MINERAL MINING TECHNOLOGY

OPTIMIZATION OF MINERAL MINING GEOMETRY
AND MINE PRODUCTION CAPACITY

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The dynamic programming of delineation variants and operating periods for a deposit is used to study the problems of estimating the varied conditions of mineral resources and optimal production capacity of a mine based on the natural characteristics of ore reserves.

Cutoff grade, mine production capacity, net present value, optimization

The methods available for determining ore body contours and production capacity of a projected underground mine require uniform standard-setting for an ore deposit as a whole [1–4]. The method for optimizing the varied conditions of minefield reserves (revealed within ore deposit boundaries and developed at separate mines) and the production capacity of mining and processing enterprises is reported in [5]. However, technological and economical factors of deposit mining in different operating periods are variable. In this connection, it is necessary to determine differentially the mining contours of ore reserves based on a preset cutoff grade of a valuable component.

The problem on joint optimization of a cutoff grade $\alpha_c$ and estimated capacity $A$ of a mine is generally solved by searching possible combinations of variables $\alpha_c$ and $A$ within the preset limits of their variability and finding their relationship such that efficiency factor, the net present value (NPV), is maximum.

Denote by $f_t(\alpha_c, A)$ the maximum NPV starting from the project life beginning up to a period $t^*$ inclusively, that can be attained by optimizing $\alpha_c$ and $A$; by $k_t(\alpha_c, A)$ the optimal control of $\alpha_c$ and $A$ during $t$ in order to provide the maximum NPV conjointly with the optimal control over these parameters in the previous periods; and by $g_t$ the maximum NPV in $t$ period.

Under the influence of $k_t$, the optimization system state transfers from $\alpha_c$ to the value $\alpha^*_c = w(\alpha_c, A, k_t)$ during the period $t$. The maximum NPV is expressed as follows:

$$f_t(\alpha_c, A) = g_t(\alpha_c, A, k_t) + f_{t-1}(\alpha^*_c, A)$$

* In the paper, we assume the straight order of the problem solving optimization by the dynamic programming when the first and second steps are primarily optimized, then the second and third steps, etc., until the last step is included into the solution.

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or

\[ f_i(\alpha_c, A) = g_i(\alpha_c, A, k_i) + f_{i-1}(w(\alpha_c, A, k_i^*)) \].

The first summand is the value of NPV at the given step, and the second summand is the NPV value from the start of the project up to the given step. The control \( k_i^* \) is optimal when \( f_i(\alpha_c, A) \) reaches maximum.

The basic functional equation of the dynamic programming as a recurrence relation is:

\[ f_i(\alpha_c, A) = \max \{ g_i(\alpha_c, A, k_i) + f_{i-1}(w(\alpha_c, A, k_i^*)) \} \]  \hspace{1cm} (1)

Relation (1) allows evaluating the function \( f_i(\alpha_c, A) \) if \( f_{i-1}(\alpha_c^*, A) \) is known. Firstly, it is necessary to determine the maximum NPV at the first step and the corresponding optimal control for \( \alpha_c \) and \( A \):

\[ f_1(\alpha_c, A) = \max_{k_1^*} \{ g_1(\alpha_c, A, k_1^*) \} \]  \hspace{1cm} (2)

Substituting \( f_1(\alpha_c, A) \) and \( k_1^* \) in (1) makes it possible to determine \( f_2, k_2 \), etc. To start a task-oriented search for optimal values of \( \alpha_c \) and \( A \) using the corresponding characteristics of a mining production process, let us itemize the components of (1) and (2).

The most significant geological characteristics of ore reserves preferable in the optimization model are the ore reserves mined under different delineation schemes, \( Q \); the valuable component content in ore, \( \alpha \); the ore body thickness variable in different delineation variants, \( m \) [6].

The definitive parameters in the delineation variants should be reduced to a uniform dimension. That is why it is reasonable to express \( \alpha \), \( m \) and \( A \) in relative magnitudes by dividing them by indices of their basic variant (one of the delineation variants):

\[ \frac{\alpha_i}{\alpha_1} = J_{\alpha(i)}, \quad \frac{m_i}{m_1} = J_{m(i)}, \quad \frac{A_i}{A_1} = J_{A(i)} \]

where \( J_{\alpha(i)} \), \( J_{m(i)} \) and \( J_{A(i)} \) are the variation indices for the valuable component content \( \alpha \), ore body thickness \( m \) and mine production capacity \( A \) for the \( i \)-th variant relative to their basic values \( \alpha_1 \), \( m_1 \) and \( A_1 \), respectively.

According to [2, 3], the dependence of a mine construction period \( T_c \) on its production capacity may be approximated by the expression:

\[ T_c(A) = \alpha_1 + \alpha_2 J_{A(i)} \]  \hspace{1cm} (3)

where \( \alpha_1 \) and \( \alpha_2 \) are the constant coefficients found statistically, or based on direct calculations of \( T_c \) by the data of the construction regulations.

The price \( U \) of a ton of mined ore is the product of the valuable component content \( \alpha \) in ore reserves and of the cost \( P \) of metal subject to variation coefficients of ore grade change during its mining and its extraction on concentration:

\[ U = \alpha k_\varepsilon \varepsilon P \]  \hspace{1cm} (4)

where \( k_\varepsilon \) and \( \varepsilon \) are the variation coefficients of ore grade in mining and metal recovery on concentration, respectively.