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ALGORITHM OF OPTIMIZATION THE OPEN PITS USING THE COMPUTER PROGRAMS WHITTLE AND GEMCOM***

Abstract

The world mining companies in assessment the financial sustainability and defining the optimal strategy for development of mine, to the aim of rational and economical utilization the mineral deposits, use the computer programs for optimization and design. Among the leading programs in this field are Whittle and Gemcom. This work an algorithm of work with the necessary input data, procedure of work and output results in design the open pits, using the computer programs Whittle and Gemcom, for optimal utilization the deposit, what is a necessary precondition for responsible management of mineral resources.

Keywords: open pit, design, optimization, computer software Whittle and Gemcom

INTRODUCTION

Natural mineral resources of a country present the base of its economic and social prosperity. In the economic value of mineral resources at its disposal, Serbia does not belong to the rich countries. Therefore there is an obligation to carry out the mining activity according to the principles of rational management of mineral resources.

The application of software for design in mining [1-13, 15] presents nowadays the standard in the world, primarily because it allows fast and with high accuracy assessment the most suitable solutions for mining the mineral resources, in terms of their rational utilization from deposits to achieve maximum profit.

For rational and economical utilization the deposit with a large number of data,

used for calculation of reserves, as well as determining the optimal open pit contour and dynamics of excavation and disposal, the advantage of computer technology is indisputable, compared to other methods of calculation. This advantage is reflected in the following:

- Due to the size of deposit, the state of open pits and production capacity (large amounts of excavation), the designs and design modifications are very complex with optimal working and final contours of the open pit. Digital model with calculated reserves by mini-blocks, facilitates and accelerates this process, as it is possible in a short period of time to see large number

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of variants and to find the best solution.

- The results obtained by design and economic analyzing on digital models have satisfactory quality, i.e. they are accepted in the world as satisfactory.
- Potential concessionaires require that the deposit has to be present in a digital form.

WORK PROCEDURES IN THE PROGRAMS WHITTLE AND GEMCOM

The first step in working with programs Whittle and Gemcom is a construction of

digital 3D block - deposit model [16-19], Figure 1. Block - model of deposit is a set of individual blocks. Each single block is defined by the following parameters:

- Sizes of the block;
- Spatial position of the block;
- Type of material from which the block is made;
- Bulk density of material in the block;
- Contents of individual components in the block (copper, gold, silver,...).

The block model is constructed in the program Gemcom based on geological parameters that may be imported from the Excel application of Office.

Figure 1 Block – model of deposit in the program Gemcom 6

The second step in working with these programs is the construction of 3D field model [14]. The field model can be imported from the program AutoCAD. If the situational map of the field in AutoCAD is done in 3D (each point has X, Y and Z coordinates), a direct import is done in the program Gemcom. If situational map of the field in AutoCAD is not done in 3D (all points have zero Z elevation), the real Z elevation have

to be assigned to the points, and then import in the program Gemcom is done.

After preparation and processing of data in Gemcom, the export block-model is done with topography in the program Whittle.

In Whittle [1, 2-5, 7, 9, 10-13], a construction of possible open pits is made based on the Lerches and Grossman algorithm. The Lerches and Grossman algorithm is a procedure for determining the optimal open

pit like the one with the highest value for the corresponding set of costs and factors of return.

For optimization in the program Whittle, the following input parameters are needed:

- Angle of general open pit slope for each region
- Operating costs of mining (OPEX), \$/t
- Dilution of ore and loss in excavation
- Operating processing costs, \$/t
- Cut-off grade for all elements
- Recovery of processing for all elements
- Selling price for each element individually, \$/t
- Selling costs for each element individually, \$/t
- Initial capital costs, \$
- Residual value, \$
- Costs of equipment replacement, \$
- Discount rate, %
- Annual capacity of excavation mining
- Annual capacity of mining the mineral resources
- Annual capacity of the final product, optionally (typically not limiting)
- Defined criteria for selection the final open pit outline (maximum profit, service life, spatial limits due to the existing facilities, etc.

After optimization, the set of open pits is obtained; each with different amounts of excavation and different value, Figure 2.

Figure 2 Diagram of the open pits with different value and amounts of excavation in Whittle

The open pits obtained in this manner do not have benches and transport routes. The export into Gemcom is done by selection the optimum open pit and push backs,

where detailed open pits with benches and transport routes are constructed, which are exported back to Whittle that defines the dynamics of excavation [6, 8], Figure 3.

Figure 3 Diagram of amounts of excavation by periods of exploitation in Whittle

The obtained contours of the open pits by periods of exploitation in Whittle do not also have benches and transport routes, and they are exported to Gemcom,

where detailed open pits with benches and transport roads are constructed for each period of exploitation, Figure 4.

