
Argentina	19	31	36	41	46	48	69	103	138	153	153
% growth	4%	63%	16%	14%	12%	5%	44%	49%	34%	11%	0%
China	18	23	28	35	35	35	35	35	37	38	43
% growth	-16%	29%	22%	25%	O%	0%	0%	0%	6%	3%	13%
SAD	4.5	4.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
% growth	0%	0%	33%	0%	%	0%	0%	0%	0%	0%	0%
Rest of the world	10	10	10	10	10	10	10	10	10	10	30
% growth	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total kt	171	201	242	278	311	358	411	450	497	523	548
% growth	9%	18%	20%	15%	12%	15%	15%	9%	10%	5%	5%
Lithiumdemand/ (in kt)											
Electricvehicles	25.1	39.7	50.4	68.7	82.4	109.4	128.0	146.9	166.0	185.5	204.8
% growth	152%	58%	27%	36%	20%	33%	17%	15%	13%	12%	10%
Energy storage	0.4	0.7	1.4	2.2	4.3	5.8	7.7	11.1	15.9	23.4	33.8
% growth	0%	62%	96%	57%	92%	36%	32%	45%	43%	47%	45%
Electric bicycles	2.9	7.1	16.9	28.6	41.7	53.6	60.3	67.1	73.8	73.8	73.8
% growth	0%	145%	136%	70%	45%	29%	13%	11%	10%	0%	0%
Glass,ceramics	42.6	44.0	45.7	47.3	49.1	50.9	52.8	54.7	56.8	58.9	61.0
% growth	-3	3%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Batteries (traditional market)	45.6	46.3	48.1	50.2	53.1	55.0	56.4	57.8	59.3	61.0	52.7
% growth	11%	1%	4%	4%	6%	4%	2%	3%	3%	3%	3%
Fat	19.0	19.6	20.3	21.0	21.7	22.5	23.2	23.9	24.7	25.5	26.3
% growth	13%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Air treatment	7.3	7.5	7.8	8.1	8.4	8.7	9.0	9.3	9.7	10.0	10.4
% growth	-9	3%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Polymer	6.2	6.3	6.5	6.7	7.0	7.2	7.3	7.5	7.7	7.9	8.1
% growth	-4	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Medical materials	6.7	6.8	6.9	6.9	7.0	7.1	7.1	7.2	7.3	7.4	7.4
% growth	20%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%

Continuation Table 1

Primary batteries	2.9	3.0	3.1	3.3	3.4	3.5	3.6	3.8	3.9	4.1	4.2
% growth	-8%	3%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Aluminium	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5
% growth	26%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Castingpowders	7.6	7.6	7.8	7.9	8.0	8.1	8.3	8.4	8.5	8.7	8.8
% growth	-21	1%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Others	15.0	18.0	20.7	22.8	23.6	24.5	25.4	26.3	27.3	28.3	29.4
% growth	63%	20%	15%	10%	4%	4%	4%	4%	4%	4%	4%
Total (kt)	184	209	238	277	312	359	392	427	464	498	534
% growth	18%	14%	14%	16%	13%	15%	9%	9%	9%	7%	7%
Market surplus (deficit)	-13	-8	3	1	-2	-2	19	22	33	25	14

The State of California in the USA offers $2500 USD incentives for purchase of electric vehicles (the US average is $1000). Over the next two decades, demand for gasoline in the United States will be reduced from 5% to 20%, assuming that the share of electric vehicles will be 35%. In Germany, the electric vehicles are exempt from annual taxes for period of 10 years. Estimations are that the driving of electric cars represents a fifth of consumption the traditional cars (gasoline/diesel car per 100 km). In the United Kingdom, vehicles that emit less than 100g CO_2/km are exempt from the annual taxes. Germany the strongest economy in Europe, also wants to ban the sale of gasoline cars by 2030. Thus, the Netherlands want to go the same way as planning to ban the sale of gasoline engines by 2025. Unlike in most European countries, hybrid or electric cars in Serbia are a rarity. In addition to the lack of appropriate infrastructure for charging, the biggest obstacle to purchase these types of vehicles in Serbia is their price or the unwillingness of our country to subsidize the purchase of electric cars and encourages customers providing the other benefits. Croatia is far ahead of Serbia. In order to encourage citizens, the firms and private companies when purchasing the new vehicles to choose those ones that less pollute, the Croatian Ministry of Environmental and Nature Protection and the Environmental Protection and Energy Efficiency Fund announced a public call for co-financing the purchase of electric and hybrid cars, electric scooters and motorcycles. Individuals may get an incentive for one vehicle; a prerequisite is that it must be kept in their property for at least a year, while companies can get around 91,500 Euros for several vehicles that must be kept in the property for a minimum of three years. The purchase of new vehicles, which can be purchased in any EU country, but must be registered in Croatia, is subsidized as well. The incentives for electric vehicles are up to 9,150 Euros, and for hybrid "plug-in" vehicles up to 6,550 Euro. The novelty is that as of 2015 incentives were being given to purchase the electric vehicles with built-in system for extension the movement (electric vehicle with a gasoline engine that serves solely as a power generator), and this is for models with emissions up to 50 g of CO_2/km. The following calculation demonstrates that the electric vehicles emitt lower amount of CO_2 in comparison with hybrid and gasoline vehicles.

Car on motor fuel gasoline consumes 9.5 l/100 km (average for 2015 model year) times 2.31 kg CO_2 emitted per litre gasoline burned. 21.9 kg CO_2 per 100 km travelled is emitted in the atmosphere.

Electric car: 17.9 kWh/100 km (70 kWh Tesla Model S), with the charger efficiency 80% (factory of electric cars Tesla claims that some users report 95%, and some users report 80%) times 0.527 kg CO_2 per kWh (EPA average, includes line losses on the) equals 11.8 kg CO_2 per 100 km travelled.

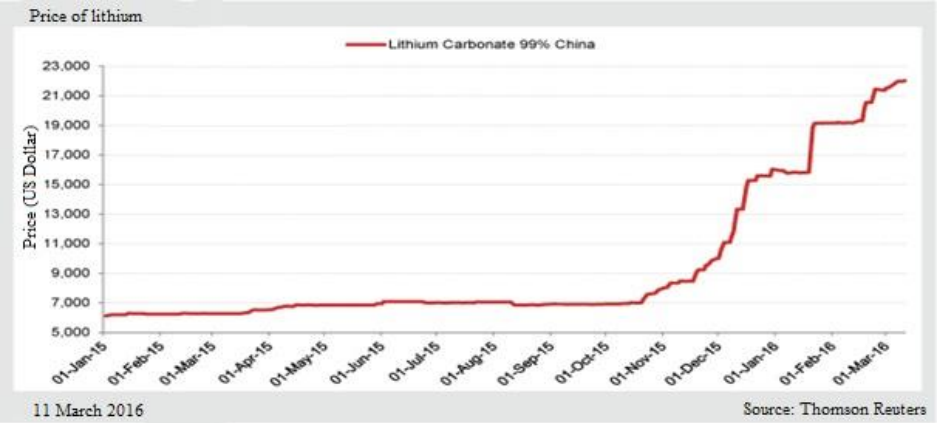
The average American using a gasoline vehicle emits around 300 g CO_2/km, while the new hybrid, a mixture of electric and gasoline vehicle emits 180 g CO_2/km. The law requires that the new vehicles registered in the EU by 2015 do not emit more than an average of 130 g of CO_2/km [16]. By 2021, according to the new European standard for CO_2 emission, the requirement to be achieved by the new cars is 95 grams of CO_2 per kilometre with a gradual reduction to 65-70 g/km by 2025 and 65-70 g/km by 2030[13].

Table 2 *Number of registered EV, the EV market share, CO_2 emissions, the number of public and private charging stations, the total number of EVs per million inhabitants in the world 2014-2015 [16]*

Year	2015	2014	2014	2015	2015
Country	**Number of registered electric vehicles**	**Market share by countries**	**Emissions of new passenger cars g CO_2/km(*)**	**Number of private and public charging stations**	**Total number of electric vehicles per million inhabitants***
China	600000	1.0	-	46657 (Pu and Pr)	265
SAD	474000	0.7	225	28150 (Pu)	1340
U.K.	91000	1.0	125	8716 (Pu)	933
Norway	135000	23.3	110	6357 (Pu)	15143
Germany	75000	0.7	132	4787 (Pu)	664
Holland	113000	9.7	108	17786 (Pu)	6280
France	108000	1.2	115	10122 (Pu and Pr)	970
Slovenia	239	-	-	-	-
Croatia	87	-	-	-,	-
Serbia	13	-	-	-	-

3 TENDENCIES AND TRENDS ON THE WORLD MARKET RELATED TO THE GREEN MINERAL LITHIUM

Trends on the world market show that lithium will be more profitable and that this mineral is getting epithet as pointed out by Goldman Sachs – the new gasoline or white oil. It envisages that its use in electric vehicles will grow 11 times and that is more than 300,000 tonnes by 2025. This calculation becomes obvious when the fact is taken into account that hybrid and electric cars contain 40 to 80 kilograms of lithium [7]. This is confirmed by the price of lithium per ton which escalated in China from $7,000 in a mid 2015 to over $20,000 per ton of lithium in March 2016, so that the prices in the reporting period have grown more than 300% (Graph 1).



Graph 1 *Change the price of lithium in China, January 2015- March 2016[15]*

Demand for lithium in the world grew by 11 percent between 2010 and 2015, and export price of 99 percent pure lithium carbonate in China has more than doubled at the end of 2015. It is expected that theglobal demand for lithium will grow from 280,000 to 285,000 tons by 2020 (in 2015 was 163,000 tons). A half of the lithium carbonate world market is controlled by only two companies. At this stage during 2016, the market is supplied by the Greenbushes mine in Western Australia, which is the property of Talison Lithium (51% owned by China Chengdu Tianqi, and the rest owned by giant chemical industry Albemarle based in Baton Rouge, Louisiana). Australia, Chile, and Argentina are the largest producers of lithium with 89% of production in the world (Figure 1).

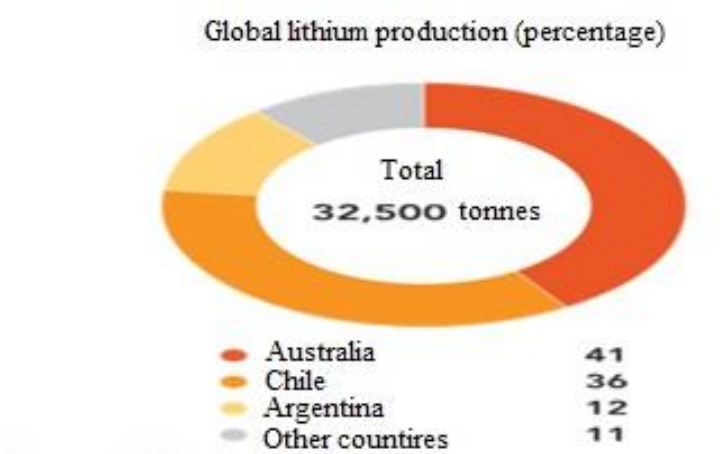


Figure 1 *Lithium producing countries in the world in 2015 (percentage) [20]*
(Source: U.S. Geological Survey)

Table 3 *Global production, reserves and resources of lithium by country 2013-2014[22]*

Country	Production 2013	Production 2014	Reserves	Resources
SAD	870	NA	38,000	5,500,000
Argentina	2,500	2,900	850,000	6,500,000
Australia	12,700	13,000	1,500,000	1,700,000
Bolivia	-	-	-	9,000,000
Brazil	400	400	48,000	180,000
Chile	11,200	12,900	7,500,000	7,500,000
China	4,700	5,000	3,500,000	5,400,000
Portugal	570	570	60,000	-
Zimbabwe	1,000	1,000	23,000	-
Others	-	-	-	4,000,000
Total	33,940	35,770	13,519,000	39,780,000

Viewed from the standpoint that this is the mineral of the future, our stance is that the world instead of being dependent on oil could become dependent on lithium. Lithium reserves are mainly found in two countries: China and Chile. Therefore, it is important to plan in order to avoid bottlenecks and unnecessarily high prices. In general, lithium is the limited resource in the world, and production cannot be infinitely large due to the geological, economic and social constraints. In fact, the reserves are those quantities that are usable from the viewpoint of current socio-economic conditions. To the contrary resources are more academic categories and denote a geological amount of metal available for exploitation. The concentration of metal in several countries has dropped, what could lead to more expensive and deficient acquisition of lithium in the future [8] (Table 4).

