The European Proceedings of
Social & Behavioural Sciences
EpSBS

Future Academy ISSN: 2357-1330

http://dx.doi.org/10.15405/epsbs.2017.07.02.8

RRI 2016
International Conference «Responsible Research and Innovation»

DETERMINATION OF PROVIDED RESERVES SIZES FOR OPENCAST MINING

Sergei Igorevitch Fomin (a), Ekaterina Ivanovna Bazarova (b)*

* Corresponding author

(a) Mining department, Saint-Petersburg Mining University, Saint Petersburg, Russia, fominsi@mail.ru, 89217881382
(b) Saint-Petersburg Mining University, Saint Petersburg, Russia, bazarova_ei@mail.ru, 89313681377

Abstract

Formation of the demanded amount of existing reserves of ores during the open cast mining of complex-fields requires taking into account the parameters of the system development and excavation, loading equipment, as well as mining and geological characteristics of complex ore blocks, which improves the accuracy of the forecast ore reserves of different categories. Effective cast mining during production of final products is provided by the establishment of a definite correlation between the amount of exposed and ready-to-excavation reserves in the excavation zone, guaranteeing reliable mining operation. The regularities of the changes reveal ready-to-excavation and long-term reserves of ores in the quarry work area, depending on system parameters. The size of existing reserves of ores including fossils is determined. The discovery of the reserves at any given time leads to their development into ready-to-excavation reserves. Fluctuations in exposed and provided reserves should be within strictly defined limits, without reaching the very minimum values.

Keywords: Opencast mining; provided reserves; probability factor; quality averaging ore; normative value; productivity.

1. Introduction

The opencast mining engineering system consists of subsystems of stripping and mining operations, which have separate goals and objectives aimed at fulfilling a single function - mining. The reserve of ready-to-excavation resources on each bed allows mining operations regardless of the works in the overlying bed during some time interval. Ready-to-excavate reserves are a part of reserves prepared on

http://dx.doi.org/10.15405/epsbs.2017.07.02.8
Corresponding Author: Ekaterina Ivanovna Bazarova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

each bed, which can be excavated without mining on the overlying bench when maintaining a minimum working area. To rank reserves to this category, it is necessary that the bench roof should be cleared of the remnants of overburdens (Fomin, 1999).

Provision of the open cast with ready-to-excavation ore resources is a factor affecting its performance. Insufficient amount of these reserves leads to a reduction of the front of mining works, to an increase of ore dilution, to a loss of quality, and to an increase in production costs. Exceeding the optimal level of provision of ready-to-excavation reserves leads to losses related to the conservation of significant working capital, to an increase of expenses for maintenance and repair of mining equipment, as well as to an increase in ore losses. Development of complex structural ore deposits by means of open casts, using folded ore-rock benches is characterized by the variability of the volume of ready-to-excavation reserves both in plan and in depth. The magnitude of the volumes of ready-to-excavation resources concentrated in the backup belt of the working platforms depends on a number of mining and geological factors (Fomin, 2012).

