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Condition for Effective Functioning of Enrichment Plants

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ABSTRACT:*In the present paper we propose a planning methodto reduce deviations from the predetermined planned value of the controlled indicator and to improving the operation of the enrichment plant. The determination of the number of excavators required to ensure the planned output, their location in the mining blocks, and the quantities of transported ore are of great importance. For that purpose, the algorithm for the free direction of the dump trucks to the individual excavators. The optimization parameter can be taken as the time for their stay. The goal objective function is proposed*.

KEYWORDS: *Enrichment plant, Traffic planning for excavators and trucks, Optimization problem.*

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I. INTRODUCTION

The condition for effective functioning of enrichment plants is to process ore with quality indicators that do not change significantly over time. This means that planning of mining operations should be carried out in such a way as to ensure these indicators. In the development of structurally complex open-pit deposits, the quality of the extracted ore usually fluctuates widely. Studies have shown that changes in the quality indicators of the useful mineral in space have a wave-like character [2, 9]. This is due to the primary genetic conditions during the formation of the deposit, and the wave-like changes are complex, containing harmonics of different lengths and amplitudes. Therefore, for deposits with proven irregular changes in quality indicators, operational planning of mining operations is necessary to average the quality of the ore. This planning method leads to a reduction in deviations from the predetermined planned value of the controlled indicator and, consequently, to improving the operation of the enrichment plant.

II. METHODS OF INVESTIGATION

Geological-survey information allows for the geometrization of all blast fields based on operational testing data. Data from core drilling testing allows for the formation of a digital model of each blast field with respect to the average content of the useful component. As a result, a plan is obtained with isolines of equal metal content and a square grid with average values of the metal content marked at each point. Based on the digital model, each blast field is divided into a 24-hour yield, with the coordinates of the excavator belts fixed.

Each 24-hour yield consists of several elementary volumes determined by the square grid. With equal elementary volumes and known values of the useful component content in them, the average value of the content in the 24-hour yield is obtained:

$$\alpha_{cp} = \frac{\sum_{i=1}^{n} \alpha_i}{n} \quad , \tag{1}$$

where:

α_i - the content of the useful component in the elementary volume [%];

n - volume number.

In open-pit mines for ore extraction, single-bucket excavators are widely used. Studies show that the productivity of the excavators follows a distribution law close to normal. With sufficient practical accuracy, it can be assumed that the probability density distribution of their productivity follows the Gaussian law, i.e.

$$f\left(Q\right)=\frac{1}{\sigma_Q\sqrt{2\pi}}e^{-\frac{\left(Q-m_Q\right)^2}{2\sigma_Q^2}} \tag{2}$$

In such a case, the performance of each excavator can be expressed by the following formula:

$$Q_i=m_Q+n_i\sigma_{Q_i} \tag{3}$$

In fact, to determine the average content of the useful component in the ore extracted from several blocks, the following can be written:

$$\alpha_{cp}=\frac{\sum_{i=1}^{n}\alpha_i\left(m_Q+n_i\sigma_{Q_i}\right)}{\sum_{i=1}^{n}\left(m_Q+n_i\sigma_{Q_i}\right)}, \tag{4}$$

where:

α_i - the content of the useful component in the *i*elementary volume;

$m_Q+n_i\sigma_{Q_i}$ - the amount of extracted ore from the i volume.

The problem of operational planning of mining operations in open-pit mines comes down to optimizing the performance of the excavators in the mining blocks for certain time intervals, in accordance with the changes in the quality composition of the extracted ore. This is one of the main prerequisites for the functioning of the enrichment plants.

It is known that the performance of the excavators depends significantly on the type and organization of transportation. The main mode of transportation for conveying the extracted ore to the enrichment plant is by road transport. The movement of this type of transport can be organized in a closed or open cycle.

The choice of algorithm for managing road transport largely depends on the nature of the changes in the useful component. For a homogeneous mining mass, the algorithm is not complicated. If the problem of operational planning and management involves maintaining a certain quantitative composition of the ore, then the management algorithm becomes more complex. In this problem, the determination of the number of excavators required to ensure the planned output, their location in the mining blocks, and the quantities of transported ore are of great importance.

In the algorithm for the free direction of the dump trucks to the individual excavators, the optimization parameter can be taken as the time for their stay. In this case, the goal objective function is:

$$\Phi\left(t_{ij}\right)=\sum_{i=1}^{N}\sum_{j=1}^{M}t_{ij}\rightarrow\min, \tag{5}$$

where:

t_{ij} - the times for the dump trucks to wait in front of the i excavator upon their arrival at j course;

N - number of excavators;

M - number of dump trucks courses.

The minimizing of the objective function, can be achieved under the following constraints:

$$\sum_{j=1}^{M}v_{ij}\geq Q_{s_i};\ \sum_{i=1}^{N}\left(m_Q+n_i\sigma_{Q_i}\right)\geq Q_{pl};\qquad t_{ij}\geq 0,$$

where:

v - the volume of the dump truck's bucket;

Q_{s_i} - the shift productivity of the i excavator;

Q_{pl} - the planned productivity of the mine.