Table 4 *Worldwide lithium resources and reserves in 2014[2]*

Country	Resources	Percentage	Reserves
Argentina	6.5 mil. tons	17%	850
Australia	1.7 mil. tons	4%	1,500
Bolivia	9.0 mil. tons	23%	24%
Russia	1.0 mil. tons	3%	-
Canada	1.0 mil. tons	3%	-
Chile	7. 5 mil. tons	19%	7,500
China	5. 4 mil. tons	14%	3,500
Congo	1.0 mil. tons	2%	-
Brazil	180.000 tons	,	48
Serbia	1.0 mil. tons	3%	-
SAD	5.5 mil. tons	14%	38
Austria	130,000 tons	-	-

4 THE JADAR PROJECT - ENVIRONMENTAL AND ECONOMIC OPPORTUNITY FOR SERBIA AND MINERALS LITHIUM AND BORATES

A discovery of Jadarite has taken place relatively recently. It was discovered in 2004 by a geologist Bob Kellie in Jadarit valley near the village of Draginac in the picturesque valley on the Cer Mountain near the town of Loznica. Jadarite is an excellent source of lithium and borate. Lithium is an important component that is mostly used in hybrid and electric cars. Borat in jadarite can be used for products such as glass, ceramics, fertilizers, detergents and many other products. Serbia with the Jadarit mine covers 3% of the resources in the world, and 10% of the world demand for this resource with 80% of reserves in Europe. Researches, conducted by Rio Tinto clearly, tell us that this mine is rich in lithium and borate prompting scientists to name it Jadarit. According to an assertion, made by the company Aker Solutions, the sites at 300-600 meters depth with approximately 227 million tons of ore Jadarite could provide 1.6 million tons equivalent of lithium carbonate, and 8.1 million tons of boric acid [17]. The other studies support this endeavour and as of 2013 Jadarite mineral resources are estimated at 118 million tons at an average grade of 1.6% lithium oxide, and 18 million tons of resources borate [23]. So far, Rio Tinto has invested about 70 million dollars in the Jadar project.

Donji Jadarit (Lower Jadarit) zone has 125.3 million tons of Jadarite ore at a weighted average of lithium oxide LiO_2 with concentration of 1.8%, and 16.2 million tons of borates B_2O_3 or 12.9% borate [9]. The Borate project in Serbia comes amid forecasts of increase in the global demand for these minerals on the market in value of about 4.9 billion dollars annually [3]. It is expected that the global demand for borates B_2O^3 will increase up to 2.2 million tons (Mt) in 2018, compared to 1.5 million tons (Mt) in 2009. Using fairly conservative calculation for Jadarite ore, it represents a financial value of 80 billion dollars for Donji Jadarit zone[1].

Price of boric acid as borate product is in favour of the Jadar project and ranged from 800 to 1000 dollars per ton in 2015. China is the biggest borate consuming country with GDP which generally in this economy is slowing down, but with a robust demand for borate. Global consumption in the world is expected to remain strong, primarily in the ceramic industry, agriculture and other activities in which the borate is being used. Unlike many raw materials such as iron ore and coal, demand for borate is more correlated with middle and higher class of durable consumer goods. US are the second largest borate consuming country in the world. Global demand for borate will reach 2.2 million tons in 2018, compared to 1.5 million tons in 2009 [4]. With this lithium and borate resource potential, Serbia could be well positioned on the green minerals market. The Jadarit mine would directly employ 450 people and about 800 to 1,000 workers in the very near future that would be indirectly related to the mine. With a designed exploitation for 50 years, the Jadarit mine should ensure not only the long term economic prosperity of the region, but the whole of Serbia. Some estimation show that the Jadarit mine near Loznica would bring 30-40% of total re-venues of the municipality. If the experience of Bolivia is used, it is very interesting because this country has large lithium reserves under the Uyuni salt desert, which is at this point and tourist attraction of the country. In

addition to the ore extraction, the President Evo Morales asked investors to open a lithium battery factory, and even start producing the electric cars. We suggest that Serbia just like Bolivia use this expensive and rare mineral and that this mineral becomes a way to initiate an investment here.

Table 5 *Jadarite resources in Serbia[14]*

	Tons (Mt)	Li2O%	LCE	Compatible
Donji Jadarit	125.3	1.80%	5.58%	JORC Compliant
Gornji Jadarit	46	1.50%	1.71	NI 43-101 Compliant
Srednji Jadarit	34	1.50%	1.26	NI 43-101 Compliant
Total	80	1.50%	2.97	NI 43-101 Compliant

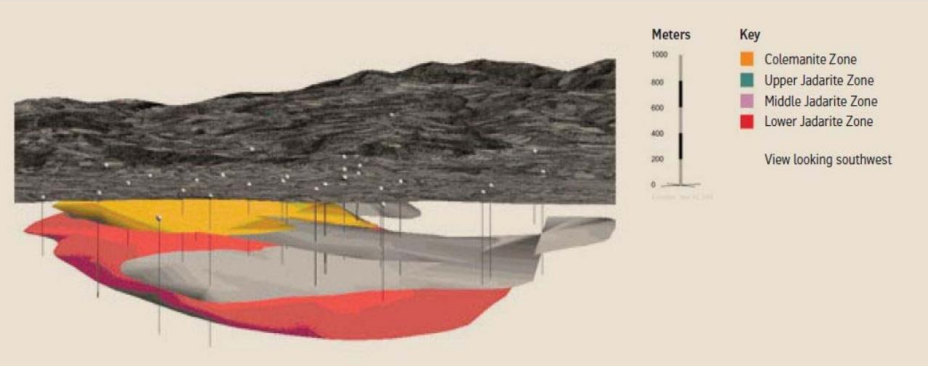


Figure 2 *Mineralization in Jadarite divided into upper, middle and lower layer of lithium mineral and sodium borate (Na2B4O7), calcium borate (Ca2B6O11) and sodium-calcium borate (NaCaB5O9)[14](Source: Rio Tinto Jadar factsheet, September 2011)*

Typical lithium minerals have lithium content from 0.5% to 2% and in some cases of extremely high-quality content and over 3% as demonstrated by the geological properties of lithium in Jadarit shown below (Table 6). The deadline for the exploitation of this resource in the world is the longest in Australia, Canada, the United States, the Democratic Republic of Congo and Serbia (in Jadarit). The percentage content of lithium and hence the quality of the ore in Serbia is among the highest in the world. According to some studies, better values of lithium in the world are only in Australia in its Greenbushes mine, Canada with Bernic Lake mine (2009 ceased to be exploited), Namibia and Zimbabwe, with its Bikita mine [18].

Table 6 *Geological properties of lithium mineral in Jadarit–Serbia[8]*

Name	Formula	Content(% Li)	Hardness	Density g/cm^3]
Jadarite	LiNaSiB3O7(OH)	3.16	4-5	2.5

5 CONCLUSION

There is a tendency for t lithium in the next period to become the first mineral of green revolution that awaits us in the future. Lithium is not part of the global chain like oil, coal, iron, copper and other metals, but it is certainly on its way to become the first resource of energy supply in the world. The four main producers Chile, Argentina, USA and China are controlling 85% of world supply, and the main reserves of this mineral are located there. Therefore, the price of lithium will continue to be exerted, and it will be under continuous exertion by the major producers, after all, and due to poor utilization of capacity. The fact confirming this statement is that today many prices of goods are in the recession while only the lithium price is on the rise.

This can lead to the onset of the crisis in supply of lithium due to a bottleneck, and that is the reason why prices are high in perspective, even more than before. In addition to the above mentioned economies, Bolivia, Chile and Argentina, in the future will become the key players in lit-hium industry. The result of green revolution indicates a shift towards hybrid and electric cars and thus lithium batteries. As estimated all these electric cars factories will require 100,000 tons of lithium carbonate by 2021. This initiative with regard to the use of electric cars has been continuously supported by the government initiatives of the major economies of the world. All this contributed to the fact that lithium batteries denote green energy in the world today, and especially in the future. Many countries are focused at reducing carbon dioxide emissions and the use of clean energy has become a basic question of European and international enviromental policy.

However, the structuring of reserves and resources in the world, carried out by four major producers,raises a question of oligopoly position of those countries, because there is a limited number of suppliers and thus challenged projection of the electric car factory succes in the world. Due to these dominant producers, our opinion is that the potential Jadarit mine in Serbia should be seeking opportunities. The final goods containing boric acid and sodium carbonate could meet demand not only in the region, but wider in Europe and the world. This is undoubtedly an opportunity for growth in exports through lithium processing and production of final goods.

As per mining and lithium minerals, the effects of ore processing are visible in three to five years, and even longer. Money turnover in the mining industry is very slow. Estimatations of Rio Tinto for Jadarit mine near Loznica show that, although the lithium and boron mine fields in Serbia are profitable, it takes about six years to organize the exploitation. Hence, it raises a question whether the assessments of economic and environmental effect of this mineral in our country are cost-effective just from the viewpoint of our economy, because investments in mining are visible only in a few years.

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QUALITY MANAGEMENT IN THE TOURISM INDUSTRY

Abstract

The traditional approach to the management in the function of quality the tourist industry has not offered the high quality product or service. Namely, dissatisfaction is a response to the managerial approach, reduced customer satisfaction, and small profit. This work points out to a continued access to the quality, necessity of total quality management, levels of TQM implementation and benchmarking. Furthermore, it analyzes the monitoring of quality control to be allocated and coordinated in the organization.

Keywords*: quality, benchmarking, monitoring, TQM*

INTRODUCTION

The issue of quality is a very important issue in the management theory nowadays. Quality, in this sense, is commonly defined as the ability to meet the needs of consumers in 100% of time. Undoubtedly, managers in truly progressive organizations are concerned about quality. They understand the basic relationship between a competitive advantage and ability to always deliver quality products and services to its customers.

Total quality management is a comprehensive approach to a continuous improvement the whole organization quality. Every effort done in a context of the total quality management is focused on building quality into all aspects of process, starting from the initial acquisition of resources through the processes and work systems, along the road to the final delivery of products and services to the consumers. What is important is that this approach invites all to commit to a continuous improvement in all aspects of their work. Not only is the total quality management focused on the needs and interests of consumers, but it also emphasizes the importance of employee involvement in all aspects of improving the quality and delivery. There is no doubt that the total quality management will remain an integral part of the success of the organization in the future.

1 QUALITY

According to the well-known project "Profit Impact of Market Strategy", also known as PIMS program,[1] the quality, in addition to the market share, is the most important determinant of profitability. According to this study, in addition to the

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market share, amongst 30 identified factors, it was shown that the quality is in the strongest positive correlation with the return on investment.

Literature defines the term quality very differently. Thus, a well-known researcher in this field, W. Edwards Deming, went so far that the quality is defined as a new religion.[2] However, all these different definitions and approaches regarding the quality, according to PIMS concept can be summarized in two versions. According to the first version, the definition of quality is based on the internal view on quality. This practically means that the quality is measured by the internal requirements set out in the pre-defined specifications. All activities in this context are aimed at meeting these internal requirements, defined specifications. Hence, this approach to the quality is often treated as an internal view of quality. This approach to the quality usually results by reducing costs through an emphasized control of production, and other activities in the company.

The second, more important approach to defining the quality is the so called external perception of quality. It is based on the consumer's attitude, perception of product value. According to prof. Charles Hill, the quality products in the goods and services are those that are able to satisfy the sense in which they are designed (designed) to do so[3] In the other words, the quality of products (services) is determined by a degree of its ability to meet the needs for which it was manufactured and offered. Of course, the ultimate judgment on this possibility, on degree of satisfaction, is given by the consumer himself as incorruptible arbiter whose needs are met by your product or service.

The impact of high-quality products on a competitive advantage of the company is twofold. First, by providing the high quality products, the value of such products is increased in the eyes of customers. In this way, the goal is to gain the customer's loyalty, which is in a direct proportion to the level of product quality. Bidders, who enjoy consumer loyalty have, of course, lower marketing costs, because the customers-service users come back again even without an extensive advertising. Loyalty to a particular company - the hotel is a very effective entry barrier to the other similar customers, which leaves the company rooms in the industry to increase the price of such products, the more it produces services that are differentiated by the quality of the other, have a lower price-elasticity.

Another effect of the high quality companies at a competitive advantage stems from the high efficiency, i.e. lower costs realized from a concern about the quality and content of the offer. The quality hotel offer provides the twofold way contribution to a competitive advantage of the company: through the market situation, that provides a high sales price, and through the internal efficiency, which provides the low operating costs.[3]

Quality management will predominantly determine in the future the attitude of the legal entity towards given future, including the overall quality in itself, benchmarking, attitudes toward competition and a complete and complex attitude to the customer-defined content offerings. This essentially means having an active attitude and affirmation of overall business performance interconnections.

Due to the intensity changes, be they quantitative in terms of offer content that continuous change or increase, or qualitatively competitive emphasis on TQM, it is necessary more than anywhere else, in

tourism as a propulsive activity, to provide the business process reengineering, which appears as a dynamic tool for renewal, maintenance and increase the economic power of the entity.

Technical and technological development is the result of materialization the results of scientific research activities and we are free, despite the views of some prominent authors, to say that the creative innovation and qualitative relationship to it, is the core of all, where the management activities implement the innovative and research activities into development achievements in the business processes. Information technologies that contribute to the acceleration of scientific, technical and technological progress, have enabled the effective cross-functional connectivity, organization and business processes, where many activities take place according to a pre-defined software. Thus established - networked processes, carry with them the presumption predefined start and continuous quality. This is applied to the primary, secondary and tertiary sector. Deterioration in the quality and processes is only possible by the controller and manager - a man, because in case of any discontinuity in the activities, the system stops and prevents breakdown. Through the quality, we actually enter into the process of reversibility when things and processes are put back to their original state.

Neither innovation nor imitation must not forget the emphasis on the quality, because the customers, regardless what is the object of purchase or sale, are not ready to respect deviations in the quality.

In terms of development and in terms of business success, it is necessary to give the answers to the Latin next questions: Why? What? How? When? What? Where? Ever?