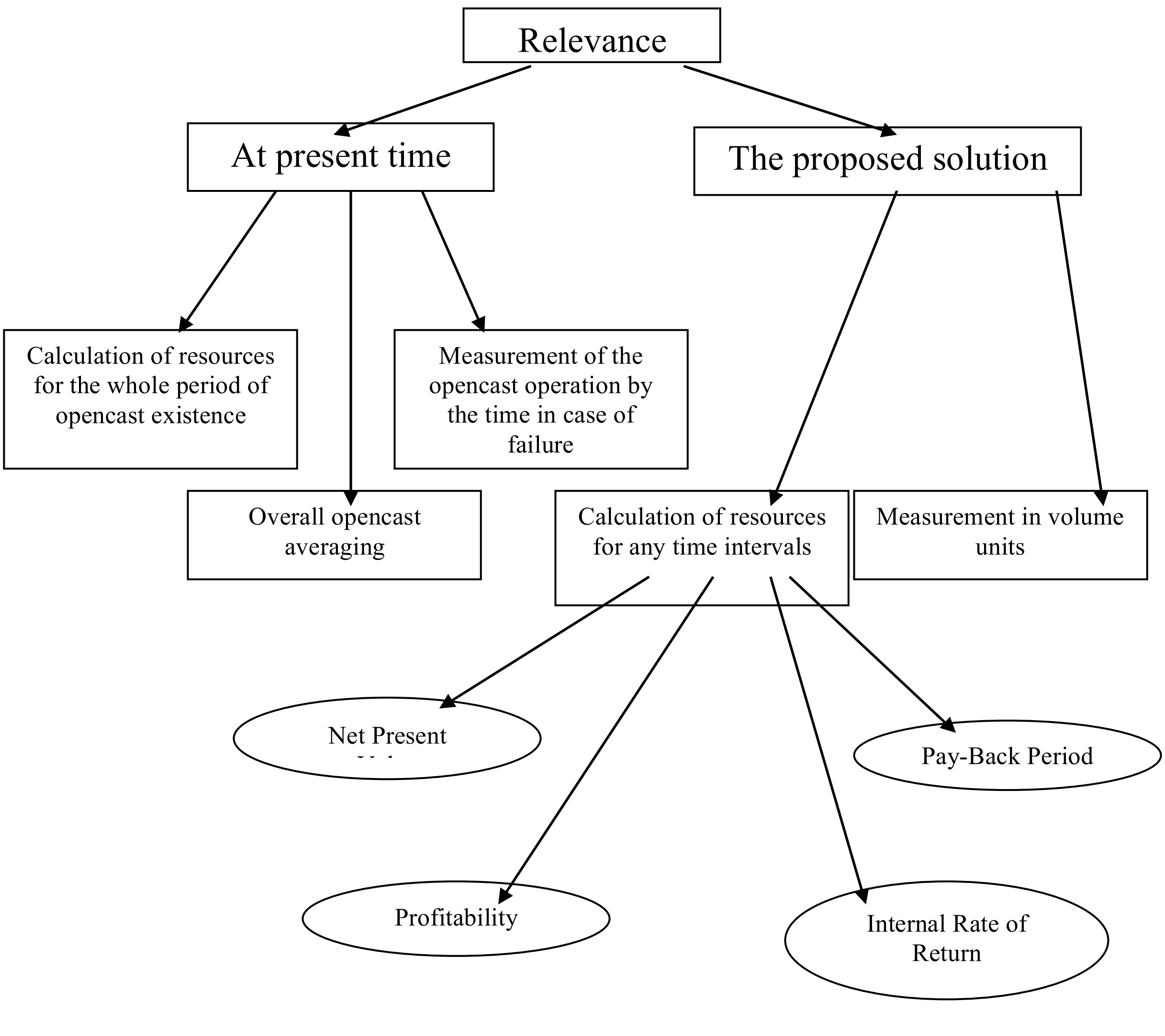

Fig 1. Relevance of the problem

http://dx.doi.org/10.15405/epsbs.2017.07.02.8
Corresponding Author: Ekaterina Ivanovna Bazarova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Ensuring the relative independence of advance of adjacent benches is possible due to the abandonment of resources in the backup belt of the working platform. These categories of resources, in addition to ensuring the independence of the advance of adjacent benches [2], allow solution of the tasks aimed at ensuring the required quality of minerals, creation of a backup belt of the working platform for the temporary placement of equipment, highways, etc. Owing to the resources abandoned in the backup belt, it is possible to conduct operative selective mining and averaging of a mineral in the case of a complex structure of the deposit.

2. Methods

The calculation of standards ready for extraction of prepared and developed resources is conducted based on the condition of performing the rated capacity of an open cast, a preset level of iron-ore raw material averaging, and adherence to the design parameters of the working platforms at the benches (Fomin, 2012).

Let us take the magnitude of ready-to-excavation resources, which is minimally required for fulfilling the established requirements for the opencast productivity and quality averaging of iron ores, as a standard. With the change of the applied mine-transport technology and mining technology, the intensity of deposit development and the variability of the quality of the extracted iron-ore raw material, the standards of resources must be reestablished (Fomin, 1999).

The border of the ready-to-excavate reserves on each bench from the direction of the goaf is an actual position of the bench slope, constructed under the condition that the width of the working platform on the overlying horizon remains minimal. Reserves of this category include a block which is prepared for drilling operations and freed from the bulk of the overburden (Fomin, 2012).

The opencast productivity and uniformity of the quality composition of extracted minerals depend mainly on the number of mining units. If opencast productivity and the level of uniformity of raw materials are preliminary specified and are represented by predetermined values, the number of mining units must ensure fulfillment of established requirements and thus be minimally obligatory. The calculation of the number of mining units that provide implementation of rated capacity of the open cast, fulfillment of requirements for in-pit averaging of the qualitative composition of the mined iron-ore raw material, must be made in the following order (Camus, 2002):

- calculation of the number of mining units, implementation of established productivity of the open cast;
- calculation of the characteristics of quality averaging of the ore in the open cast;
- determination of the homogenization efficiency of ore averaging in reserves plot;
- calculation of the number of mining units, ensuring compliance with established productivity of open cast and requirements for the quality averaging of ore.

