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EFFECT OF STAGE DEVELOPMENT OF MINING OPERATIONS ON MAXIMIZATION THE NET PRESENT VALUE IN LONG-TERM PLANNING OF OPEN PITS**

Abstract

Long-term planning in the mining industry has one main goal: maximizing the value that is realized by excavation and processing of mineral resources.

When designing the open pits, determining the stages of development the mining operations, (eng. Pushback) is one of the important factors in the process of long-term production planning.

Using the different scientific methods and mathematical algorithms underlying the operation of modern software for strategic planning of production, it is possible to control the business economy.

This work presents the influence of the open pit development phase of the South Mining District Majdanpek on significant increase the net present value.

Keywords: *optimization, development stages of the open pit, net present value*

INTRODUCTION

The main goal of any mining operation is that the exploitation of the ore body has to be implemented to realize maximum profit. By application the techniques of designing the final open pit, it is easy to determine the economic depth and final limit of the open pit.

Design and planning of the mine (open pit) is very complex and multi - disciplinary process that requires the overall knowledge of this field and a good understanding of many issues. For projects, the basic principle is that only projects with positive net present value (NPV) are accepted.

Optimization the open pit limit and mining dynamics involves geological and operational modeling, which is realized through the application of software for optimization

using some mathematical algorithms. The process involves identifying the combination of controlled variables that maximize the value of the project in the context of a given set or range of assumptions. With the application of geostatistics, 3D modeling, Lerchs - Grossmann's algorithm, Lane's algorithm and many other procedures based on computer programs, it is possible to create better mining plans nowadays. The consequence of this is to achieve significantly better results both in the exploitation of mineral deposits with low content of useful components and in complex operating conditions [5, 6].

The problem of exploitation planning refers to the criterion that is used for optimization the open pit. Despite the sophisticated algorithms, the optimization problem is still

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basically an economic problem, within which the procedures are defined for assessment the required economic parameters.

Design of the open pits and solving the optimization problem is achieved by problem modeling using the software. The work of used software is based on an algorithm that is applied to three-dimensional block model of some ore body.

METHODOLOGY

Long-term planning of ore mining depends on several factors, and one of the most important is to define the optimal stage of development the mining operations.

After determining the final limit of excavation, the next step in the process of designing the open pits is the defining the excavation stage. On this occasion, the attention must be paid on the following:

- to meet minimum allowed distance between the limits of stages
- to meet minimum operation width bottom of each stage
- NPV of each stage must be positive
- NPV for defined stages must be maximum

The main reason for planning the stage development of the open pit is of economic

nature, i.e. maximizing the net present value. In addition to the economic, the stage development of the open pit must also have a practical significance. Namely, the large number of stages can lead to the following:

1. Increased costs due to maintenance more work sites
2. Increased costs due to reconstruction of transport routes
3. Insufficient width of working plateaus for machinery operation
4. Increased number of primary and auxiliary equipment, etc.

Therefore, designing an excessive number of stages may cause that the resulting NPV is unrealistic, while a smaller number of stages leads to the reduction of NPV. Therefore, the proper approach to this problem is in establishing a compromise between the geological-exploitation conditions and desire to achieve maximum NPV. Today, many types of software for optimizing own modules for automatic selection of excavation stages with the goal of maximizing the NPV (e.g. software Whittle uses Whittle Pushback chooser).

Figure 1 presents an overview of the stage development of mining operations at the open pit [3].

Figure 1 View of stage development of mining operations in the open pit

Conducted analysis in this work with the aim of maximizing the net present value is realized by the use of geostatistical mo-

deling method, the method of long-term planning and optimization methods of the open pits.