If we, from the control technology position, being a key to everything even business success, delivered high-quality solutions as a form of answers to the previous questions, we would approach the theoretical concept of absolute organization. But there is no absolute organization, due to the fact that we have an intense effect of changes that occur under the influence of two upcoming operating processes: the competition and technical and technological progress.

Most theories of economic development emphasizes the necessity of technical progress as well as increase the technical progress rate. Certain records of accelerating the technical progressis necessary. This category of development typically requires the capital, entrepreneurial skills, managerial and technical skills and trained labor force, which is generally limited in the underdeveloped countries. Balance of payments problems often prevent the import of these factors to a significant extent, so we have that many less developed countries depend on the assistance program to provide some starting points.[4] Technical and technological knowledge and skills, complemented by experience, appear as the prerequisites for successful innovation and development response. Here it is necessary to add the need for assimilation and expansion the marketing efforts, which may also occur as a function of business success.

Quality is the position of the present, but it is necessary that the blocks on offer and over the content output bears the vision that should be based on a system of complex social as well as business forecasts, which in turn should serve as an information base for its operational and strategic planning which basically causes planned future. Prognostic futurological attitudes and the strategic choices of carriers of operating activities present a challenge to the intended future, because

they synchronize with social realities and makes the process of steady functioning whole.

According to a broader understanding the quality, we can present so that TQM is an opportunity to fundamentally improve business functions and business processes in the company, which will result in the superior products that meet thecustomer needs and business results that meet the needs of the top all other stakeholders.[5]

2 QUALITY AS THE BASIC ASSUMPTION OF THE TOURISM DESTINATION MANAGEMENT

Quality as a characteristic of not only output, but of the overall course of business activities is a precondition for duration the continuous innovation. By disregarding the quality of the commitments of strategic management, the future of business subject is at risks. Quality becomes the dominant approach to the company future.

The need for continuation the operation alignment and harmonization the management activities, is conditioned by the challenges that come from the environment, and efforts to address these challenges as a chance to reply.

Cultural and historical realities as an expressive and familial tourism resources, and their environment appear as two main factors of success the tourist destinations, taking into account the fact that each branch and each company is a case for itself.

The prescriptive approach views quality as a factor to "create", so as to obtain the maximum strategic advantage.

Modern approach still does not have a unique view on this question. The results will be presented in this work. What is characteristic for it is the emphasis on human resources in tourism, being hardly predictable factors of great importance, because it affects the success of achieving the goals, in particular the quality strategy goals. This should affirm the need for companies to create a close correlation relationship between their resources, their exploitation through the process of putting into use, quality of output and the environment.

Due to its specificity, the prescriptive approach has been more processed and represented in literature, but it will be proven that the solution is an optimal if a successful combination of both approaches is achieved. By combination the research methods, the adequate results will be got, and d the key factors of success will be determined on the basis of the quality as the dominant approach to the modern management.

In the business world, no one is longer prepared to tolerate lack or deviations from quality. An offer, process and its structure, content and outputs on one hand, and assumed demand dynamic on the other side, are subject to defining, standardizing, planning and operationalization the quality system. The quality, inputs and outputs appear as a prerequisite of potential business system success. Starting from the fact that tourism is primarily a business which uses the existing structure design offers of tourist destinations to achieve the positive business success.

Science has found that there is an interaction between system and environment, but it also exists between parts within a single whole. This interaction leads to communication informing each other on the status and changes taking place within them, that leads to the operation of each

other. Components organized like this and their relationship is an organization, as an organized whole of individual parts.

Science has found that the quality of the whole and its way of functioning is conditioned by the way of structuring and linking its parts, as a dynamic structure. This dynamic moves within certain limits, since no system can come into a state of absolute perfection, only chaos is absolute.

Holistic system concept takes into account the objective reality of change. It assumes that the changes are a result of movement, which objectively changes the existing balance, or condition. Therefore, it is determined that everything that exists in the world, is the result of movement, and that nothing is created out of nothing, but out of something. This fact is important to be able to look for the cause of certain changes and directing the movement towards change, which will lead to the specific goals.

Identification of diversity parts in the system, makes it easy to explore the whole. Researchers and designers have to make a grouping of individual differences in the system, but also of certain similarities. So grouped similarities and differences change over time, appear and repeat status changes in the individual segments or parts of the whole. This leads to the conclusion that everything that exists in the world is in all of the changes, which imposes the need for researchers to learn about the characteristics of repeatability, or ways, dynamics and consequences of change.

Holistic is based on the originality of research and findings the most efficient and most effective ways to achieve the set goals.

3 BENCHMARKING AS AN EXTERNAL COMPONENT OF TQM

Benchmarking provides a continuous process of comparison the organization with the others aimed at finding and executing the best practices to ensure the long-term competitive advantage.[9] Quality revolution or phase in the history of management called the Total Quality Management is based on several important assumptions:

- labeling the consumer and buyer of product, i.e. service users, as the main partner of the business chain;
- orientation towards constant improvement of business, products, services and attitudes towards work;
- active participation of staff in flows of value creation and the use of modern methods and techniques for measuring the business results.

TQM is a special approach to the organization of business based on quality management.[12] TQM helps to concentrate on what we do wrong and to find ways to improve, but always looking at what and how others are doing, which aims to set the maximum targets that must be achieved. Disorientation on the market represents a failure.[10] Thus, TQM, which has primarily an internal character, gets from benchmarking a comparable foreign component. It follows that the benchmarking is an integral element of the philosophy of total quality management and continuous improvement the business culture. It is this philosophy and approach to that component of the development of character which is essential to any organization. Differentiation of products and services through the quality leads to competitiveness in designing the best products, ser-

vices, flexibility and versatility, innovation and time. In both cases, the quality stands as an essential attribute, as the first factor that will lead the company or any organizational system to desired position in the market. Increasing competitiveness of the business system represents one of the ten goals of the business system, which is achieved by introduction the quality systems. These objectives are:[6]

- Design, implementation and certification the quality systems provide a full development of business system and its subsystems. This means that at any moment it is known who, how, when and where activities are carried out related to the optimal functioning of the business system to ensure the quality;
- An increase in profits of the business system;
- Reduction the operating costs;
- Satisfaction and increase the quality of products and services that achieve greater economic effects;
- Provision the quality management from the idea phase to the after use product phase;
- Reducing the risk that the business system does not turnout and fail on domestic and international markets;
- The ability to increase the selling prices on domestic and international markets based on quality;
- An increase in the price of business system when changing the ownership;
- Reduction the cost of products and services that can be realized through the cost reduction

For quality:

- The meeting market demands, and
- Increasing competitiveness of the business system.

Regardless the fact that the emphasis of work is on the control technology in the tourism industry, the validity of this technology will be at a much higher and preferred level if the quality system is included.

Contrary to our views on the evident benefits of TQM, there are also controversies: investing in quality are unprofitable; quality and productivity are incompatible; You cannot have both, let alone to gain the quality over an competitive advantage.

Historically speaking, it was impossible to imagine that they will improve the quality of the way that will increase productivity, because it was thought that it had just to decrease !? Quality begins with the aim of defining management, and is of great importance for the management, because it is, if not the only, then the safest way to evaluate the products and services.

Given that the business in restaurants is one of the infrastructure components of tourism destinations, the previous chart shows the relationships that are characteristic for the spinal column or fish skeleton. This is a diagram “cause – effect” that typically draw teams of people, usually members from the ranks of quality, who are familiar with this problem. Displaying possible causes of the problem in the form allows the team to analyze the problem and find a way of overcoming it.

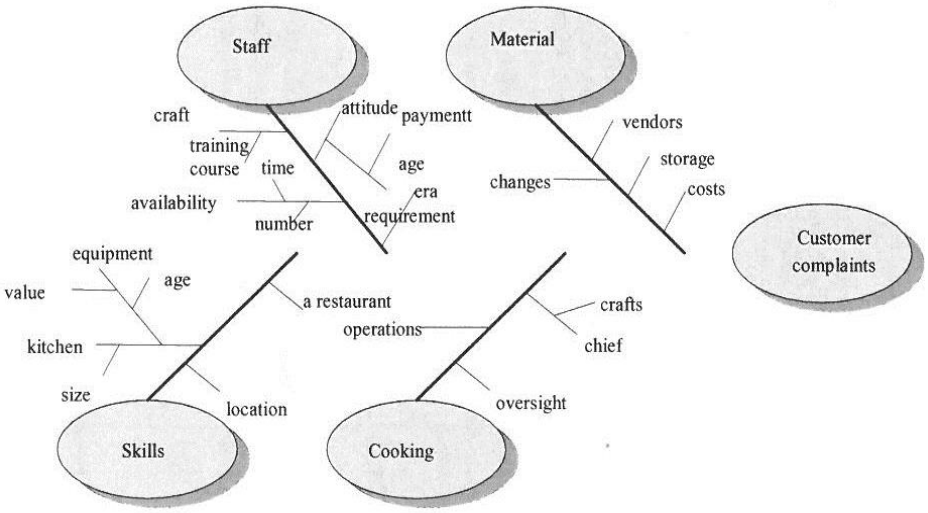

Figure 1 *Diagram "cause - effect" to appeal to a hamburger restaurant*

4 QUALITY CONTROL MONITORING

A lot of efforts are invested in the quality control of tourism and its accompanying activities, especially in hotels and restaurants, especially during provision of services, taking into account the all dimensions of time and stages of the process: before, during and after. It would be reasonable if all the deficiencies were found during a large control. However, the longer faulty process, more time is needed for its detection and much more investment in type and process control.

5 LEVELS OF APPLYING TQM

The acceptance of total quality management carries with it a presumption of its application at three levels: the organizational level, process level and business (executive) level.[7]

At the organizational level, the quality refers to meet the basic demands of customers or users of services. Organizations need to seek the answers to the questions used to assist in defining the quality at this level:

- What products and services meet customer expectations?
- Which are not met?
- What products and services are necessary for the guests, and which are not accepted?
- Do guests use the products and services they do not need?

The level of processes (functions) includes the organization functions such as marketing, design and type of service, operations, finance, procurement, sales, etc. As these functions are not independent organi-

zations and interact, there is a risk to the quality of management and optimization of their activities individually in the company (in the case of a complex enterprise) that can lead to a de-optimization. Managers at this level have to answer the questions such as:

- What are the most important products and services for a guest as a consumer?
- Which processes result in these products and services?
- What are the main inputs into the process?
- In which processes are the most significant effects on the target consumer performance standards?
- What are the most important guests – consumers, and what are their needs?

The executive level (level of task determinations) have already certain standards based on the quality and compliance with the customer requirements previously established at the organizational and functional level. These standards include requirements such as the accuracy, completeness, innovation, timeliness, and cost price. For each output of each execution of the tasks may be to ask the question:

- What is common to the requirements of all types of guests - the consumer?
- How will these requirements be measured (standardized for the possibility of planning and control)?
- What are the specific standards for each request?

From the perspective of responsibility, the quality managers for respective level are responsible for it, as the delegation of a task delegated the responsibility. The organizational level focuses on the top management, level of function or processes of middle level managers, level of enforceability or missions of all employees and managers of that level. It may be no-ted that all employees in the organization are involved in the total quality management process.

Acceptance of the concept of total quality helps companies to: [8]

- clearly focus on the needs of their markets,
- achieve superior quality performance in all areas, not only in the quality of products and services,
- simple handling procedures necessary to achieve the quality,
- critically and continuously examine all processes to eliminate the non-productive activities and losses,
- witness required improvements and develop a performance evaluation,
- understand, in whole and in detail their competitiveness and to develop the effective competitive strategies,
- develop a team approach to the problem solving, develop a good communication and procedures for improvement or confirmation the good work,
- continuous review processes to develop a strategy of continuous improvement - benchmarking.

Quality as a kind of output is essentially a synthesis of a multitude the synchronized activities of a business process.

6 CONCLUSION

Quality is the result of technical equipment of operation and technical contemporary means of production, but also the skill and knowledge of workers. Achieving the total quality is a strategic decision, which involves the entire organization. Quality management ceases to be a special function, because it becomes an integral part of the process, so that the structure and organiza

tion of the whole take responsibility for their quality.

The extent of possible changes in the environment, as a rule, is controlled by a flow of defined scenarios. It is the information that the system - the country - the company receives from the institutional environment in which the macro level is obliged to offer the stability and dynamic environment in which the existence and operations are implemented. The challenges of technological progress and competition, as a rule find their implementation, depending on the characteristics of the created environment. The state usually appears as a synonym for the environment.

None of models or a group of models will reveal the truth about the future, but they can still discover the useful differences regarding our operating environment and certain limitations of our capacity to understand this environment. As we do so, we can make more choices.

It is important to evaluate the synergy effects resulting from the combination of at least two dependencies that amplify or weaken the influential factors. Quality appears as as assumed constant, dependent on several variables.

In addition to the synergistic effects of influential areas, through the control system, the reflection effects may be achieved. These are generally the information society-state system emitted to the environment, impacts and other activities that reflect the environment in another form, and to each other. Reflecting impacts of the system on the environment and the environment on the system should be constantly checked. The extent of possible changes must be analyzed and elaborated in order to be able to prepare and take a position in the strategic orientations that time beyond the fact of ongoing changes.

Quality certainly performs reflection effect and thus affects on gaining the competitive advantages and create the additional value.