Figure 4 2D and 3D view of the open pit in Gemcom

Output data are analytical dynamics that can be exported from Gemcom to the Office application Excel and dynamic

graphics that can be exported from Gemcom to AutoCAD. The final results of optimization are:

1. Analytical view the amount of mineral resources, waste and total excavation with contents for each bench by years of exploitation and operations in Excel format;

2. Constructed open pits with benches and transport roads by years of exploitation in AutoCAD.

The algorithm of design in the software Whittle and Gemcom is given in the next text.

CONCLUSION

An important factor in the use of computer programs for design the open pits is relatively easy and quick change of parameters related to the geological interpretation of deposit by entering the new data into the base of drill holes, the variation of technological-economic parameters of optimization as well as the ability of changing and comparison of several scenarios for mining.

It is also considerably much less time of design development in relation to the classic design, which in today's market conditions is of great importance in obtaining the jobs and favorable conclusion of financial contracts.

Both for the geological interpretation of deposit and design of open pit, a designer is still the most important. However, using the computer software the designer's job is much easier in terms of time and quality due to the accurate analysis in order to select the best solutions.

Quality of developed design documentation using the computer programs Whittle

and Gemcom is certainly one of the main reasons why the use of these and similar programs has become a necessity and standard in design the open pits.

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ALGORITAM OPTIMIZACIJE POVRŠINSKIH KOPOVA U RAČUNARSKIM PROGRAMIMA WHITTLE I GEMCOM***

Izvod

Svetske rudarske kompanije kod procene finansijske održivosti i definisanja optimalne strategije za razvoj rudnika u cilju racionalnog i ekonomičnog iskorišćenja ležišta mineralnih sirovina, koriste računarske programe za optimizaciju i projektovanje. Među vodećim programima iz ove oblasti su Whittle i Gemcom.

Ovde je prikazan algoritam rada sa potrebnim ulaznim podacima, procedurom rada i izlaznim rezultatima pri projektovanju površinskih kopova računarskim programima Whittle i Gemcom, čime se postiže optimalno iskorišćenje ležišta, što je nužan preduslov odgovornog upravljanja mineralnim sirovinama.

Ključne reči: površinski kop, projektovanje, optimizacija, računarski programi Whittle i Gemcom

UVOD

Prirodna rudna bogatstva jedne zemlje predstavljaju osnovu njenog ekonomskog i društvenog prosperiteta. Po ekonomskoj vrednosti rudnih bogatstava kojim raspolaže, Srbija ne pripada bogatim zemljama. Zato postoji obaveza da se rudarska delatnost obavlja po principima racionalnog upravljanja mineralnim resursima.

Primena softvera za projektovanje u rudarstvu [1-13, 15], predstavlja danas standard u svetu, pre svega zato što omogućava brzo i sa velikom tačnošću sagledavanje najpovoljnijih varijanti eksploatacije mineralnih sirovina, sa aspekta njihovog racionalnog iskorišćenja iz ležišta uz postizanje maksimalnog profita.

Za racionalno i ekonomično iskorišćenje ležišta, sa velikim brojem podataka koji se

koriste za proračun rezervi, kao i određivanje optimalne konture kopa i dinamike otkopavanja i odlaganja, neosporna je prednost računarske tehnike, u odnosu na proračune drugim metodama. Ova prednost se ogleda u sledećem:

- Zbog veličine ležišta, stanja površinskih kopova i kapaciteta proizvodnje (velike količine iskopina), jako su složena projektovanja i izmene projekata sa optimalnim radnim i završnim konturama površinskog kopa. Digitalni model, sa proračunatim rezervama po mini-blokovima, olakšava i ubrzava taj proces, jer je moguće u kratkom vremenskom periodu sagledati veliki broj varijanti i iznaći najbolja rešenja.

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- Rezultati koji se dobijaju projektovanjem i ekonomskim sagledavanjem, na digitalnim modelima, zadovoljavajućeg su kvaliteta, odnosno u svetu su prihvaćeni kao zadovoljavajući.
- Potencijalni koncesionari zahtevaju da ležište bude prikazano u digitalnom obliku.

POSTUPAK RADA U PROGRAMIMA WHITTLE I GEMCOM

Prvi korak pri radu sa programima Whittle i Gemcom je konstrukcija digitalnog 3D blok – modela ležišta [16-19], slika 1.

Blok – model ležišta je skup pojedinačnih blokova. Svaki pojedinačni blok je definisan sledećim parametrima:

- Dimenzije bloka;
- Prostorni položaj bloka;
- Vrsta materijala od koga je blok sačinjen;
- Zapreminska masa materijala u bloku;
- Sadržaji pojedinačnih komponenti u bloku (bakar, zlato, srebro, ...).

Blok model se konstruiše u programu Gemcom na osnovu geoloških parametara koji se mogu importovati iz Office aplikacije Excel.