The procedure is carried out through the following steps:

- 1) The first step involves modeling the deposit, which is performed in the software Gemcom Gems.
- 2) In the second step, the block model is used to optimize the final contours of the open pits and defining the stage development of mining operations. In this work, optimization of the open pit of copper ore was carried out in the software Whittle, which applied the modified Lerchs-Grossmann algorithm. Software for generating the nested open pits and defining the pushbacks uses the technique of parameterization (Revenue Factors), and the calculation is based on the undiscounted cash values.
- 3) The third step presents defining the excavation dynamics. In this step, simulation and DCF analysis are carried out to obtain the most favorable variant, or determine the number of stages that affect the maximization of the net present value through the long-term planning of the open pits. This analysis is based on the Milawa algorithm, which is specifically designed for

defining the mining dynamics with the long-term planning strategies of mining.

CASE STUDY: THE COPPER DEPOSIT SOUTH MINING DISTRICT MAJDANPEK

The copper deposit South Mining District Majdanpek is located in the south of the town of Majdanpek in the immediate vicinity.

Geological reserves of the copper deposit South Mining District Majdanpek were calculated by the method of mini blocks, whereby sizes of blocks are $15 \times 15 \times 15$ m. This small block size was chosen for height of exploitation levels at the open pit South Mining District, which is 15 m, and in this case it is the third dimension of a small block, i.e. the thickness of the ore in it. The basis for calculation the geological reserve is a digital block model of the deposit formed in Gemcom software [4], [5].

The method of real kriging was used for evaluation of calculation blocks.

Figure 2 shows a three-dimensional view of the block model of Cu in the deposit South Mining District.

Figure 2 Three-dimensional view of the block model of Cu in the deposit South Mining District

By development a block model, the following values are defined for each

block: type of rock, bulk density, content of useful component Cu (%) and associ-

ated components S (%), Au (g/t), Ag (g/t), Mo (g/t), and economic value of the block, or the amount of copper in the block or profit, that is realized by mining of the block [6].

After defining the block model of the deposit, the next step in design is optimization of excavation boundaries.

The adopted starting techno-economic data, needed to assess the deposit value, are shown in Table 1. They were adopted on the basis of many years of mining experience in this mine, mine planning documents, existing studies for mining of this deposit and assessment the trends in market prices of metals in the world and coming period [6, 7].

Table 1 Starting techno-economic parameters for optimizing the deposit

Parameter	Unit	Value
Base metal prices		
➤ Copper	USD/t	6,000.00
➤ Gold	USD/kg	35,000.00
➤ Silver	USD/kg	650.00
Costs of ore mining	USD/t	1.50
Costs of overburden excavation	USD/t	2.50
Costs of flotation ore processing	USD/t	3.20
Costs of metallurgical treatment of concentrate		
➤ Costs of copper production from concentrate	USD/t Cu cathode	600.00
➤ Costs of gold refining	USD/kg	150.00
➤ Costs of silver refining	USD/kg	15.00
Flotation copper recovery from ore	%	86.0
Metallurgical copper recovery from ore	%	98.5
Total recovery of gold	%	50.0
Total recovery of silver	%	50.0
Annual capacity of ore processing	t/year	8,500,000
Discount rate	%	10

Figure 3 presents the results of optimization for the basic copper price of 6,000 USD/t, based on which the opti-

mum contour of open pits and development stages of the open pit are carried out.

Figure 3 Graphical view of optimization results (Pit by pit graph)

Figure 4 presents a view of optimum (final) contour of the open pit South Mining District after processing in the software *Gems*.

Figure 4 View of the final contour of the open pit South Mining District after processing in software *Gems* with presentation the Cu block model of deposit in 3D format

Based on geometrical analysis of the area affected by the final contour of the mine, the possible number of stages of the open pit development, including the final open pit, is six stages. Figure 5 shows the stages of the open pit development, which are generated in the software *Gems* as the Pit List Files

and represent the input for further analysis of excavation dynamics in the software *Whittle*. Based on this analysis, the discounted values of the cash flows per year, and the net present value of excavation variants with one, two, three, four, five and six stages are obtained.