The starting assumption of the need quality planning is in the functions of government - in the management organizational system. Quality planning should be viewed as a continuous process and as part of a systematic approach in the company functioning as an organizational system.[11]

The management activities cannot be carried out without a good planning. Planning define ex ante situation, one in which we want to get, and to extend its duration. For management in the tourism industry, it is deemed that the project approach would be suitable, due to the fact that no matter what such heritage constitutes a whole, it must be considered individually, because the act of uniqueness, that each cultural and historical property has and affirms.

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OPTIONS OF IMPLEMENTATION THE MODERN BUSINESS QUALITY MANAGEMENT METHODS IN MINING

Abstract

Modern business conditions, which are reflected in the process of the world market globalization, inevitably influence all spheres of business. With the aim of continued existence, the growth and development, companies in all sectors are required to follow the modern tendencies in business processes. Mining, as a base business operation, with all its specificities is not excluded from this process. Furthermore, the modern technological processes are based on scientific research in all segments of business, as well as on implementation the innovative scientific accomplishments in all areas of scientific activity. This paper is based on consideration the economic aspect of application the modern business methods, through implementation of methods for the business process improvement regarding to the mining complex, in actual work on presenting the effects of innovative procedures in the lead-zinc ore flotation in the 'Kopaonik' – RMHK 'Trepca' facility.

Keywords: *innovation, production, management, reengineering, system performance*

INTRODUCTION

The modern world, economic environment and companies themselves undergo the constant *changes.* Restructuring, reorganization and other great changes are necessary frequently, with the aim of improving the company, or at least, ensuring its survival in increasingly harsher market competition. The mining complex, as a very intricate system, is not spared from these influences. If anything, it is even more affected by the technical - technological innovative changes. Keeping in mind that an 'economic - value indicator of mining reserves and mining production indicate that lead reserves on the territory of Serbia amount to 6% of the world reserves, or 20% of the European reserves and zinc reserves are 4% of the world and 14% of the European reserves[1], focus on exploitation of this potential through implementation the modern economic - technological methods is the imperative of the modern mining production. Adapting companies to modern business conditions is a prerequisite for implementation a growth and development strategy, as well as recovery and survival, with serious implications to the national economic activity. This conclusion is derived from the fact that the 'foreign trade, enabled by mining operations production, was of strategic importance for national economy of Serbia. Non-ferrous and precious metals, non-ferrous metals concentrates and products held the top positions in export.[2] Precisely, due to this reason, the managers and experts have been dealing with problems related to a transformation as a special phenomenon since the nineteen-nineties of the twentieth century until today, although the various enterprise restructuring models existed before that time. In this sense, the organizational – technolo-

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gical changes are among the most delicate, considering they affect the entire company, so the role of these changes in the overall company performance is particularly emphasized. The effective ness of these changes can be viewed in the context of effect the organizational changes on various aspects of business, primarily on the business efficiency in terms of cost reduction and management's reaction in crisis situations and understanding of changes and manner of their influence on workforce performance.

INNOVATIVENESS A AS PRECONDITION FOR HIGHER BUSINESS QUALITY

Considering the fact that innovation implies a process of introduction the new findings in economy, investments in the new technology and employees are necessary for its realization. This leads to the conclusion that, in order to execute decisions for implementation of innovations, a significant investment of capital is necessary for obtainning the new technology and workforce trainings. Implementation of innovations in the base industry, such as mining, is a precondition for business success of a company. Creative thinking should be an integral part of a long - term capability of a company, which is the foundation of innovation. Analyses show that companies which grow faster are those that implement the new knowledge and innovations. The difference between the successful and less successful ones lies in different approach to innovations.

Companies that wish to keep the existing and win the new markets must innovate more efficiently than their competitors, as well as secure human and material resources for the purpose of innovative activities. The most important thing about innovations and innovators is creating an aspiration for achievement the desired results.

In the modern business context, scientific laws and manners of their practical application are the primary and decisive for successful business dealings of a company. Scientific laws are the basis for development of innovations. All innovations are the result of human creative processes. It would be difficult to find an innovation which is not based on the already known scientific law, more or less modified. Each innovation involves a number of changes which need to be executed in an organization. The modern scientific research has shown that the actual knowledge and skills that people possess and using that knowledge in practice are the principal and decisive condition for development the work productivity. The only successful management systems are those with strong intellectual base.

The latest approaches to innovation supplement the models which see its origins in connecting the technical capabilities with the market needs. Innovative companies serve as a model, influenced by two main groups of environmental factors: current use of products and processes on one hand, and needs, i.e. demand for the new products and processes, on the other.

SELECTION OF METHODS FOR THE BUSINESS QUALITY IMPROVEMENT

Quality improvement is conditioned by application the adequate methods which are either already known, or the strategic management of a company needs to create them. In that Sense, the management has several, already tested methods on its disposal, such as the following:

- Business Process Reengineering
- Production System Just in time (JIT)
- Balanced Scorecard (BSC)
- Total Productive Maintenance (TPM)
- Total Quality Management (TQM)
- ISO System
- Method Six Sigma
- Lean Manufacturing
- European Foundation for Quality Management (EFQM)
- The Twenty Keys Method

Considering the specific nature of their application in the quality improvement process, each of these methods must be considered separately, so that the company management could decide for the ones that will secure the highest possible level of efficien

cy the managerial activity. One of potential strategic options involves the processes reengineering, which is the focus of this paper, with consideration of reengineering application in the mining - processing complex, with presentation the actual results of this concept application in the floatation facility "Kopaonik" Leposavic.

AN EXAMPLE OF BUSINESS PROCESS REENGINEERING IN THE FACILITY FOR FLOTATION OF LEAD-ZINC ORE "KOPAONIK" LEPOSAVIC – RMHK "TREPCA"

In the ever more competitive environment in which the companies operate, there is a requirement for continual development and innovation. One of the possibilities for achieving that is the application of reengineering as a radical approach. Constant changes in the world markets and application the new technologies lead to the new dynamic objectives and strategies and changes at all company levels. One of the management concepts for achieving the new strategy goals is the business process reengineering. Reengineering is a new beginning, i.e. an attempt to do the business differently than before. The reasons which indicate the need for reengineering are the sharp competition, constant changes and more demanding customers.

Practical illustration of reengineering as the company management's strategic option from the perspective of mining - processing industry with all its specificities is shown in an example of operative section of the RMHK Trepca - flotation of lead-zinc ore in the 'Kopaonik' facility, located in Leposavic.

The 'Kopaonik' Leposavic facility is a part of RMHK Trepca – North, and its main operation is related to the processing (flotation) of lead-zinc ore from the capacity of the following mines:

'Belo Brdo', 'Crnac', 'Zuta Prla' and open pit 'Koporic'. The main facility, which is the focus of this paper, possesses 375.000 t of annual capacity. During exploitation, this facility processed approximately 7.5 million tons of lead-zinc ore, out of which 333.000 t was lead concentrate with 70-72% lead content (Pb) and around 390.000 t of zinc concentrate with 47-49% content (ZN). The current market flows, technical - technological characteristics of production process, as well as more stable, social and political climate, lead to a management's decision on reengineering the production capacities in terms of improvement the technical - technological features of production facility. The main goal of these measures is to modernize the technological process, which will lead to better use of ore reserves, as well as an increase in processing capacities. Comparative analysis of processing quality of the old and new, technologically more advanced facility, are presented in Tables 1 and 1a.

Table 1 *Grain size distribution of KMD 1200T crusher (old crusher)*

Particle size class, mm	M%	M%↓	M%↑
20	33.3	33.3	100
-5	16.1	49.4	66.7
-5	20.3	69.7	50.6
-10+0,3	28	97.7	30.3
-0.3	2.3	100	2.3

Table 1a *Grain size distribution of CH 420 crusher (new crusher)*

Particle size class, mm	M%	M%↓	M%↑
20	4	4	100
-5	11.5	15.5	96
-5	41.5	57	84.5
-10+0,3	38.2	95.2	43
-0.3	4.8	100	4.8

The comparative analysis presented above (Tables 1 and 1a) of grain size distribution of crushed ore clearly indicates the result of tech-innovation, particularly in a size class -15 mm, where this grain size as a representative sample in KMD-1200 T crusher is present in 50% of the total amount of processed ore, while with CH-420 crusher that is a technological innovation of the processing method, the content of the same size amounts to 84.5% of the total amount of processed ore.

Comparative analysis of processing capacity (grinding) indicates that the grinding capacity has been increased from 620 t of processed ore per day to 820 t of processed ore on a daily basis, which in cumulative monthly quantities is an in-crease of around 5.000 t in the amount of processed ore. So, this innovation through reengineering of the production process, in terms of improvement the technological processes, only through capacity increases, leads to an unequivocal conclusion on significance the management innovative actions. The economic effect of implementation the innovative action is also reflected in a considerable reduction in electric energy costs by 30% (from 110 kW to 77 kW), lower maintenance costs, as well as the use of agents - frothers from 50 g/t to 25 g/t, i.e. by 50%. Besides all these advantages, the technological superiority of innovation is particularly important when it comes to the environmental protection and employees' health.

The parameters presented above confirm a justifiability of reengineering implementation as a strategic option of company because, as it can be seen from the afore mentioned parameters, reengineering of technical - technological parameters in terms of adapting the technical - technological processes to the needs of the specific market, leads to a significant improvement in economic business parameters, in this particular case to increase in operational capacity (former bottle neck) by 35%, leading to an increase in mining production, which is a raw material base of flotation. In the final outcome, apart from the cost reduction, this has a significant cumulative effect on improvement the financial parameters of company.

Reengineering process must be comprehensive in order to successfully combine the all specific potentials of company on one hand, and the environment needs, on the other. Reengineering methodology is defined in six phases. Each phase involves a group of processes, comprised of a number of activities. Each process can be expanded or adjusted so as to comply with all individual requirements of company and reengineering as a whole. Each organizational unit of company should be given a separate consideration and for each of them, teams should be formed, consisting of people with adequate level of knowledge, Figure 1.

Reengineering is combination the strategy for enhancing the business innovation and strategy for making improvements in the process. Although potential cost effectiveness of reengineering is great, there is also a risk of failure due to the environmental disturbances. During implementation of reengineering, traps which can emerge and which should be avoided, such as a lack of vision or inefficient reengineering team.

Cost reduction and quality improvement are the main conditions for survival of every production system. Product competitiveness is measured by the quality, price, delivery term and customer's satisfaction, so continual quality improvement contributes to the ability of producer to accomplish them.

'Reengineering implies the fundamental rethinking and radical redesign of business processes – in order to achieve the dramatic improvements in critical, important performance measures, such as the costs, quality, service and speed.'[3]

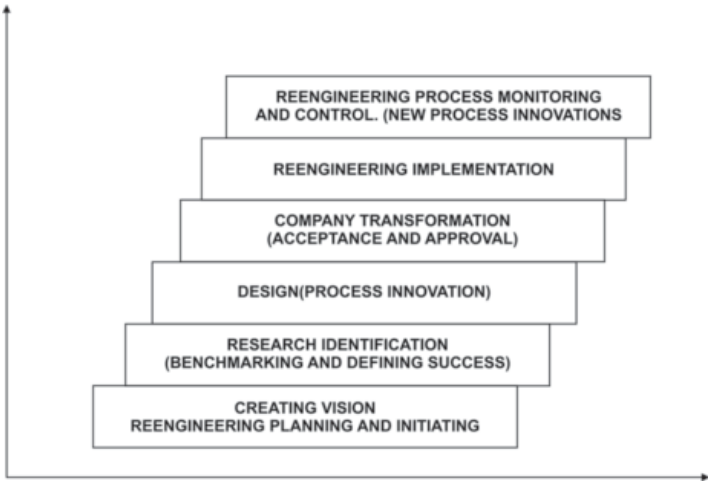

Figure 1 *Reengineering methodology presentation*

(Source: Miladinović, Ž., Adamović, Ž., Impact of Reengineering on Improving Companies' Business Quality, International Scientific Conference on Management 2010, p. 341)

Even in times of economic crisis, reengineering is interesting because it offers fast and efficient solutions. Modern economic crisis indicates that, apart from efficiency, social criteria must be taken into consideration, as well as interests of employees, customers, public services, etc. Interest in engineering is also present in the financial sector, education system, judiciary system, military and other branches of economy, which, of course, includes mining and ore processing. Reengineering should be additionally enhanced, so that it can achieve the certain new goals which were not that pronounced originally. This primarily involves a new consideration for demand for product quality and need for prompter response to the market demands, both of which require a constant acknowledgement and support of the new knowledge and creativity.

Success of reengineering implementation calls for definition the key processes. Key processes carriers are responsible for the process implementation, monitoring and correction, if necessary. These are, most frequently, leaders, managers, teams and consultants. They are the company members with special knowledge and skills, individuals with authority and experience in implementation of certain changes. Furthermore, they need to be people of trust, with charisma and influence on behavior of their employees, team work oriented and acting within the accepted reengineering concept. Leaders' role in the reengineering process is to create a vision, motivate the employees, define key values and createteams for design and implementation the radical changes.

Apart from the top manager, who initiates the change process, leads and motivates the employees during the transition phase, as potential change management agents, literature mentions the groups or individuals who plan and implement changes, and consultants, comprised of groups of people with a vision of necessary changes, but without authority and control of resources required for initiating the changes.[4]

Business processes reengineering is a transition into a new technological model without division of business processes into sectors or functions, but the organization is based on the business processes, the main goal of which is to meet the customers' needs. Reengineering at the process level implies radical changes of certain business

processes, in the area of material processing or information.