The number of mining units, thus complying with established productivity of career D_P, is:

$$N_0' = \frac{1.05 \cdot D_P}{S \cdot \bar{k} \cdot \bar{d}_{sm}}, \quad (1)$$

http://dx.doi.org/10.15405/epsbs.2017.07.02.8
Corresponding Author: Ekaterina Ivanovna Bazarova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

S - the number of shifts of the mine within a month; $\overline{k}$ - the average utilization rate of mining units; d_{sm}- mean-shift productivity mining units in the open cast; 1.05 - reserve ratio, which takes into account the non-uniformity of the production of mining operations.

Values $\overline{k}$ and $\overline{d}_{sm}$ must conform to operating results of excavators adopted in terms of the development of mining.

The consistent quality of extracted minerals evaluates static characteristics - mean square deviations and the probability of rejection of the content averaged component from its average value.

Mean square deviations of the content of the component (set of n samples) are (Camus, 2002, O`Hara, 1991):

$$\sigma_\alpha = \sqrt{\frac{1}{n}\sum_{1}^{n}(\alpha_i - \overline{\alpha})^2}, \qquad (2)$$

α_i - mineral content in some samples; $\overline{\alpha}$ - average mineral content.

The value of standard σ_α can go to other estimates of the uniformity of quality of raw materials. So, for example, iron ore raw materials are supplied to the concentration, agglomeration and crushing and sizing plants; the requirements limiting fluctuations in iron replacement or daily volume of ore mined range up to ±2.0 % of the planned content of 80 ÷ 100% of the cases, i.e. with a probability of P = 0.8 ÷ 1.0.

From the quarry, ore enters the factory between deviations from the average of useful component content *Δ* and value σ_α in the following relationship:

$$\Delta = t \cdot \sigma_\alpha, \qquad (3)$$

t – probability factor

The values of probability factor t are shown in Table 1.

Table 1. Probability factor

t	1.0	1.3	1.47	1.5	1.65	2.0	2.5	3.0
Probability	0.683	0.800	0.850	0.866	0.900	0.954	0.987	0.997

In the event of detention, the averaged component of the required *Δ* = ±1.5 % is with probability *P* = 0.8, *t* = 1.3 and value σ_{α_0} = 1.15 %. If *Δ* = ±1.0 % with probability *P* = 0.8, then σ_{α_0} = 0.77 %. In this case, when the requirements for averaging limit the variation of the mineral content in the produced feed; i.e. in 100% of cases, according to calculation formula (3), it should be t = 3.0.

In the event that the requirements for averaging and value set $\sigma_\alpha = \sigma_{\alpha_0}$ are given, we can determine the required number of mining units to provide the desired level of mine averaging:

$$N_0'' = \frac{1}{\sigma_{\alpha_0}^2 \cdot k_u^2}\left[\overline{\sigma}_\alpha^2\left(V_d^2+1\right)+\delta_\alpha^2 \cdot V_d^2 - \sigma_{\alpha_0}^2 \cdot k_u^2 \cdot V_d^2\right], \qquad (4)$$

http://dx.doi.org/10.15405/epsbs.2017.07.02.8
Corresponding Author: Ekaterina Ivanovna Bazarova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

where $\sigma^2_{\alpha_0}$ - average variance of the content of the averaged component in one ore stream; δ^2_{α}- downhole variance; k_u - averaging factor related to the homogenization or transshipment warehouse.

These values are determined by formulas 5 and 6:

$$\overline{\sigma}^2_{\alpha} = \frac{1}{\sum_1^N S_i} \sum_1^N \sigma^2_{\alpha_i} \cdot S_i ; \quad (5)$$

$$\sigma^2_{\alpha_i} = \frac{1}{S_i} \sum_1^{S_i} (\alpha_{i \cdot j} - \overline{\alpha}_i)^2 , \quad (6)$$

$\alpha_{i \cdot j}$ - iron content of the ore produced in the i-th face in the j-th shift; $\overline{\alpha}_i$ - average mineral content of the ore produced in the i-th face during some period; S_i - the number of definitions (shifts, days, etc.):

$$\delta^2_{\alpha} = \frac{\sum_1^N \overline{\alpha}_i^2 \cdot S_i}{\sum_1^N S_i} - \overline{\alpha}^2 , \quad (7)$$

$\overline{\alpha}$ - average iron content in ore mined.

