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A PROCEDURE FOR SELECTING AN OPTIMAL MINING TECHNOLOGY TAKING INTO ACCOUNT THE EXTRACTION AND QUALITY CHANGE RATIOS OF THE MINED-OUT ORE

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ABSTRACT

A general scheme of the necessary initial data on ore extraction and processing is presented: quantity of reserves and resources, extraction and quality change ratios and cost indices. A model has been developed based on compensation of the damages caused by ore losses and impoverishment in comparing two mining technologies. When generating more than two variants, a set of contrasted pairs is formed thus enabling us to determine the variant with the best technical and economic indices. A software package TWOTECH has been designed for solving problems related to both operative planning and a preliminary survey of technologies applicable under real natural conditions.

INTRODUCTION

Modern approaches to selecting an optimal mining technology require a technical and economic assessment because of the high degree of variability of the natural and mining factors.

Some of these factors enter the categories of known classifications. Others (mainly economic factors) allow for broad interpretation depending on the particular aims of the procedure. In the long run, the technical and economic assessment of the mining methods should proceed through several stages, one of these being the joint consideration of ore extraction and ore processing at the dressing plant, i.e. taking into account the end product (concentrate).

This stage is the subject of the present paper and the study is based on the principle of the technical and economic comparison of two mining technologies.

FORMULATION OF THE TASK

The selection of the mining method is based on criteria based on the ore extraction indices in applying a given mining technology. This approach is discussed in the works of M.I. Agoshkov. In this particular case we start with the natural and recoverable value of 1 t of balance reserves and 1 t of crude ore, respectively. The balance reserves Z_{bal} and the metal content in the ore and wallrock, A_m and A_c respectively, are basic values. The initial data required for the computational procedure are classified in two separate groups:

First group of indices whose values depend on the type of mining technology:

- losses, a_e , %;

- contamination, b , %;
- prime cost of 1 t of extracted crude ore ex stope, C_{ex} , USD/t.

Second group of indices independent of the type of mining technology:

- metal price at the London Metal Exchange, P_{lme} , USD/t;
- geological exploration costs ensuring growth of reserves R_{ge} , USD/t; the geological exploration costs can be determined according to the expression $R_{gl} = 0,01A_m\delta_iP_{lme}$, where δ_i is the coefficient characterizing the relative share of the geological exploration works in the metal price. According to data from real practice δ_i varies within (0,01 - 0,05);
- costs for processing 1 t of crude ore at the dressing plant C_{pr} , USD/t;
- transportation costs per 1 t of crude ore to the dressing plant, C_{tr} , USD/t;
- recovery ratio in ore processing at the dressing plant α_0 .

On the basis of the initial data we calculate the following indices characterizing the mining technology.

1. Metal content in the actually extracted crude ore A_a ,

$$A_a = A_m - b(A_m - A_c), \quad \% \quad (1)$$

2. Ore extraction ratio during mining operations η ,

$$\eta = 1 - \frac{a_e}{100} \quad (2)$$

3. Quality ratio of extracted ore, ρ ,

$$\rho = 1 - \frac{b}{100} \quad (3)$$

4. Quantity ratio of actually extracted ore, k_{gty} ,

$$k_{gty} = \frac{\eta}{\rho} ; k_{gty} > 1 \text{ or } k_{gty} < 1 \quad (4)$$

5. Quantity of actually extracted crude ore Z_a ,

$$Z_a = Z_{bal} k_{gty} = \frac{Z_{bal}(100 - a_e)}{100 - b}, \quad t \quad (5)$$

6. Natural value of 1 t of balance reserves V_{bal} ,

$$V_{bal} = 0.01A_m \delta_1 P_{lme}, \quad \text{USD/t} \quad (6)$$

Where δ_1 is The coefficient characterizing the relative share of the metal price up to the metallurgical treatment stage; it is determined on the basis of the concentrate price and metal content in it.

7. Total prime cost of extraction, transportation and processing of 1 t of crude ore, C_{cr} ,

$$C_{cr} = C_{ex} + C_{tr} + C_{pr}, \quad \text{USD/t} \quad (7)$$

The calculations from point 1 to point 7 are a prerequisite for the essential part of the technical and economic comparison. It is reduced to comparing two mining technologies and is carried out in the following sequence. First, the respective indexing for each technology is introduced $i = 1, 2$. The mining technology that permits lower exploitation losses, assumes index $i = 1$, and the alternative one - $i = 2$. Thus, according to (2), we have the condition $\eta_1 > \eta_2$. The analysis is based on the quantity of lost balance reserves Z_{lb} , which is determined by the expression:

$$Z_{lb} = Z_{bal}(\eta_1 - \eta_2), \quad t \quad (8)$$

Taking into account the assumed impoverishment b_i , ρ_i respectively, according to (3) we determine the total prime cost of 1 t of balance reserves C_{bal_i} by the following formula:

$$C_{bal_i} = \frac{C_{cr_i}}{\rho_i}; \quad (i = 1, 2), \quad \text{USD/t} \quad (9)$$

Then the value of 1 t of lost balance reserves V_i , taking into account the ore recovery at the dressing plant ε_0 will be:

$$V_i = \varepsilon_0 V_{bal} - C_{bal_i} + R_{ge}; \quad (i = 1, 2), \quad \text{USD/t} \quad (10)$$

In expression (10) we assume that the lost balance reserves have not been turned into production costs. In this

particular case we should emphasize it since such costs are likely to exist (e.g. for extracted but undelivered ore).