Competition makes impact on the business system with the aim of protection their customers and market position. Systems behave in two manners – some implement reengineering as a preventive measure, which enables them to keep current position or expand within the existing or new markets, while the others act when their market position is threatened, and when advantages of the competitor are visible.

CONCLUSION

Monitoring and implementation the modern trends in the business process organization, today is the foundation of growth and development the successful company. Monitoring and implementation dynamics should certainly be adjusted to the dynamics of the field in which the business operates, but being in the specific economic branch does not reduce the need for participation in the modern business flows. Business process of reengineering, as one of the strategic options for management action, is one of the most efficient options, especially when it comes to the production industry, and then it involves technical and technological aspect of business.

Mining, being the base industry, is characterized by not so fast technical and technological changes, i.e. environments' demands for change. However, the main motive for innovativeness of the business process arises from the economic parameters which, even with the specificities of the base industry, are observed through the lens of financial results.

Considering the all specificities of mining and ore processing on one hand, and business process requirements, on the other, 'the lowest common denominator' must be found which would drive the overall business towards growth and development. This common denominator are business costs, i.e. inclination towards their reduction because they are the latent basis for business success. Based on that, the business process of reengineering is viewed as a formula of choice when it comes to implement the mentioned inclinations, which can be clearly seen in description and presented results of the representative example of the 'Kopaonik' flotation, stated in this paper. This strategic option certainly requires securing the adequate conditions, technical, as well as financial, and conditions regarding to the human resource. However, it is important to emphasize that reengineering can be successfully applied in the business processes of the base industry, what was the purpose of this paper work.

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PdNi5 ALLOY: EFFECT OF THERMO-MECHANICAL TREATMENT ON MECHANICAL AND MICROSTRUCTURAL PROPERTIES[***]

Abstract

In this paper, the effect of thermomechanical processing on microstructure and mechanical properties of cold rolled samples of PdNi5 alloy was investigated for the purpose of its characterization. After melting and casting in a vacuum, a thermomechanical treatment was applied including the homogenization annealing in temperature range 800-1000^{o}C for 30, 60 and 90 minutes, cold rolling with deformation degrees of 60, 85 and 97%, recrystallization annealing in the temperature range of 200-1000^{o}C for 20, 30 and 40 minutes and electroresistant annealing at speed of 14, 16 and 24 meters per minute for the PdNi5 wire with diameter of 0.15 mm, and at speed of 18, 22 and 24 meters per minute for the PdNi5 wire with diameters of 0.111 and 0.08 mm with measurement of hardness, tensile strength, relative elongation and observing the structural changes using optical and SEM microscopy

The test results of influence of parameters of thermomechanical processing on the mechanical and structural properties of the PdNi5 alloy show that the process should be led in strictly defined conditions in order to be able to use this alloy for making catalyst-catchers in high-temperature catalytic processes in the production of nitric acid.

Keywords: *PdNi5 wires, catchment gauze, thermo-mechanical treatment*

INTRODUCTION

The high price of palladium is a limiting factor in the study of Pd-Ni alloys, so the number of scientific papers which include their characterization is relatively small. However, a widespread application of the platinum based alloys in the processes of catalysis, electronics industry, the jewelry industry, for production the medical and dental equipment, has led to a fact that researchers in many countries make the significant efforts to study this system alloys [1-7]. The binary phase diagram of the Pd-Ni system is shown in Fig. 1 [8]. It shows a complete solubility of components in the solid state, with minimum on the liquidus and solidus curve (1273^{o}C at 45at.% Pd) [8] without superlattices or intermediate phases [9]. In the alloys of Ni-Pd system, at cooling, surface-centered cubic α-solid solution is formed. As soon as is reached at cooling the area of interruption in solubility in the solid state is reached, at cooling, the surface-

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centered cubic α-solid solution decomposes into two also surface-centered cubic α - solid solutions of different composition: α_1 - solid solution is richer in nickel, and α_2 - solid solution is richer in palladium than it fits the overall composition of the alloy. Decomposition of surface-centered cubic α-solid solution on the two solid solutions of different composition but the same lattice, is the result of different lattice constants of the Ni (a = 0.35238 nm), and Pd (a = 0.38902 nm).

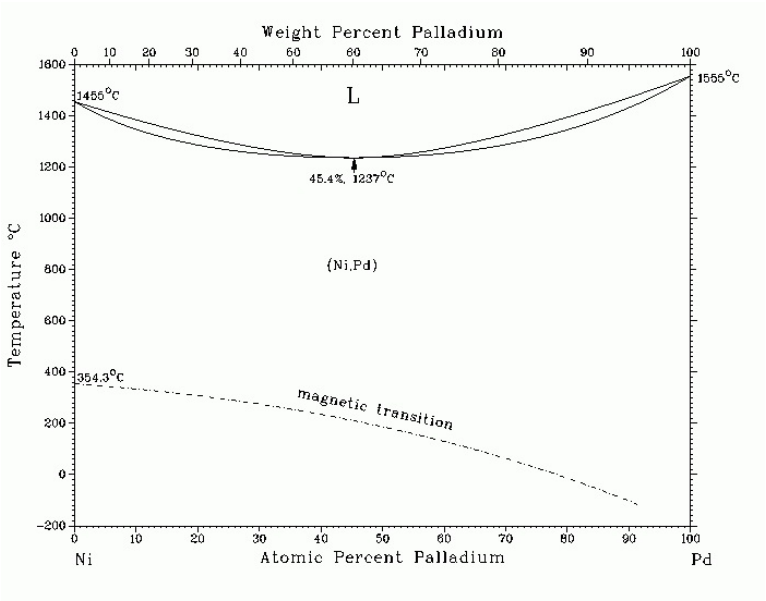


Figure 1 *The binary phase diagram of the system Pd-Ni*

Only a few papers have been found [10, 11] by the authors who dealt with Pd-Ni and thermo-mechanical treatment on the properties of PdNi5 alloy, and that is why this alloy was selected for the study in order to determine the optimal conditions for thermo-mechanical processing regime, so it could be used for making catalyst-catchers to capture the platinum in catalysis process at high temperatures.

Therefore, the object of this paper is to study the effect of the complex thermo-mechanical treatment on improvement the mechanical properties and electrical conductivity, as well as the structural changes occuring in the alloy. Keeping in mind the complex influence of deformation degree, annealing time, annealing temperature and texture on the recrystallization rate, and also on the recrystallized grain size and mechanical characteristics, the experiments with annealing time and annealing temperature change on the alloy Pd-5% mass Ni with different degree of deformation for further plastic processing in order to make yhe Pd-catalyst-traps, was carried out in this work.

EXPERIMENTAL

The binary Ni-Pd alloy with 5% mass nickel was obtained by melting of 99,99% purity palladium powder and 99,95% purity nickel as a sheet metal in the medium frequency induction furnace, in a MgO casting pot, sized $h_1 x h_2$ = 85x80 mm,

d_1xd_2 = 65x55 mm. In order to achieve better compacting of materials, Pd-powder and Ni-sheet metal were pressed on a hydraulic press with a force of 270 daN/cm^2. Casting temperature of PdNi5 alloy was 1520^{o}C. Molten batch was overheated before casting of 150-170^{o}C. Casting was done in a graphite mold, pre-heated at temperature of 350-400^{o}C. Samples were melted and cast in vacuum. All cast samples with a circular cross-section (Ø20 mm) were homogenized at 800, 900 and 1000^{o}C during 30, 60 and 90 minutes in an electric resistance furnace of chamber type LP08. All samples were quenched in water. After quenching, the samples were cold rolled on the stand rolls with calibrated rollers, system square-square, to the calculated dimensions of 11.2 mm; 6.8 mm and 2.3 mm with 60%, 85% and 97% reductions, respectively, with the inter-phase annealing for 15 minutes at 900°C followed by quenching in water. Heat treatment after rolling consisted of the recrystallization annealing the samples of PdNi5 alloy, in a wire form, in the electric resistance furnace of chamber type LP08 without protective atmosphere, at temperatures in the range 200-1000^{o}C during 20-40 minutes interval. All samples were quenched in water after annealing. The final wire drawing dimensions (Ø 0.15 mm, 0.11 mm and 0.08 mm) were achieved by drawing with 99% reduction. After reduction, all samples were exposed to the recrystallization annealing at the electrical resistance annealing speed from 14 m/min to 24 m/min for different annealing voltages from 20 V to 36 V.

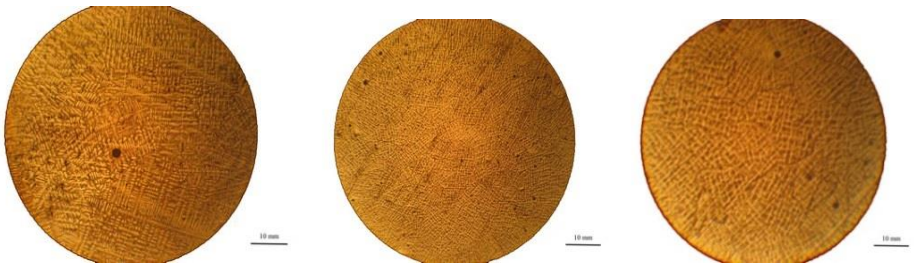
After the thermo-mechanical treatment, the values of hardness, tensile strength, elongation and electrical conductivity were measured and structural changes were observed by the optical and scanning electron microscopy. Hardness measurement was done on the combined device for measuring the hardness of Vickers and Brinell, WPM, Leipzig, Germany, at a load of 5 kgf and load duration of 15 s according to ASTM:E384, taking the 3-point average. Tensile strength and elongation were measured using a universal device for tensile testing, type „Mohr + Federhaf + Losenhansen“ – Manheim and testing machine Otto Wolpert up to 100 kg with the extent to 5 kg. Before testing, all samples were cut to a length of 150 mm. Electrical conductivity was measured using the Wheatstone bridge. Microstructural changes in the course of thermo-mechanical treatment were observed on a metallographic microscope EPYTIP 2, with magnification of 80 to 400 times and on a JEOL JSM-6610LV scanning electron microscope with an EDS detector. For the metallographic testing, samples were prepared according to the standard procedure - grinding, polishing (polishing machines ROWA E-KG) with 0.05 μm Al_2O_3 powder, and etched a few seconds with solution of 1 g CrO_3 +20 ml HCl to obtain a microstructure.

RESULTS AND DISCUSSION

I The effect of homogenization annealing on mechanical properties and microstructure

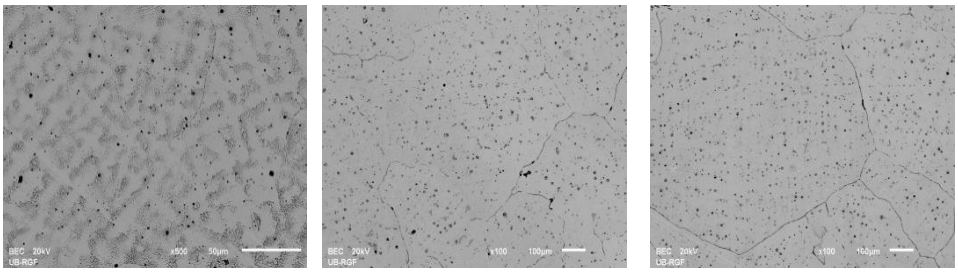
Figure 2 shows the optical microphotographs, while Figure 3 shows the scanning electron microphotographs of the alloy after different thermo-mechanical treatment. Microsrtucture of the alloy after homogenization annealing at 800^{o}C for 30 minutes is shown in Figures 2a and 3a. It is noted that the used heat treatment did not lead to degradation of cast dendritic structure. Homogenization annealing was carried out in order to eliminate a segregation and obtain a homogeneous structure [12]. Further increasing of the annealing temperature to 900^{o}C for 30 minutes (Figures 2b and 3b) led to some equalization of concentrations of alloying element. Dendrites form and their boundaries to the areas that solidified last, still exist, but the contrasts have de

creased and dendrites are just discernible. It is noticeable that duration of homogenization annealing (30 minutes at 900^{o}C) was not sufficient for complete homogenization of the structure, or complete breakdown of the dendritic branches. Furtherincreasing of the annealing temperature to 1000^{o}C, Figures 2c and 3c , leads to a solid solution grain boundaries become clearly marked. It can also be seen that the orientation of dendrites inside a grain is always the same, but considerably varies from grain to grain, showing a good agreement with the literature data [13,14].



a) *b)* *c)*

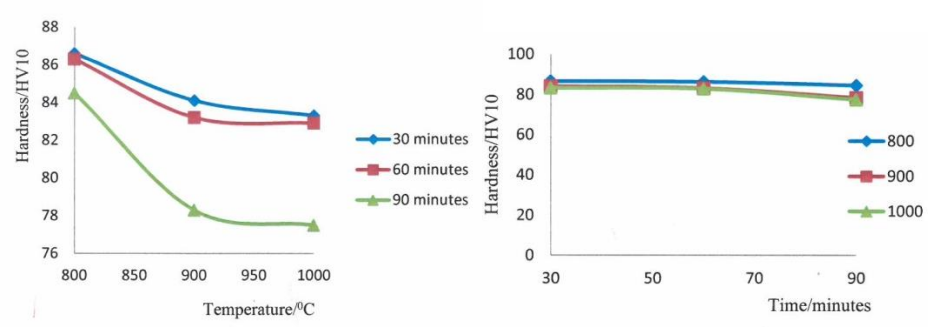
Figure 2 *Optical microphotographs of the alloy after homogenization annealing during 30 minute at: (a)800^{0}C, (b) 900^{0}C, (c) 1000^{0}C, 80x. The samples are quenched in water*



a) *b)* *c)*

Figure 3 *Scanning electron micrographs of the alloy after homogenization annealing during 30 minute at: (a)800^{0}C, (b) 900^{0}C, (c) 1000^{0}C*

Figure 4 shows the effect of different parameters of homogenization annealing on hardness values. An increase in the temperatures values contributes to a decrease in hardness values due to the equalization of concentration difference in the structure. Temperature influence in comparison with influence the time of homogenization annealing on a change of hardness values (Figures 4a and 4b) is significant. The cast samples have a highest hardness value 98 HV 10 and the annealed samples at 800^{o}C for 30 minutes have 86.6 HV 10. Further increase of temperature to 900^{o}C and 1000^{o}C leads to a decrease to 84.1 HV 10 and to 83.3 HV 10, respectively.



a) *b)*

Figure 4 *Effect of parameters of homogenization annealing on hardness values*

Figure 5 shows the effect of parameters of homogenization annealing on microhardness values. It can be observed that th microhardness values of homogenized samples decrease with increase of temperature and time of homogenization annealing. A sample after homogenization annealing at 1000°C for 90 minutes has minimum microhardness value (102.56 HV 0.15). According to the microhardness value of sample after homogenization annealing, it can be concluded that the microhardness at 800°C for 30 minutes decreases for 36%.