The effectiveness of averaging in reserves estimated by averaging ratio k_a:

$$\kappa_u = \frac{\sigma_{in}}{\sigma_{out}} , \quad (8)$$

σ_{in} - standard deviation averaged component content in the ore coming from the quarry to the warehouse; σ_{out} - standard deviation averaged component content in the ore coming from the warehouse to the factory.

From two highest values, N_0' and N_0'' is selected, i.e. one that provides productivity and the planned mine output, and the other - requirements for the averaging of ore quality.

When the number of mining units is N_0, thus complying with established productivity requirements and with quality averaging of extracted minerals known, the standard provision stock is:

$$H_G = N_0 \left(2 \cdot \overline{d} + t' \cdot \sigma_d \right) + P - B = N_0 \cdot \overline{d} \left(2 + t' \cdot V_d \right) + P - B , \quad (9)$$

t - probability factor; $\overline{d}, \sigma_d, V_d$ - mean, mean square deviation and variation factor of productivity of a mining excavator in the interval between bursts of minerals; P, B- respectively loss and clogging mineral in an open cast in the period under review.

If adopted by a two-week career interval, between bursts of mineral mining in mine $\overline{d}$ and σ_d, there are, respectively, the mean and mean square deviation of the two-week productivity of the mining excavator.

http://dx.doi.org/10.15405/epsbs.2017.07.02.8
Corresponding Author: Ekaterina Ivanovna Bazarova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Value $N_0 \cdot t' \cdot \sigma_d = \Delta H_{G_1}$ is provision stock characterizing unevenness of mining operations. Value $\overline{d}$ is calculated from mean-shift productivity excavator $\overline{d}_{sm}$, its utilization rate $\overline{k}$ and the duration of time interval τ between bursts of minerals:

$$\overline{d} = \tau \cdot \overline{k} \cdot \overline{d}_{sm} . \quad (10)$$

3. Findings

Optimal standards of provision stock, prepared and accessed stocks suggest:

- uniform supply of all mining provision stock, prepared and accessed stocks at the normative level;
- work in an open cast of mining regulatory units, necessary and sufficient to achieve the specified productivity and averaging the qualitative composition of extracted raw material;
- provision of each mining unit of the broken ore reserves in an amount necessary for its best productivity in the received time interval between the explosions.

One of the most important parameters that determine the normative value of provision stock is the time interval between bursts of mineral mining in the mine. It is necessary therefore to organize blasting, a massive explosion was carried out in all the faces; at the same time, the interval between bursts is 2-3 weeks. This will allow, along with an increase in the rhythm of work mining equipment and open casts in general, reducing downtime during blasting and increasing performance of the open cast.

Inventory control of broken ore in the open cast should be implemented in such a way that in each front at the time of the explosion, the rescued value stocks are sufficient to ensure the interval between bursts of maximum productivity of the excavator.

The normative value of provision stock can be reduced if the direction of the stope excavator quarry face is parallel to the direction of the lower content averaged autocorrelation index. In this case, bottom-hole dispersion $\overline{\sigma}_{\alpha}^{2}$ is lower, resulting in a decrease in the number of mining dredges, defined by formula (4) and the regulations provision stock.

4. Conclusions

The use of standards for the preparing of ore reserves at the quarry, which provide better conditions for the open cast averaging through the establishment of mining regulatory units, which provides both the performance and the achievement of the established requirements for averaging, reduces fluctuations in the qualitative composition of the extracted raw material entering the processing plant and increases the cost-effectiveness of field development.

References

Camus, J.P. (2002). Management of mineral resources. *Mining engineering (SME)*, 17-25.

Fomin, S.I. (1999). Productivity of opencasts and demand for mineral raw materials. *S-Pb, Publishing. «Тема»*, 33-39.

http://dx.doi.org/10.15405/epsbs.2017.07.02.8
Corresponding Author: Ekaterina Ivanovna Bazarova
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Fomin, S.I. (2012). Risk analysis method for opencast mining project annual. Sofia, University of mining and geology St. Ivan Rilski. Part II, 55, 23-28.

O`Hara, T.A.(1991). Quick guides to the evaluation of ore bodies. *Bull. Can. Inst. Min. Metall*, 73, 87-99.