Sl. 1. Blok – model ležišta u programu Gemcom 6

Drugi korak pri radu sa ovim programima je konstrukcija 3D modela terena [14]. Model terena se može importovati iz programa AutoCAD. Ukoliko je situaciona karta terena u AutoCad-u rađena u 3D (svaka tačka ima X, Y i Z koordinatu) vrši se direktni import u program Gemcom. Ukoliko situaciona karta terena u AutoCAD-u nije rađena u 3D (sve tačke imaju Z elevaciju nula) prethodno se moraju dodeliti realne Z elevacije tačkama pa se tek onda vrši import u program Gemcom.

Nakon pripreme i obrade podataka u programu Gemcom, vrši se export blok – modela sa topografijom u program Whittle.

U programu Whittle [1, 2-5, 7, 9, 10-13] vrši se konstrukcija mogućih kopova koja se bazira na Lerches and Grossman algoritmu. Lerches and Grossman algoritam je postupak za određivanje optimalnog kopa kao onog sa najvećom vrednošću za odgovarajući set troškova i faktora povraćaja.

Za optimizaciju i programu Whittle potrebni su sledeći ulazni parametri:

- Ugao generalne kosine kopa za svaki region
 - Operativni troškovi otkopavanja (OPEX), \$/t
 - Osiromašenje i gubici pri otkopavanju
 - Operativni troškovi prerade, \$/t
 - Granični sadržaj (cut off) za sve elemente
 - Iskorišćenje na preradi za sve elemente (recovery)
 - Prodajna cena za svaki element pojedinačno, \$/t
 - Troškovi prodaje za svaki element pojedinačno, \$/t
 - Inicijalni kapitalni troškovi, \$
 - Ostatak vrednosti, \$
 - Troškovi zamene opreme, \$
 - Diskontna stopa, %
 - Godišnji kapacitet otkopavanja iskopine
 - Godišnji kapacitet otkopavanja mineralne sirovine
 - Godišnji kapacitet finalnog proizvoda, opciono (obično se ne ograničava)
 - Definisani kriterijumi za izbor konačne konture kopa (maksimalni profit, vek eksploatacije, prostorna ograničenja zbog postojećih objekata, i sl.)
- Nakon optimizacije dobija se set kopova od kojih svaki ima različite količine iskopine i različitu vrednost, slika 2.

Sl. 2. Dijagram kopova sa različitom vrednošću i količinama iskopine u programu Whittle

Kopovi dobijeni na ovaj način nemaju etaže i transportne puteve. Po odabiru optimalnog kopa i međuzahvata (push backs) vrši se eksport u program Gemcom, gde se kons-

truišu detaljni kopovi sa etažama i transportnim putevima, koji se eksportuju nazad u program Whittle u kome se na osnovu njih definiše dinamika otkopavanja [6, 8], slika 3.

SI. 3. Dijagram količina iskopine po periodima eksploatacije u programu Whittle

Dobijene konture kopova po periodima eksploatacije u programu Whittle takođe nemaju etaže i transportne puteve, pa se eksportuju u program Gemcom,

gde se konstruišu detaljni kopovi sa etažama i transportnim putevima za svaki period eksploatacije, slika 4.

SI. 4. 2D i 3D prikaz kopa u programu Gemcom

Izlazni podaci su analitička dinamika koja se iz programa Gemcom može eksportovati u Office aplikaciju Excel, i grafička

dinamika koja se iz programa Gemcom može eksportovati u program AutoCAD. Konačni rezultati optimizacije su:

1. Analitički prikaz količina mineralne sirovine, jalovine i ukupnih iskopina sa sadržajima za svaku etažu po godinama eksploatacije i zahvatima u Excel formatu;
2. Konstruisani kopovi sa etažama i transportnim putevima po godinama eksploatacije u AutoCAD-u.

U daljem tekstu dat je algoritam projektovanja u programima Whittle i Gemcom.

ZAKLJUČAK

Važan činilac upotrebe računarskih programa za projektovanje površinskih kopova je relativno laka i brza promena parametara vezanih za geološku interpretaciju ležišta unošenjem novih podataka u bazu bušotina, varijacija tehno – ekonomskih parametara optimizacije, kao i mogućnost promene i upoređivanja više scenarija dinamike otkopavanja.

Takođe je značajno mnogo kraće vreme izrade projekata u odnosu na klasično projektovanje, što je u današnjim tržišnim uslovima od izuzetnog značaja pri dobijanju poslova i sklapanju povoljnih finansijskih ugovora.

Kako za geološku interpretaciju ležišta tako i za projektovanje površinskih kopova i dalje je najvažniji projektant. Međutim upotrebom računarskih programa posao projektanta je znatno olakšan sa aspekta

vremena i kvaliteta usled mogućnosti brze analize u cilju odabira najboljih rešenja.

Kvalitet urađene projektne dokumentacije računarskim programima Whittle i Gemcom svakako je jedan od osnovnih razloga zašto je primena ovih i sličnih programa postala neminovnost i standard u projektovanju površinskih kopova.

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