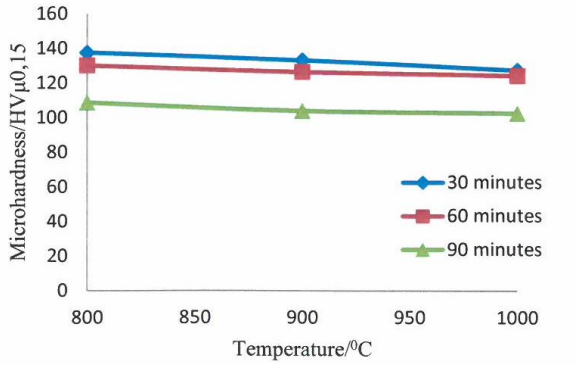


Figure 5 *Effect of parameters of homogenization annealing on microhardness values*

The effect of homogenization anneling on electrical conductivity values is shown in Figure 6. Pure metals have a proper and uniform crystal lattice, and therefore have a small electrical resistance. Additives in small quantities distort the crystal lattice, and increases electrical resistance. The same is also with the alloys from a solid solution, i.e. which together with the solidification are crystallized, and atoms are incorporated in a crystal lattice of the other element. The temperature increase leads to the intense thermal vibrations of atoms in the crystal lattice, but the mobility of conductive electrons is less due to the collisions with atoms of the crystal lattice. Comparative effect of these factors affects the electrical conductivity values as shown

in Figure 6. It can be observed that the electrical conductivity values slightly decrease with an increase of homogenization annealing time and temperature.

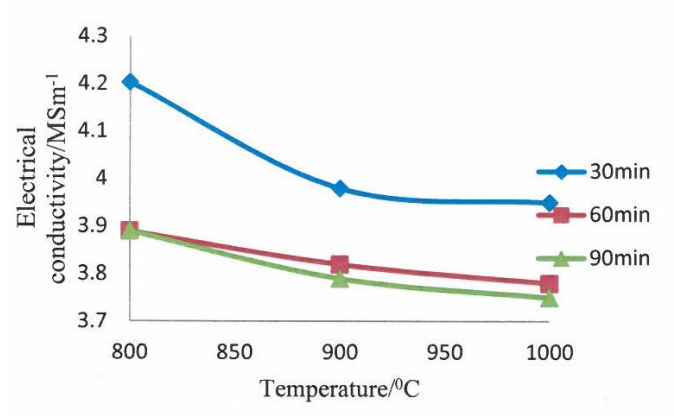


Figure 6 *Effect of parameters of homogenization annealing on electrical conductivity values*

II The effect of recrystallization annealing on mechanical properties and microstructure

Figure 7 shows the effect of annealing on the hardness values of finally rolled samples with 60%, 85% and 97% reduction. It can be seen that during annealing, the hardness values of the cold deformed alloy at temperatures below 400°C do not change, but internal stresses are removed.

In the temperature range from 400°C to 500°C, i.e. in the interval of recovery of crystals, there is a continuous decrease of hardness in samples deformed with lower degrees of deformation (60% and 85%), while in samples deformed with deformation degree of 97% this interval extends up to 600°C. In this temperature range, in addition to the removal of internal stresses, the recovery of crystal structure occurs by removal the small defects in the crystal lattice due to the increased rate of diffusion of atoms. In the area of recovery no changes in hardness of samples occur, given that there is no change in dislocation density, but only to their redistribution, so there is no change in the structure (Figure 7a). At 500°C (ε = (60 or 80)%) and at 600°C (ε = 97%) the hardness rapidly decreases indicating the occurrence of a texture change, i.e. a new structure appeared (Figure 7b). The newly formed structure, during the primary recrystallization process, is a polygonal and with the strain free grains. This character of change in mechanical properties in this temperature range is caused by reduction a dislocation density and removal the subgrain boundaries. Further increase in annealing temperature above the recrystallization temperature results in a gradual, but quite small, reduction of hardness, due to the increase in grain size, which is a sign of the secondary recrystallization (Figure 7c).

Hardness values after recrystallization annealing decrease with the increase of the cold plastic deformation degree.

Recrystallization temperature of pure palladium is around 500°C [12] and depending on the presence of impurities and de

formation degree. It is noted (Figure 6), that the joint effect of the alloying palladium with nickel and deformation degree effect in the Pd-Ni alloy, shifts the recrystallization temperature to even 600°C. With increasing deformation degree, recrystallization temperature shifts to the lower temperature values, as a results of the increased stored energy, which causes a smaller critical size of the nucleus and decrease in the activation energy for recrystallization, i.e., nucleation and growth of recrystallized grains become easier [12,15].

Microstructure of the PdNi5 alloy with 97% reduction after annealing at different temperatures for 30 minute is given in Figure 8. It was noted that to the annealing temperature of 500°C oriented deformation structure retains, in all samples (Figure 8a). Comparing to the structure of the cold-deformed samples of PdNi5 alloy, no change can be observed in the structure. The shape and size of grains correspond to the state after the end of the plastic deformation, and also the grid orientation of individual grains remains the basically retained [16]. By increasing the annealing temperature to 700°C, the elongated grains vanished, and the new polygonal grains were formed (Figure 8b). This is a distinctive sign of recrystallization. The increase in the annealing temperature at 900°C causes further growth of the grains (Figure 8c).

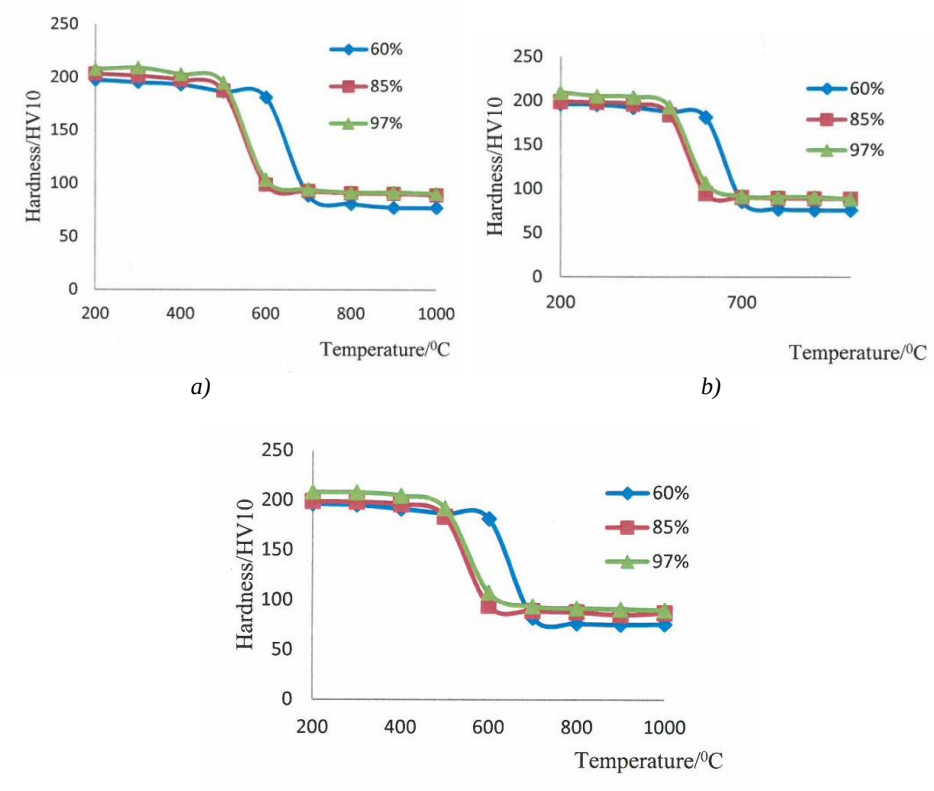
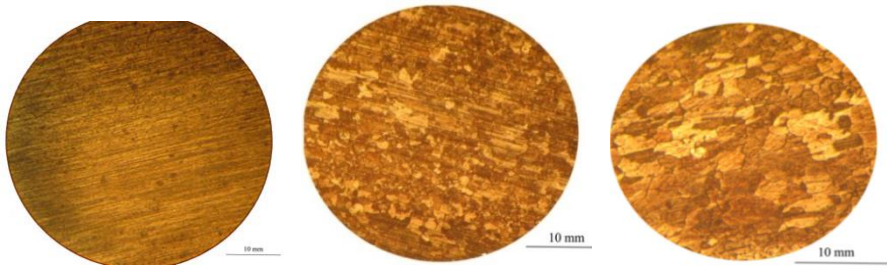


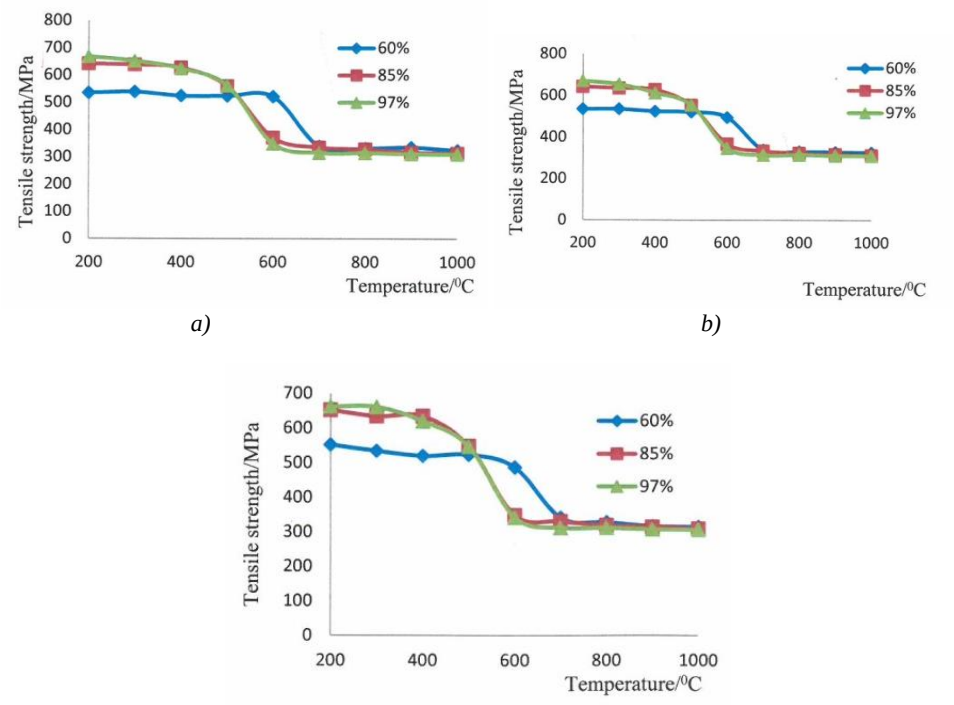
Figure 7 *Dependence of hardness, HV, PdNi5 alloy of deformation degree, annealing temperature and time: a) 20 minutes; b) 30 minutes; c) 40 minutes*



a) *b)* *c)*

Figure 8 *Optical microphotographs of the alloy with a deformation degree 97%, after annealing for 30 minutes at: (a)500^{0}C, (b) 700^{0}C, (c) 900^{0}C, 400x. The samples are quenched in water*

Figure 9. shows an effect of annealing on the tensile strength values of finally rolled samples with 60%, 85% and 97% reduction.



a) *b)*

c)

Figure 9 *Dependence of tensile strength PdNi5 alloy of deformation degree, annealing temperature and time: a) 20 minutes; b) 30 minutes; c) 40 minutes*

From the study results it can be seen that the tensile strength of cold-deformed and differently heated PdNi5 alloy samples in the form of wire, does not change continu

ously with increasing annealing temperature. Tensile strength virtually does not change to a temperature of 400°C, while in the temperature range 400-500°C there is a slight decline in R_m. This is a consequence of reducing the concentration and redistribution the errors in a lattice. At 500°C, there is a rapid decrease of tensile strength in samples deformed with a greater deformation degree (85% and 97%), while in samples deformed with adeformation degree of 60%, this change occurs at 600°C. This change takes place in a very narrow temperature range (500-600°C) or (600-700°C), and is a result of advancement the recrystallization process and formation of a new, undeformed structure, which is noted by metallographic examination (Figure 8). Further increase of annealing temperature above 600°C or above 700°C leads to grain growth, which causes a further slight decrease in tensile strength, due to occurrence the secondary recrystallization, or structure enlargement.