The damages caused by ore losses are compared with the compensations related to the lower costs for ore extraction, transportation, processing and recovery. The compensations related to the costs for extraction of 1 t of balance reserves K_{ex} will be:

$$K_{ex} = \frac{C_{ex_1}}{\rho_1} - \frac{C_{ex_2}}{\rho_2}, \quad \text{USD/t} \quad (11)$$

The compensations related to the costs for transportation of 1 t of balance reserves to the dressing plant K_{tr} will be:

$$K_{tr} = \frac{C_{tr_1}}{\rho_1} - \frac{C_{tr_2}}{\rho_2}, \quad \text{USD/t} \quad (12)$$

The compensations related to the costs for processing 1 t of balance reserves at the dressing plant K_{pr} will be:

$$K_{pr} = \frac{C_{pr_1}}{\rho_1} - \frac{C_{pr_2}}{\rho_2}, \quad \text{USD/t} \quad (13)$$

The compensations related to the change in K_{re} will be:

$$K_{re} = V_{bal} - (\varepsilon_{01} - \varepsilon_{02}), \quad \text{USD/t} \quad (14)$$

Therefore, the total compensation K_{sum} will be:

$$K_{sum} = \sum_{j=1}^4 K_j, \quad \text{USD/t} \quad (15)$$

where $j = 1, 2, 3, 4$ corresponds to the indices (ex), (tr), (pr), (re).

In the expressions from (11) to (15) K_{ex} , K_{tr} , K_{pr} , K_{re} , K_{sum} we can have positive or negative numbers. If $K_{sum} < 0$, then the procedure should be stopped since there is actually no compensation for the damages caused by greater losses in applying the second technology ($i = 2$). If $K_{sum} > 0$, then we have compensation of the damages caused by greater losses and the analytical procedure should continue.

The total compensation for damages caused by losses, in relation to 1 t of lost balance reserves K_{lb} will be:

$$K_{lb} = \frac{K_{sum} Z_{bal} \eta_2}{Z_{bal}(\eta_1 - \eta_2)} = \frac{K_{sum} \eta_2}{\eta_1 - \eta_2}, \quad \text{USD/t} \quad (16)$$

Then the economic consequences of the losses caused in relation to 1 t of lost balance reserves S will be:

$$S = V_{i_1} - \frac{K_{sum} \eta_2}{\eta_1 - \eta_2}, \quad \text{USD/t} \quad (17)$$

In expression (17) S can be a positive or negative number. If $S > 0$, then the compensations for the damages caused by losses are lower than the value of 1 t of lost balance reserves

V_{i_1} and preference should be given to the technology with an index $i = 1$. If $\mathbf{S} < 0$, then the compensations for the damages caused by losses are higher than the value of 1 t of lost balance reserves $V_{заб_1}$. The technology with an index $i = 2$ should be accepted as a better one.

The determination of \mathbf{S} in formula (17) is the essence of the technical and economic assessment in comparing the two mining technologies. The end results of the analysis made should be referred to the balance reserves Z_{bal} since they are the basic parameter. Then the economic consequences of the damages caused by losses, with respect to 1 t of balance reserves $\Delta\mathbf{S}$ will be:

$$\Delta\mathbf{S} = \frac{SZ_{bal}(\eta_1 - \eta_2)}{Z_{bal}} = S(\eta_1 - \eta_2), \quad \text{USD/t} \quad (18)$$

Obviously, the algebraic signs of \mathbf{S} and $\Delta\mathbf{S}$ according to (17) and (18) coincide. For $\Delta\mathbf{S} < 0$ we determine not only qualitatively but also quantitatively the additional profit with respect to 1 t of balance reserves if the technology with an index $i = 2$ is applied. In this form the procedure can be successfully applied in investigating the possibility to apply different variants of mining technology as well as the technical and economic feasibility of replacing the mining method.

COMPUTER IMPLEMENTATION

The practical implementation of the proposed procedure for a technical and economic assessment of a mining technology involves the development of an algorithm and a computer software package TWOTECH. The software program is written in the algorithmic language FORTRAN. It has been used for solving particular mining-engineering problems related to the justification for introducing efficient mining technologies for working polymetallic ores of non-ferrous metals.

Apart from the technical and economic comparison of two mining technologies with indices $i = 1, 2$, the program TWOTECH permits the determination of the marginal value of the metal content in the ore A_{mar} , for which the two technologies will be equally efficient, i.e. $\mathbf{S} = 0$ according to expression (17). By means of TWOTECH it is possible to determine the ultimate metal price at the London Metal Exchange $P_{lme(min)}$ up to which the mining technology will be

profitable. It also enables us to calculate the losses suffered for a certain period of time with the view of the possibilities to compensate them when mining other mine districts. In case more than two technologies are applicable or a set of a given number of variants is considered, we form the matrix $\|\Delta\mathbf{S}\|_{mn}$, where m and n are the columns and rows of the matrix. The columns correspond to the number of mining methods and n corresponds to the features by which the individual variants are formed.

The program TWOTECH determines the maximum value element of the matrix $\|\Delta\mathbf{S}\|_{mn}$ that is used as a basis for further analyses of the applicable mining methods.

CONCLUSION

A procedure has been developed for a technical and economic assessment in comparing two mining technologies or their variants, which is based on the compensations for damages caused by losses. It depends directly on natural and economic indices such as metal prices, costs for extraction, transportation and processing, level of losses and impoverishment, recovery in ore treatment, intensity of mining operations, etc. The approach proposed permits the evaluation not only of the applicability of the mining technology but also the boundary values of the metal contents in the ore, ultimate metal exchange prices for which a given technology is efficient and effective.

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