Figure 5 Development stages of mining operations

RESULTS AND DISCUSION

The results of realized analysis the effect of stage development of the open pit South Mining District on cash flows in the process of long-term exploitation or maximizing the net present value are shown in Table 2 and Figures 6 and 7.

Table 2 *Cash flow and net present value*

Year	Cash Flow, \$					
	Variant 1 (1 stage/ pushback)	Variant 2 (2 stage/ pushback)	Variant 3 (3 stage/ pushback)	Variant 4 (4 stage/ pushback)	Variant 5 (5 stage/ pushback)	Variant 6 (6 stage/ pushback)
1	-69,738,083	-7,895,380	-7,788,945	-7,797,983	-7,797,983	-7,761,066
2	-48,772,936	2,726,486	364,850	-226,719	-226,719	-1,703,526
3	-53,791,889	7,372,247	-12,944,352	-4,954,726	-4,954,726	30,107,028
4	-45,268,067	-48,638,805	6,255,650	22,434,247	22,434,247	59,383,531
5	-32,381,083	-40,025,898	41,022,052	40,226,911	47,182,929	9,617,603
6	-20,719,235	-27,860,146	24,280,909	40,293,184	46,303,697	39,873,202
7	-2,642,558	-16,948,811	33,739,990	28,027,784	30,029,483	28,923,259
8	6,399,052	-4,886,191	-15,304,123	29,381,294	34,375,260	37,863,961
9	7,697,139	-2,373,307	-11,271,076	38,065,616	39,178,265	34,226,928
10	11,433,416	1,470,462	5,459,868	29,416,376	29,799,288	34,337,588
11	16,147,743	10,598,196	10,407,259	33,096,220	28,282,884	29,679,034
12	22,174,662	21,804,022	17,080,968	18,398,214	32,595,244	18,850,531
13	25,333,921	25,387,836	24,541,966	26,059,904	31,507,878	25,343,546
14	26,414,995	26,556,860	26,015,131	27,494,204	18,571,128	27,651,356
15	25,930,409	27,045,896	26,234,184	14,313,069	9,938,665	15,733,554
16	26,635,770	26,803,987	26,492,402	22,465,915	22,251,881	19,412,012
17	25,627,703	26,678,394	25,533,307	21,322,198	21,322,318	21,370,336
18	24,300,042	24,744,525	23,393,301	19,848,962	19,645,515	20,082,255
19	22,777,992	22,760,003	20,981,693	19,318,576	18,580,441	19,193,296
20	20,313,124	19,860,721	19,113,387	16,176,720	17,387,230	16,112,184
21	18,055,201	17,722,468	17,187,727	14,626,041	14,287,831	14,360,902
22	15,813,359	15,746,116	14,803,703	8,987,722	8,983,019	7,068,602
23	14,157,498	13,960,136	12,356,997			
24	12,568,104	12,263,880	10,085,776			
25	10,890,579	10,507,377	2,274,525			
26	9,137,934	8,571,421				
27	7,310,752	3,559,558				
28	298,427					
NPV, \$	76,103,971	177,512,053	340,317,149	456,973,729	479,677,775	499,726,116

Figure 6 Cash flow for different number of stages in development of the open pit

Figure 7 Dependence of the net present value on number of stages of the open pit development

The obtained results point out the following:

- 1) Increase the number of stages increases significantly the NPV. Thus, if the works would be done with only one stage, which essentially repre-

sents the final limit of the open pit digs, the NPV is \$ 76,103,971. Working in six stages will achieve the NPV in the amount of \$ 499,726,116.

- 2) Increase the number of stages to four leads to a significant increase in the NPV of 600%, then increase the number of stages to a much lesser extent will influence to the additional increase in NPV, and it is 9.35%.
- 3) Increase the number of stages reduces the number of years of exploitation due to the possibility of defining the constant capacity in ore excavation, which otherwise is not possible with a smaller number of stages. In this way, higher utilization of primary and auxiliary machinery is achieved, while total costs are lower.