Figure 10 shows an effect of annealing on elongation values the finally rolled samples with 60%, 85% and 97% reduction.

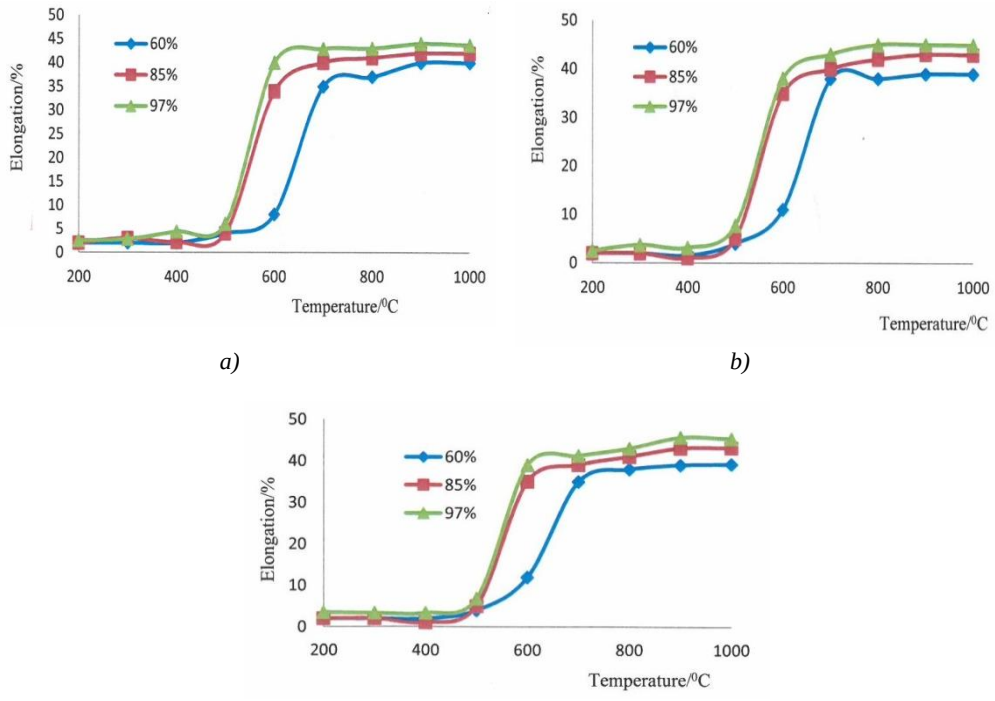


Figure 10 *Dependence of elongation PdNi5 alloy of deformation degree, annealing temperature and time: a) 20 minutes; b) 30 minutes; c) 40 minutes*

III The effect of electrical resisatnce annealing on mechanical properties

Figures 11 and 12 graphically present the dependence of tensile strength (Rm) and elongation (A) of drawn PdNi5 wires produced by high deformation (97%), on annealing voltage and speed after cold work.

It can be concluded from the results, shown in Figures 11a) and 12a), for the wire diameter 0.15 mm, that with the increase of voltage and resistance annealing speed, the values of tensile strength slightly decrease, while, at the same time, the relative elongation values slowly increase. The maximum values of elongation (46.5%) with acceptable value of tensile strength (321,45 MPa) for the aforementioned wire is achieved by annealing at voltage of 24V and speed of 24 m/min.

For the wire with diameter 0.11 mm (Figures 11.b) and 12.b)) values of tensile strength and elongation show a similar behaviour as for the wires of 0.15 mm in diameter. The maximum value of elongation (36.5%) with acceptable value of tensile strength (313.5 MPa) was achieved by annealing at voltage of 28V and speed of 18 m/min.

For the wire with diameter 0.08 mm with increasing voltage and resistance annealing speed, the values of tensile strength also slightly decrease while the relative elongation values rapidly increase (Figures 11c) and 12c)). The maximum value of elongation (35.5%) with acceptable value of tensile strength (286 MPa) was achieved by annealing at voltage of 32 V and speed of 18 m/min. This character of change the mechanical properties was caused by the consolidation of recrystallized structure.

For voltage values lower than 20 V, for wire of $\emptyset$ 0.15 mm, and 28 V for wires of $\emptyset$ 0.11 and 0.08 mm, as well as for the voltage values higher than 24 V and 36 V, the tensile strength and elongation show the values unsuitable for further use of wires for making palladium catalysts-catchers. Namely, the insufficient or excessive annealing of wire occurs, which results in the low values of tensile strength and elongation.

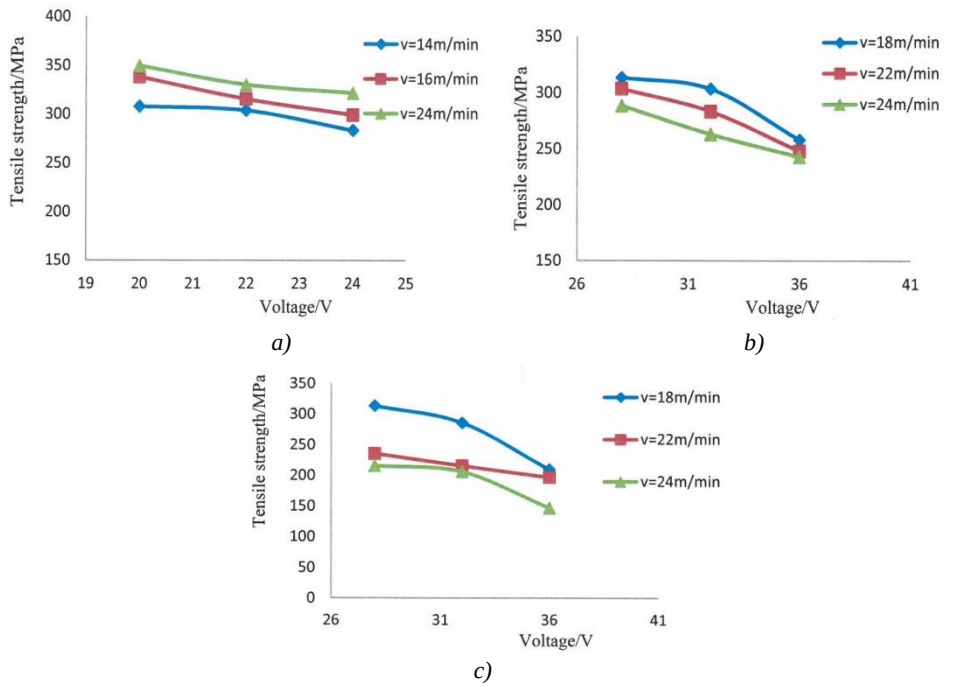


Figure 11 *Dependence of tensile strength drawn PdNi5 wire of different diameter of resistance annealing parameters: a) 0.15; b) 0.111; c) 0.08 mm*

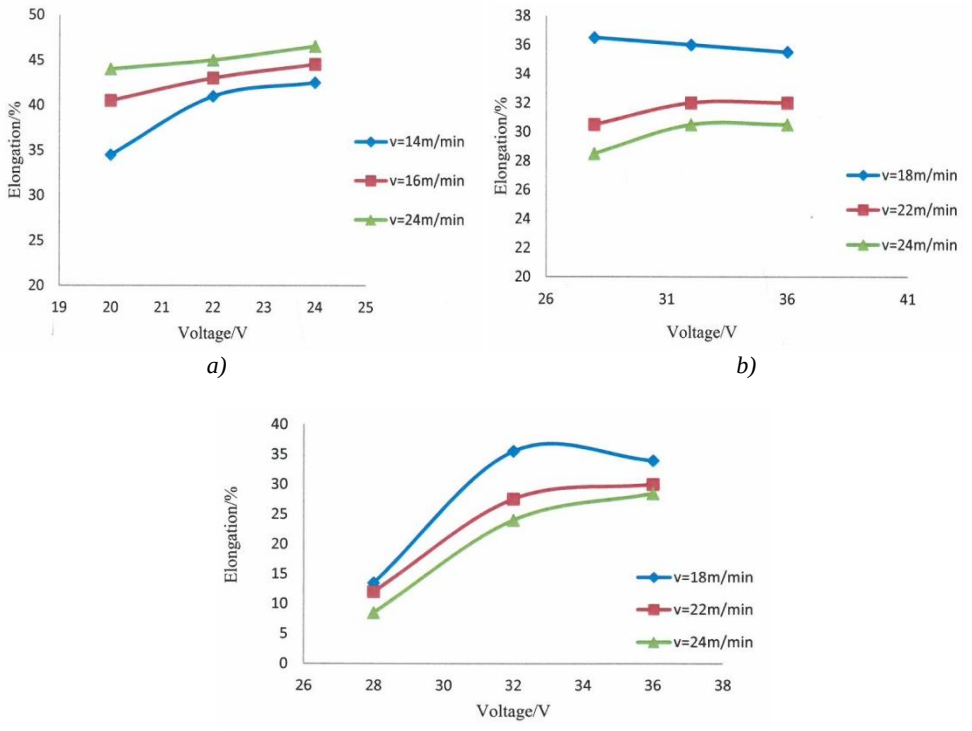


Figure 12 *Dependence of elongation drawn PdNi5 wire of different diameter of resistance annealing parameters: a) 0.15; b) 0.111; c) 0.08 mm*

CONCLUSION

Based on the study of the effect of thermo-mechanical treatment on the properties improvement and structural changes in the Pd-5 wt.% Ni alloy, it can be concluded that the best combination of properties of the final wire (diameter 0.08, 0.111 and 0.15 mm) was achieved in the following regimes of thermomechanical treatment:

- Regime of homogenization annealing (900^{o}C for 30 minute). With the selected regime of homogenization annealing, the values of hardness (84,1 HV), microhardness (133,32 HV) and electrical conductivity (3,9 MSm-1) allows further plastic processing.
- Regime of recrystallization annealing (900^{o}C for 30 minutes). With the selected regime of recrystallization annealing for sample deformed with the highest deformation degree (97%), the highest value of relative elongation (45%) is achieved, with very satisfactory values of tensile strength (310 MPa) and hardness (90,8 HV). For the samples deformed with lower deformation degrees, under the same annealing conditions, the relative elongation values are lower, while the values of tensile strength and hardness are slightly higher.

- Regimes of resistance annealing (U and v) are different depending on the final wire diameter. So,
  for Ø 0.15 mm U = 24 V and
  v = 24 m/min;
  for Ø 0.111 mm U = 28 V and
  v = 18 m/min;
  for Ø 0.08 mm U = 32 V and
  v = 18 m/min.

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ELECTRO - FILTER ASH USE IN THE UNDERGROUND COAL MINES

Abstract

Thermal power plants in the Republic of Serbia spend 35-40 million tons of coal annually, mostly lignite, with about 6 million tons of ash or slag as a by-product of electricity and heat production, deposited on the landfills. The Law on Waste Management defines the possibility of reusing of ash and slag. The Rulebook on categories, testing and classification of waste, as well as the Decree on technical and other requirements for ash, as building material intended for use in the construction, reconstruction, rehabilitation and maintenance of infrastructure facilities of public purpose, electro-filter ash and slag are characterized as the non-hazardous waste for a wide range of use. In recent decades, the electro-filter ash has been used in several fields in the coal mines, increasingly gaining in importance, and what is the subject of this work in order to demonstrate the efficiency of its use and at the same time contribute to the environmental protection.

Keywords: *mines, coal, electro-filter ash, fire insulation*

1 INTRODUCTION

Electro-filter ash and slag are the most commonly used secondary waste in the Republic of Serbia. About 200 million tons of ash and slag are deposited on the current landfills of over 1,600 ha of fertile land, located in the immediate vicinity of the thermal power plants, large river flows and settlements. This significantly affects the deterioration of environmental conditions and it is imperative to find a solution for using of this ash to meet both the environmental and economic parameters.

Ash consumption in construction grows increasingly, and ash is most commonly used in the industrialized countries as the Great Britain, the United States, France, the Netherlands, Czech Republic and Poland. There is no problem of disposal the electro-filter ash in the EU countries. The amount of generated electro-filter ash is insufficient to undermine the needs of an ever-increasing demand. According to data from developed countries of the European Union, 18 million tons of ash are used, primarily, in the construction industry and road construction.

In the mines of the Republic of Serbia, the electro-filter ash is now used to fill the excavated free space behind the fire isolation barriers, where it has a number of advantages compared to the other conventional ways of isolating the oxidation and fire processes. In the first place, it made the process of filling in the faster procedure, reduced the number of engaged workers and enabled continuous filling.

In some mines, filling of excavated empty spaces on a larger surface was done in order to prevent deformation of the surface of the terrain. Also, in some cases filling with electro-filter ash was carried out on the excavation fields where several cave rooms were made and through which the working

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front was passed from the mechanized long wall excavation, and these rooms had to be filled previously.