Solving the problem of distributing the dump trucks among the excavators is related to performing a series of logical operations that characterize the intensity of their movement.

Here, we will examine the issues related to the planned tasks of the mining units and the transporting capacity of the automotive transport. When planning the work volumes and managing the quality of the ore, it should be considered that the productivity of the excavator is a random variable.

The transporting capacity of the automotive transport is also of essential importance when it is available. Studies of the operation of this type of transport lead to the conclusion that the loading of the dump trucks on the stops also follows the normal law. Usually, the actual material in the dump truck's bucket is smaller than its geometric dimensions. In such cases, the required number of trips R to transport the shift productivity Q_s from the corresponding stope is given by the expression:

$$R = \frac{Q_s}{m_v + n\sigma_v} , \tag{6}$$

where $m_v + n\sigma_v$ represents the amount of ore in the dump truck's bucket.

The travel time of the dump truck mainly depends on the length of the route, the speed of movement of the loaded and empty dump truck, the condition of the mine road, and other factors. With sufficient accuracy for practice, it can be assumed that the travel time of the dump trucks also follows the normal distribution, i.e.

$$f(t_r) = \frac{1}{\sigma_{t_r}\sqrt{2\pi}} e^{-\frac{(t_r - m_{t_r})^2}{2\sigma_{t_r}^2}}$$

Then the calculated travel time t_r for the dump truck will be:

$$t_r = m_{t_r} + n\sigma_{t_r} \tag{7}$$

By setting the number of trucks, the time for transporting T_s the amount of ore per shift will be found:

$$T_s = \left(m_{t_r} + n\sigma_{t_r}\right)\frac{Q_s}{m_Q + n\sigma_Q} \tag{8}$$

The standard deviation of the flow of the load will be:

$$\sigma_Q = \frac{\left(m_Q + n\sigma_Q\right)\sigma_{t_r}}{t_r} \tag{9}$$

In this case, the probability of transporting the calculated amount of ore per shift is:

$$P = \Phi\left|\left[\frac{t_s Q_{pl}}{t_r} - Q_{pl}\right]\frac{1}{\sigma_Q}\right|, \tag{10}$$

where t_s is the duration of the shift in hours and Q_{pl} - the planned productivity of the mine.

To assess the capabilities of the transport vehicle, it is necessary to know the probability of the reliable operation of the technical system „excavator - dump trucks". Studies show that the probability of reliable operation of this system P_{TS} follows the exponential law, i.e.

$$P_{TS}(\tau) = P_1(\tau).P_2(\tau)$$

or

$$P_{TS}(\tau) = k_1 e^{-\lambda_1 \tau}.k_2 e^{-\lambda_2 \tau},$$

where:

$P_{TS}(\tau)$ is the probability of trouble-free operation of the technical system;

$P_1(\tau) = k_1 e^{-\lambda_1 \tau}$ - the probability of trouble-free operation of the excavator;

$P_2(\tau) = k_2 e^{-\lambda_2 \tau}$ - the probability of trouble-free operation of the dump truck.

Then, for practical purposes, the following formula defines limiting interval availability:

$$P_{TS} = \frac{\mu_c}{\mu_c + \lambda_c}, \tag{11}$$

where:

μ_c - intensity of recovery from emergency situations in the considered technological structure;

λ_c - intensity of failures.

Here, downtime of the dump trucks at the excavator and at the unloading point are considered as failures.

In this case, the predicted time T_{TS} for the operation of the technical system will be:

$$T_{TS} = T_k \frac{\mu_c}{\mu_c + \lambda_c} \cdot \frac{l_1}{l_1 + l_2}, \tag{12}$$

where:

l_1 - number of working shifts for the respective calendar period of time;

l_2 - number of shifts for repair;

T_k - calendar period of time.

In addition, the predicted productivity of an excavator can be expressed as:

$$Q = T_k \frac{\mu_c}{\mu_c + \lambda_c} \cdot \frac{l_1}{l_1 + l_2} \left(m_Q + n\sigma_Q \right) \tag{13}$$

Based on the predicted productivity, the number of excavators providing the planned ore production of the mine is determined:

$$N = \frac{Q_{pl}}{T_k \frac{\mu_c}{\mu_c + \lambda_c} \cdot \frac{l_1}{l_1 + l_2} \left(m_Q + n\sigma_Q \right)} \tag{14}$$

Given the circumstance that the failure intensity of the technical system changes over the years of operation, equation (14) should use the average value of the readiness coefficient, i.e.

$$\bar{K}_\Gamma(\tau_i) = \frac{1}{\tau_i} \int_{\tau}^{\tau+\tau_i} K_\Gamma(\tau) d\tau$$

or

$$\bar{K}_{\Gamma}(\tau_i)=\left\{\frac{\mu_c}{\mu_c+\lambda_c}+\frac{\lambda_c}{\mu_c+\lambda_c}\exp\left[-(\lambda_c+\mu_c)\tau\right]\right\}\exp(-\lambda_c\tau_i), \quad (15)$$

where τ_i is an interval specified for the operation of the technical system, starting from a time sufficiently far from the beginning of operation.