CONCLUSION

The main goal of any mining operation is that the exploitation of the ore body would be implemented so as to make maximum profits.

Long-term planning of the ore mining depends on several factors, and one of the most important is to define the optimal development stages of mining operations.

This work presents the importance of stage development of mining operations, which achieves the set objective of maximizing the net present value as the long-term planning of exploitation at the open pits of copper ore.

Strategy of development the works in several stages shows its justification in the case of the open pit South Mining District Majdanpek. Increase the number of stages from one to six, is constantly increasing and the value of the net present value of \$ 76,103,971 when the works are developed in one stage to \$ 499,726,116 when they are developed in six stages.

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EFEKAT FAZNOG RAZVOJA RUDARSKIH RADOVA NA MAKSIMIZACIJU NETO SADAŠNJE VREDNOSTI KOD DUGOROČNOG PLANIRANJA POVRŠINSKIH KOPOVA**

Izvod

Dugoročno planiranje u rudarstvu ima jedan osnovni cilj: maksimiziranje vrednosti koja se realizuje otkopavanjem i preradom mineralnih resursa.

Kod projektovanja površinskih kopova, određivanje faza razvoja rudarskih radova, (eng. Pushback) predstavlja jedan od bitnih faktora u procesu dugoročnog planiranja proizvodnje.

Primenom različitih naučnih metoda i matematičkih algoritama na kojima počiva rad savremenih softvera za strateško planiranje proizvodnje moguće je upravljati ekonomijom poslovanja.

U ovom radu prikazan je uticaj faznog razvoja površinskog kopa Južni revir Majdanpek na zanačajno povećanje neto sadašnje vrednosti.

Ključne reči: *optimizacija, faze razvoja kopa, neto sadašnja vrednost.*

UVOD

Osnovni cilj svake rudarske operacije jeste da eksploatacija rudnog tela bude realizovana tako da se ostvari maksimalna dobit. Primenom tehnike kreiranja konačnog kopa, lako se određuje ekonomska dubina i konačna granica kopa.

Projektovanje i planiranje rudnika (kopa) je vrlo kompleksan i multi – disciplinarni proces koji zahteva sveukupno poznavanje ove oblasti i dobro razumevanje mnogih pitanja. Za projekte, osnovni princip je da se samo projekti sa pozitivnom neto sadašnjom vrednošću (NPV) prihvataju.

Optimizacija granice kopa i dinamika otkopavanja podrazumeva geološko i operativno modeliranje, koje se realizuje kroz primenu softvera za optimizaciju koji koriste neki od matematičkih algoritama.

Proces podrazumeva identifikovanje kombinacije kontrolisanih varijabli koje maksimiziraju vrednost projekta u kontekstu datog skupa ili opsega pretpostavki. Uz primenu geostatistike, 3D modelovanja, Lerchs – Grossmann-ovog algoritma, Lane-ovog algoritma i mnogih drugih postupaka zasnovanih na kompjuterskim programima, danas je moguće izraditi kvalitetnije rudarske planove. Posledica ovoga jeste da se ostvaruju značajno bolji rezultati i u eksploataciji mineralnih ležišta sa niskim sadržajem korisne komponente i u složenim radnim uslovima [5, 6].

Problem planiranja eksploatacije odnosi se na kriterijum koji se koristi za optimizaciju površinskog kopa. Uprkos sofisticiranim algoritmima, problem optimizacije

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je uvek u osnovi ekonomski problem, u okviru koga se definišu procedure za procenu potrebnih ekonomskih parametara.

Projektovanje površinskih kopova i rešavanje problema optimizacije ostvaruje se modeliranjem problema primenom softvera. Softveri koji se koriste, svoj rad baziraju na algoritmu koji se primenjuje na trodimenzionalnom blok modelu nekog rudnog tela.

METODOLOGIJA

Dugoročno planiranje eksploatacije rude zavisi od više faktora, a jedan od bitnih jeste definisanje optimalnih faza razvoja rudarskih radova.