2 ELECTRO - FILTER ASH PROPERTIES

Electro-filter ash, which is obtained by combustion in the coal combustion boilers, is a finely ground, powdered material that is transferred by flue gas. The ash is usually collected by the electrostatic precipitators, dust collectors or mechanical collection devices, such as cyclones.

In the production of energy, three methods of ash removal from the boiler plant are applied: dry, wet and cyclone, where a dry process is most commonly used in thermo-objects in Serbia.

The ash consists of full or hollow particulate particles, mainly ball-shaped, and is mostly of glass (amorphous) nature. The specific gravity of electro-filter ash usually ranges from 2.1 to 3.0, while the specific area (measured by the Blaine's method of air permeability) can vary from 170 to 1000 m²/kg.

The chemical properties of electro-filter ash depend on coal composition, the methods of controlling the air pollution in the thermal power plants, and the techniques used for transport and storage on the landfills.

Lignite ash has a higher content of calcium oxide and a lower loss by ignition (LO1) than that from bituminous coal. Electro-filters ash from lignite and partially bituminous coal may have a higher amount of sulphate compounds compared to ash obtained from bituminous coal.

The ignition loss (LO1), which represents a measure of the amount of residual carbon retained in the electro-filter ash, is one of the most significant of its chemical properties.

In the classified ash, the loss of ignition can be from 5% to 6% according to the AASHTO or ASMT specifications. Loss by ignition indicates the similarity of using the ash as a substitute for cement in concrete, which is an important feature of it.

In addition to the chemical composition and loss of ignition, the quality of electro-filter ash is primarily determined by fineness and consistency. Fineness affects the reactivity of ash, as well as the levels of carbon content. The electro-filter ash has a greater fineness than the Portland cement and lime, and its grain size ranges between 10 and 100 microns. Ashes used for the production of concrete and solid mass for filling should be consistent, respectively resistant to the changes allowing the mixture to be tested.

Previous research on the use of electro-filter ash in Serbia has been almost exclusively related to the field of construction. It has been established that, as a raw material for the production of building materials, the electro-filter ash has application inproduction: building elements - blocks of brick, ceramics, concrete prefabricates, light concrete, light aggregates, pucolan - metallurgical cements, hydraulic lime and cement.

As a material that is directly installed at the locations of application, it is used for: masses for stabilization the pavement structures; as a filler in the asphalt mixtures and bitumen masses, for mechanical and chemical stabilization in the construction of roads, as a filler for asphalt, in the embankment, etc.

Electro-filter ash is useful for a wide variety of applications, because it is a pucolan, or silicate or alumina-silicate material that in isolated form and in the presence of water, combined with calcium hydroxide (from lime, Portland cement or dust from an annealing furnace) and forms mixtures with the characteristics of binder.

3 EXTINGUISHING OF MINE FIELD FIRES WITH THE SYSTEM FOR FILLING WITH ELECTRO-FILTER ASH

Endogenous oxidation processes and jam fires are a specific phenomenon in the underground coal mining and often follow the mining processes. Namely, endogenous fires are created by the joint operation of natural - geological and technical - technolo-

gical conditions in a particular cave object. From the natural-geological conditions, the most influential are: propensity of coal to self-ignition, thickness of the coal layers that are mined, tectonics in the excavation area, inclination and depth of recovery, characteristics of the accompanying rocks and presence of water.

The second group of conditions, i.e. technical and technological are: inadequate preparation and elaboration, applied excavation system, losses of coal during excavation, poor untimely isolation of excavated areas, inadequate rate of progress of excavation works, irregular ventilation scheme, high depression of the excavation field and pits, air flow losses, poorly defined location of tubular sewage fans and others.

The occurrence of an endogenous fire in a mining cave usually endangers the employees and equipment and leads to a temporary interruption of mining operations until it is eliminated.

Experience has shown that the excavation system, no matter how efficient and economical is, make conditions for development the oxidation processes that can turn into open fires.

Prevention of oxidation processes enters the technological system of underground coal mining and affects all its stages of work from: opening, preparation, excavation, ventilation, drainage and maintenance.

The first degree of protection against oxidation processes and cave fires are preventive measures. If the preventive measures are not adequate and sufficient, as the second level of protection, the measures of remediation or liquidation the occurrence can be used.

Recovery itself includes active and ventilation methods. Active methods include all active fire extinguishing operations with water and removal of heated and ignited coal, isolation of the fire endangered areas by temporary and permanent bulkheads, injection and interventions with inert gases.

The most commonly applied method of active procedures is the isolation of oxidation or fire area, and its goal is to stop the oxygen supply to the fire source, and the success of extinguishing depends on the isolation quality. Isolation barriers must meet a range of conditions to be effective: to be impermeable, to be able to withstand any additional water inlet, to be heat-resistant and resistant to the aggressive environmental performance, easy to maintain, to have as long life as possible, and to be able to be quickly and efficiently to built-in.

The aforementioned conditions are mostly satisfied by the so-called "sludge plugs", i.e. barrier with electro-filter ash which are in practice proven as efficient.

Also, special attention is required, which must be applied in the case of fire isolation of the area in the so-called methane conditions when there is a potential risk of ignition and explosion of methane.

The electro-filter ash filling system can be applied after the preparatory work has been carried out which fit into a further concept of exploration work in the mining cave.

At the preparatory stage, on the surface area near one of the cavities, a working plate has to be built and silos to be mounted (usually two blocks) so that the ash dispensing valve is at a height of 1.5-2.5 m in order to ash flow by gravity through the length of pipe. Below the silo, a mixer connected to both silos has to be installed, as well as and the water inlet pipe connected to the bottom of the ash inlet valve. The ash and water flow gravitating through the tube into a mixer for making a mixture of water and ash. At the outlet pipe from the mixer, a pump for transporting a mixture of water and ash is installed, and the main pipeline for the pit is installed behind it.

The description of a caving plant for filling with electro-filter ash is given below. On the plateau next to the cave entrance, the following equipment was installed:

- Two silos volumes of 20 m^3 and 18 m^3;
- For the water supply to the silos, a plastic tube diameter of 75 mm is used, and the valves of 75 mm for flow control of water filling;
- For dosing of oven ash, 200 mm ovals are installed;

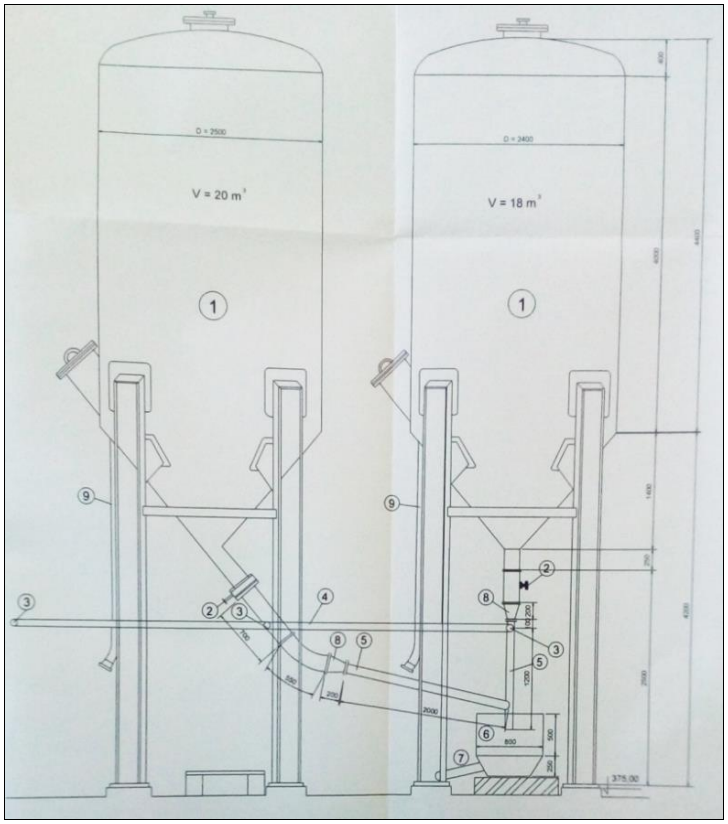
- For acceptance the sludge, a mixer - tank was built - with dimensions of 1.0 x 0.8 x 0.8 m;
- Pump for suppression of the mixture;
- Water supply, from the water supply network to the silos through a distribution for each silo.
- For controlling of water consumption, the water meter is installed in the water supply connection.

The appearance of the filling station with equipment availability is shown in Figure 1.

A plastic pipeline is used for the hydraulic transport of sludge from the tank at the surface to the production part of the cave, or to the objects that being built. At the site of the construction of the isolation facility, a prefabricated filter barrier is made and the part of the pipeline is installed behind it. The appearance of a typical solution of an isolating object from electro-filter ash is shown in Figure 2.

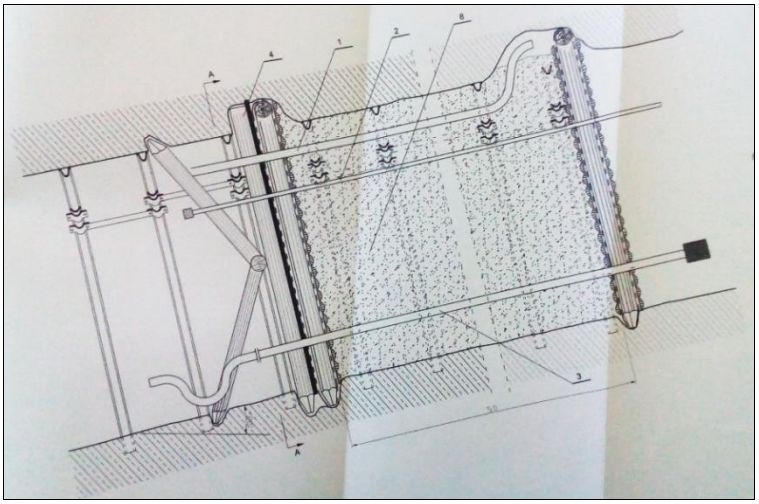
The construction of a sludge barrier must be well-done and thus ensured that there is no relaxation. The filling in the initial phase is carried out gradually with certain breaks necessary for water discharge.

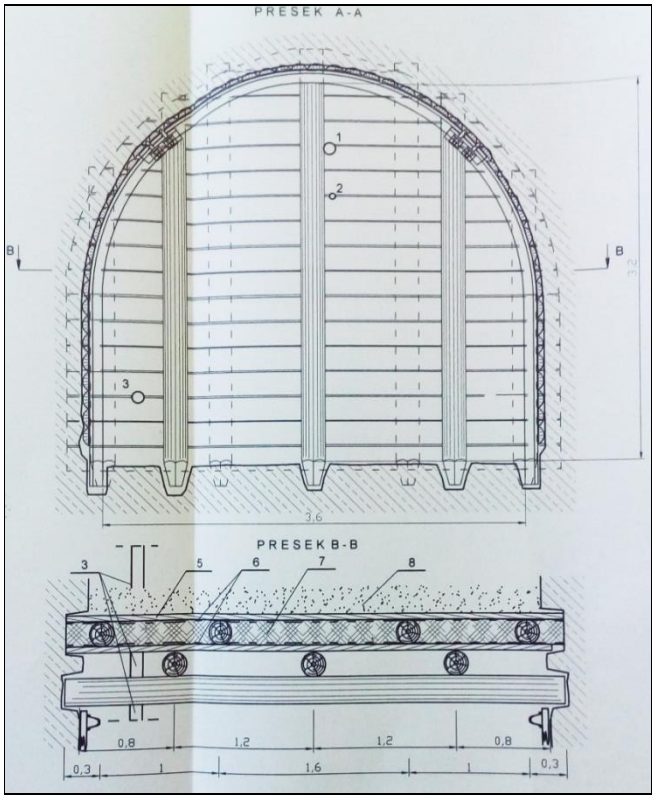
In sludge treatment, the most important is the good ratio of water and ash, because in the case of higher mixture density, there is the possibility of clogging the pipeline, while too sparse mixture extend the time of buckling and water clearing. The most common mixing ratio of water and ash is 1: 2 and 1: 4 by weight.



Legend: 1. Ash storage silos, 2. Ash dosing valve Ø 200 mm, 3. Dosing valve Ø 75 mm, 4. Water supply tube Ø 75 mm, 5. Tube for finished mass drainage of Ø 75 mm, 6. Mixer - sludge reservoir, 7. Slit tube for Ø 75 mm, 8. Transition to tube Ø 200/100 x 200 mm, 9. Silage filling tube Ø 90 mm

Figure 1 *Filling station with equipment availability*





Legend: 1. Lifting pipe Ø 100 mm, 2. Sampling tube Ø 20 mm, 3. Drainage pipe Ø 100 mm - 150 mm, 4. Wooden columns for reinforcement, 5. Wooden partitions, 6. Jut, 7. Glass wool, 8. Filter ash

Figure 2 *Isolation object of filter ash*

CONCLUSION

The use of electro-filter ash and slag is an example of sustainable development. Waste that burdens the operation of thermal power plants is now becoming useful and gaining the usable value. The use of ash generates savings, increases profits and removes substantially negative effects on the environment.

In the underground coal mines, the use of electro-filter ash, in the first place for the construction of stable isolation facilities and for filling up the excavated areas, becomes increasingly widespread, according to the demonstrated efficiency in application.

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