Then, equation (14) will be:

$$N=\frac{Q_{pl}\exp(\lambda_c\tau_i)}{T_k\frac{l_1}{l_1+l_2}(m_Q+n\sigma_Q)\left\{\frac{\mu_c}{\mu_c+\lambda_c}+\frac{\lambda_c}{\mu_c+\lambda_c}\exp\left[-(\lambda_c+\mu_c)\tau_i\right]\right\}} \quad (16)$$

To determine the number of excavators providing ore averaging, it is necessary to assess its quality composition. This assessment can be the mean square deviation of the metal content in the ore before and after averaging. For this purpose, an averaging coefficient η is introduced by:

$$\eta=\frac{\sigma_H}{\sigma_Y},$$

where:

σ_H is the mean square deviation of the metal content in the ore before averaging;

σ_Y - the mean square deviation of the metal content in the ore after averaging.

To determine the productive work N' providing the averaging quality of the ore in [7], the following relationship has been used:

$$N'=\frac{1}{\bar{\sigma}_{\alpha}^2\eta^2}\left[\sigma_{\alpha_2}^2\left(d_Q^2+1\right)+\sigma_{\alpha_1}^2 d_Q^2-\bar{\sigma}_{\alpha}^2\eta^2 d_Q^2\right],$$

where:

$\bar{\sigma}_{\alpha}^2$ is the mean variance for the metal content [%];

$\sigma_{\alpha_1}^2$ - variance for the metal content from the excavations [%];

$\sigma_{\alpha_2}^2$ - variance for the metal content in the extracted ore flow [%];

d_Q^2 - coefficient of variation of the productivity of one excavator.

Determining the number of excavators that ensure both the planned ore extraction and the averaging of the extracted ore quality is performed by comparing the obtained values for N and N', selecting the larger of the two.

Clearly, the problem of operational planning and management of mining operations in the mode of ore quality averaging is multivariate. To determine the optimal option, it is necessary to formulate a criterion for its solution. The criteria comes down to minimizing the objective function F, which represents the mean square deviation of the content of valuable components in the extracted ore from the planned content

$$F=\sum_{k=1}^{p}C^{(k)}\left(\frac{\sum_{i=1}^{n}\alpha_i^{(k)}\left(m_Q+n_i\sigma_{Q_i}\right)}{\sum_{i=1}^{n}\left(m_Q+n_i\sigma_{Q_i}\right)}-\alpha_{pl}^{(k)}\right)^2\to\min$$

with the following constraint:

$$\sum_{i=1}^{n}\left(m_Q + n_i\sigma_{Q_i}\right) \geq Q_{pl},$$

where:

$i=[1,n]$ is the stope number;

$\alpha_i^{(k)}$ - content of the k component in the ore from the i stope;

$C^{(k)}$ - weight coefficient, reflecting the value of the k component;

$\alpha_{pl}^{(k)}$ - planned value of the k component.

III. CONCLUSION

Given that the problem of operational planning and management of mining operations in the mode of averaging the quality of the ore is multivariate, its solution can only be achieved by computational techniques. The results of the calculations serve as essential input information for the automated system for managing the transportation, organized for work in an open cycle.

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REFERENCES

[1]. Tasovski, P.:Studying of using transport system in open cast exploitation.16-th World Mining Congress, Sofia (1994).
[2]. Vasiliev, M.V.:Combined transport in mines.„Nedra”, Moscow, (in Russian), (1985).
[3]. Stelele, V.I.: Imitation modeling of developing of underground mines. „Nauka”, Novosibirsk, (in Russian), (1984).
[4]. Zlatanov, P., Konstantinov, G.: Handbook for projecting of open cast mining. Sofia, (in Bulgarian), (1996).
[5]. Hines, W.W., Montgomery, D.C.: Probability and Statistics in engineering and Science. J. Wiley and Sons (1990).
[6]. Barlow, R., Proschan,F.: Mathematical Theory of reliability. J.Wiley and Sons, New York (1965).
[7]. Arsov, O., Ganev, P., Voutov, Tz.: Planning of operations in a mine „Ellatzite” under ore quality averaging mode. „Minno delo”№ 6, (in Bulgarian), (1985).
[8]. Menteshev, M.: Automation of mining production.„Technika”, Sofia, (in Bulgarian), (1977).
[9]. Lubenov, K., Parashkevova, D., Petrov, T.: Parametric analysis of transport systems in cyclic-flow technology for open pit mine development. Open Pit and Quarries in the 21-th Centuriy, Nessebar, Bulgaria, pp. 325-329, (2001).