Nakon određivanja konačne granice otkopavanja, sledeći korak u procesu dizajniranja površinskih kopova jeste definisanje faza otkopavanja. Tom prilikom mora se voditi računa o sledećem:

- da se zadovolji minimalno dozvoljeno rastojanje između granica faza
- da se zadovolji minimalna radna širina dna svake faze
- NPV svake faze mora biti pozitivna
- NPV za definisane faze mora biti maksimalna.

Osnovni razlog za planiranje faznog razvoja kopa jeste ekonomske prirode, odnosno maksimizacija neto sadašnje vrednosti. Pored ekonomskog, fazni razvoj kopa mora da ima i praktičan značaj. Naime prevelik broj faza može da dovede do sledećeg:

1. Povećanje troškova zbog održavanja više radilišta
2. Povećanje troškova zbog ponovne izrade transportnih puteva
3. Nedovoljna širina radnih platoa za rad mehanizacije
4. Povećan broj osnovne i pomoćne opreme i dr.

Dakle, projektovanjem prevelikog broja faza može da dovede do toga da je dobijena NPV nerealna, dok manji broj faza dovodi do smanjenja NPV-a. Zato je pravilan pristup ovom problemu u uspostavljanju kompromisa između geološko-eksploatacionih uslova i želje da se ostvari maksimalna NPV. Danas, mnogi softveri za optimizaciju poseduju module za automatski izbor faza otkopavanja sa ciljem maksimizacije NPV-a (na primer softver Whittle koristi Whittle Pushback chooser).

Na slici 1 dat je prikaz faznog razvoja rudarskih radova na površinskom kopu [3].

Sl. 1. Prikaz faznog razvoja rudarskih radova na površinskom kopu

Sprovedena analiza u ovom radu sa ciljem postizanja maksimalne neto sadašnje vrednosti, ostvarena je primenom metoda geostatističkog modeliranja, metoda dugoro-

čnog planiranja i metoda optimizacije površinskih kopova.

Procedura je sprovedena je kroz sledeće korake:

- fično namenjen za definisanje dinamike otkopavanja kod strategije dugoročnog planiranja eksploatacije.

Ležište bakra Južni revir Majdanpek, nalazi se južno od grada Majdanpek, u njegovoj neposrednoj blizini.

Geološke rezerve ležište bakra Južni revir Majdanpek sračunate su metodom mini blokova, pri čemu su dimenzije blokova $15 \times 15 \times 15$ m. Ovakva dimenzija malog bloka izabrana je zbog visine eksploatacionih etaža na Površinskom kopu Južni Revir, koja iznosi 15 m, a u ovom slučaju to je i treća dimenzija malog bloka, odnosno debljina rude u njemu. Osnova za za proračun geoloških rezervi jeste digitalni blokmodel ležišta koji je formiran u softveru Gemcom [4], [5].

Za procenu proračunskih blokova korišćena je metoda pravog krigovanja.

Na slici 2 prikazan je trodimenzionalni izgled blok modela Cu u ležištu Južni revir.

Sl. 2. Trodimenzionalni izgled blok modela Cu u ležištu Južni revir

Izradom blok modela, za svaki blok, definisane su sledeće vrednosti: vrsta stene, zapreminska masa, sadržaj korisne kompo-

nente Cu (%) i pratećih komponenti S (%), Au (g/t), Ag (g/t), Mo (g/t), i ekonomska vrednost bloka, odnosno količina bakra u

bloku ili profit, koji se ostvaruje otkopavanjem tog bloka [6].

Nakon definisanja blok modela ležišta, sledeći korak u projektovanju je optimizacija granice otkopavanja.

Usvojeni polazni tehno ekonomski podaci, potrebni za procenu vrednosti leži-

šta, prikazani su u tabeli 1. Oni su usvojeni na bazi dugogodišnjeg proizvodnog iskustva na ovom rudniku, planskih dokumenata rudnika, postojećih studija za eksploataciju ovog ležišta i procene kretanja tržišnih cena metala u Svetu u narednom periodu [6, 7].

Tabela 1. Polazni tehno ekonomski parametri za optimizaciju ležišta

Parametar	Jednica	Vednost
Bazne cene metala		
➤ Bakra	USD/t	6.000,00
➤ Zlata	USD/kg	35.000,00
➤ Srebra	USD/kg	650,00
Troškovi otkopavanja rude	USD/t	1,50
Troškovi otkopavanja jalovine	USD/t	2,50
Troškovi flotacijske prerade rude	USD/t	3,20
Troškovi metalurške prerade koncentrata		
➤ Troškovi proizvodnje bakra iz koncentrata	USD/t Cu katode	600,00
➤ Troškovi rafinacije zlata	USD/kg	150,00
➤ Troškovi rafinacije srebra	USD/kg	15,00
Flotacijsko iskorišćenje bakra iz rude	%	86,0
Metalurško iskorišćenje bakra iz rude	%	98,5
Ukupno iskorišćenje na zlatu	%	50,0
Ukupno iskorišćenje na srebru	%	50,0
Godišnji kapacitet prerade rude	t/god	8.500.000
Diskontna stopa	%	10

Na slici 3 grafički su prikazani rezultati optimizacije za baznu cenu bakra od 6.000

USD/t, na osnovu čega se vrši izbor optimalne konture kopa i faze razvoja kopa.

Sl. 3. Grafički prikaz rezultata optimizacije (Pit by pit graph)

Na slici 4 prikazan je izgled optimalne (konačne) konture površinskog kopa Južni revir nakon obrade u softveru Gems.

Sl. 4. Izgled konačne konture površinskog kopa Južni revir nakon obrade u softveru Gems sa prikazom Cu blok modela ležišta u 3D formatu

Na osnovu geometrijske analize prostora zahvaćenog konačnom konturom kopa, mogući broj faza razvoja kopa, uključujući i konačni kop, iznosi šest faza.

Na slici 5 prikazane su faze razvoja kopa, koje su generisane u softveru Gems kao Pit List Files i predstavljaju input za

dalju analizu dinamike otkopavanja u softveru Whittle. Na osnovu ove analize dobijaju se diskontovane vrednosti novčanih tokova po godinama, odnosno neto sadašnja vrednost za varijante otkopavanja sa jednom, dve, tri, četiri, pet i šest faza.

Sl. 5. Faze razvoja rudarskih radova

REZULTATI I DISKUSIJA

Rezultati sprovedene analize uticaja ročne eksploatacije, odnosno na maksimalnog razvoja površinskog kopa Južni mizaciju neto sadašnje vrednosti prikazani revir na tokove novca u procesu dugosu u tabeli 2 i na slikama 6 i 7.

Tabela 2. *Novčani tok i neto sadašnja vrednost*

Godina	Cash Flow, \$					
	Varijanta 1 (1 faza/ pushback)	Varijanta 2 (2 faze/ pushback)	Varijanta 3 (3 faze/ pushback)	Varijanta 4 (4 faze/ pushback)	Varijanta 5 (5 faza/ pushback)	Varijanta 6 (6 faza/ pushback)
1	-69,738,083	-7,895,380	-7,788,945	-7,797,983	-7,797,983	-7,761,066
2	-48,772,936	2,726,486	364,850	-226,719	-226,719	-1,703,526
3	-53,791,889	7,372,247	-12,944,352	-4,954,726	-4,954,726	30,107,028
4	-45,268,067	-48,638,805	6,255,650	22,434,247	22,434,247	59,383,531
5	-32,381,083	-40,025,898	41,022,052	40,226,911	47,182,929	9,617,603
6	-20,719,235	-27,860,146	24,280,909	40,293,184	46,303,697	39,873,202
7	-2,642,558	-16,948,811	33,739,990	28,027,784	30,029,483	28,923,259
8	6,399,052	-4,886,191	-15,304,123	29,381,294	34,375,260	37,863,961
9	7,697,139	-2,373,307	-11,271,076	38,065,616	39,178,265	34,226,928
10	11,433,416	1,470,462	5,459,868	29,416,376	29,799,288	34,337,588
11	16,147,743	10,598,196	10,407,259	33,096,220	28,282,884	29,679,034
12	22,174,662	21,804,022	17,080,968	18,398,214	32,595,244	18,850,531
13	25,333,921	25,387,836	24,541,966	26,059,904	31,507,878	25,343,546
14	26,414,995	26,556,860	26,015,131	27,494,204	18,571,128	27,651,356
15	25,930,409	27,045,896	26,234,184	14,313,069	9,938,665	15,733,554
16	26,635,770	26,803,987	26,492,402	22,465,915	22,251,881	19,412,012
17	25,627,703	26,678,394	25,533,307	21,322,198	21,322,318	21,370,336
18	24,300,042	24,744,525	23,393,301	19,848,962	19,645,515	20,082,255
19	22,777,992	22,760,003	20,981,693	19,318,576	18,580,441	19,193,296
20	20,313,124	19,860,721	19,113,387	16,176,720	17,387,230	16,112,184
21	18,055,201	17,722,468	17,187,727	14,626,041	14,287,831	14,360,902
22	15,813,359	15,746,116	14,803,703	8,987,722	8,983,019	7,068,602
23	14,157,498	13,960,136	12,356,997			
24	12,568,104	12,263,880	10,085,776			
25	10,890,579	10,507,377	2,274,525			
26	9,137,934	8,571,421				
27	7,310,752	3,559,558				
28	298,427					
NPV, \$	76,103,971	177,512,053	340,317,149	456,973,729	479,677,775	499,726,116

Sl. 6. Novčani tok za različit broj faza razvoja kopa

Sl. 7. Zavisnost neto sadašnje vrednosti od broja faza razvoja kopa

Dobijeni rezultati ukazuju na sledeće:

- 1) Povećanjem broja faza značajno se povećava NPV. Tako, ako bi se radovi izvodili samo sa jednom fazom, koja u suštini predstavlja ko-

načnu granicu kopa, NPV iznosi 76,103,971 \$. Radom u šest faza ostvaruje se NPV u iznosu od 499,726,116 \$.

- 2) Povećanje broja faza do četiri dovodi do značajnog povećanja NPV-a, od 600 %, a zatim povećanje broja faza u mnogo manjoj meri utiče na do-datno povećanje NPV-a, i iznosi 9.35%.
- 3) Sa povećanjem broja faza smanjuje se broj godina eksploatacije zbog mogućnosti definisanja konstantnog kapaciteta na otkopavanju rude, što inače nije moguće sa manjim brojem faza. Na taj način ostvaruje se veće iskorišćenje osnovne i pomoćne mehanizacije, dok su ukupni troškovi niži.

ZAKLJUČAK

Osnovni cilj svake rudarske operacije jeste da eksploatacija rudnog tela bude realizovana tako da se ostvari maksimalna dobit.

Dugoročno planiranje eksploatacije rude zavisi od više faktora, a jedan od bitnih jeste definisanje optimalnih faza razvoja rudarskih radova.

U ovom radu prikazan je značaj faznog razvoja rudarskih radova, kojim se ostvaruje postavljeni cilj postizanja maksimalne neto sadašnje vrednosti kod dugoročnog planiranja eksploatacije na površinskim kopovima rude bakra.

Strategija razvoja radova u više faza pokazuje svoju opravdanost na primeru površinskog kopa Južni revir Majdanpek. Povećanjem broja faza od jedan do šest, konstantno se povećava i vrednost neto sadašnje vrednosti od 76,103,971 \$ kada se radovi odvijaju u jednoj fazi do 499,726,116 \$ kada se odvijaju u šest faza.

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