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DETERMINATION OF MINING SYSTEM PARAMETERS AT A CONCENTRATION OF MINING OPERATIONS

Abstract. The problem of establishing the relationship between the working site width and the mining operations active front length in the open-pit, providing a normative ore reserve and its effect on ore output productivity is considered. It has been established that for a given ore output productivity, when determining the parameters of a mining development system, which satisfy standardized reserves, it is necessary to consider the size of the active area of the open-pit working zone, as well as the effect of the mining operations concentration on the cost price of the marketable mineral products. It is shown that in the process of determining the working site width at a given ore output productivity of the open-pit, only the length of the active front by ore and strip-mining at the time of assessment is considered. At the same time, the influence of a change in the working site width on it is not considered. On the example of a conventional open-pit, the influence of the active area size of the open-pit working zone on the parameters of a mining development system that satisfy the normalized reserves for a given ore output productivity of the open-pit is shown. A method for determining the working site width and the mining operations active front length, which satisfy the requirements of the standardized reserves, for various options for the ore output productivity of the open-pit is described.

Key words: working site width, mining operations front length, open-pit productivity, mining development system parameters.

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ТАУ-КЕН ЖҰМЫСТАРЫНЫҢ ШОҒЫРЛАНУЫ КЕЗІНДЕ ҚАЗУ ЖҮЙЕСІНІҢ ПАРАМЕТРЛЕРІН АНЫҚТАУ

Аннотация. Кеннің нормативтік қорын және оның кен бойынша өнімділігіне әсерін қамтамасыздандыратын жұмыс алаңының ені мен карьердегі тау-кен жұмыстарының белсенді фронтының ұзындығы арасындағы өзара байланысты белгілеу мәселесі қарастырылды. Кен карьерінің берілген өнімділігі үшін нормаланған қорларды қанағаттандыратын қазу жүйесінің параметрлерін анықтау барысында карьердің жұмыс аймағының белсенді бөлігінің мөлшерін, сондай-ақ тау-кен жұмыстарының концентрациясының тауарлық өнімнің өзіндік құнына әсерін ескеру қажет екендігі анықталды.

Кен бойынша карьердің берілген өнімділігі кезінде жұмыс алаңының енін анықтау процесінде бағалау кезіндегі кен мен аршыма таужыныстары бойынша белсенді фронттың ұзындығы ғана ескерілетіні көрсетілген. Бұл ретте оған жұмыс алаңының енінің өзгеруінің әсері ескерілмейді.

Шартты түрде алынған карьер мысалында карьердің жұмыс аймағының белсенді бөлігі мөлшерінің кен карьерінің берілген өнімділігі үшін нормаланған қорларды қанағаттандыратын қазу жүйесінің параметрлеріне әсері көрсетілген. Карьердің жұмыс аймағының жекелеген учаскелерінде тау-кен жұмыстарының шоғырлануы жағдайында қазу жүйесінің параметрлерін айықтау барысында қазуға тартылатын кемерлердің ұзындығын қысқарту кезінде алуға дайын қорлардың нормативтерін қамтамасыз етуді де, жұмыс алаңының енін ұлғайту есебінен осы учаскелердегі тау-кен жұмыстарының белсенді фронтының барынша мүмкін болатын ұзындығын азайтуды да ескеру қажет. Кен карьерінің өнімділігінің әртүрлі нұсқалары үшін нормаланған қорлардың талаптарын қанағаттандыратын жұмыс алаңының енін және тау-кен жұмыстарының белсенді фронтының ұзындығын анықтау әдісі сипатталған.

Түйінді сөздер: жұмыс алаңының ені, тау-кен жұмыстары фронтының ұзындығы, карьердің өнімділігі, қазуға дайын қорлар, қазу жүйесінің параметрлері.

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ОПРЕДЕЛЕНИЕ ПАРАМЕТРОВ СИСТЕМЫ РАЗРАБОТКИ ПРИ КОНЦЕНТРАЦИИ ГОРНЫХ РАБОТ

Аннотация. Рассматривается вопрос установления взаимосвязи между шириной рабочей площадки и длиной активного фронта горных работ в карьере, обеспечивающих нормативный запас руды и ее влияние на производительность по руде. Установлено, что для заданной производительности карьера по руде при определении параметров системы разработки, которые удовлетворяют нормируемым запасам необходимо учитывать размер активной части рабочей зоны карьера, а также влияние концентрации горных работ на себестоимость товарной продукции.

Показано, что в процессе определения ширины рабочей площадки при заданной производительности карьера по руде учитывается только длина активного фронта по руде и вскрышным породам на момент оценки. При этом не учитывается влияние на нее изменение ширины рабочей площадки.

На примере условного карьера показано влияние размера активной части рабочей зоны карьера на параметры системы разработки, которые удовлетворяют нормируемым запасам для заданной производительности карьера по руде. Обосновано, что в случае концентрации горных работ на отдельных участках рабочей зоны карьера при определении параметров системы разработки необходимо учитывать как обеспечение нормативов готовых к выемке запасов при сокращении длины вовлекаемых в отработку уступов, так и уменьшение максимально возможной длины активного фронта горных работ на этих участках за счет увеличения ширины рабочей площадки. Описан метод определения ширины рабочей площадки и длины активного фронта горных работ, которые удовлетворяют требованиям нормируемых запасов для различных вариантов производительности карьера по руде.

Ключевые слова: ширина рабочей площадки, длина фронта горных работ, производительность карьера, готовые к выемке запасы, параметры системы разработки.

Introduction. The possibility of a work schedule realization, compiled in the study of mining operations regime, is determined in the process of mining system designing. Based on the determined mining system elements, the direction of mining operations development is specified, which has been established in the study of the mining operations regime. Then the final decision on the nature of the development of the open-pit working area is made.

The transition to economic mechanisms, which based on changing demand for raw materials and changes in prices for minerals require coordination of the mining regime, as well as the parameters of the mining system with the financial and economic indicators of the designed enterprise, which depend on the possibilities of marketable products selling. Therefore, during designing, the numerical values of the parameters of the mining system elements, which fully describe the creation, development, and maintenance of the open pit working area at a level ensuring the smooth planning, rhythm, and reliability of the stripping and mining operations should be determined.

Materials and methods. The study of changes in the length of the active front of mining operations with increasing of working site width, using graphical methods of mining and geometric analysis of the open pit field, allows determining the necessary parameters of the mining development system, which provide the normative ore reserves in the open pit, which is ready for excavation, as well as the size of the working site active part for various ore output productivity values.

As a result of the analysis of the scientific works, it was found that in the process of determining the width of the working site for a given open pit performance, only the length of the active front ore and overburden at the time of evaluation is taken into account. At the same time, the influence of changes in the working site width on it, which lies in the fact that with an increase in the working site width, the active front length decreases, is not considered. The aim of the study is to improve the methods of planning and designing of open-pits in the field of determining the parameters of the mining development system that meet the requirements of the normalized reserves when changing the ore output productivity, which would consider the complex relationship of the mining operations regime, ore output productivity and the parameters of the mining development system.

In order to reduce the current volume of overburden operations, the width of the working site is taken to be minimal. The standards of technological design limit the reduction of the width of the working site for the safe operation of mining equipment. In addition, for reliable operation of the open pit, an ore reserve ready for excavation is needed. In turn, increasing the width of the working site leads to a reduction in the length of the active front of mining. However, the length of the working front should be sufficient to ensure the given capacity of the open pit.

Excessive reduction or increase of the front relative to the required value can worsen the technical and economic results of mining development. Thus, transportation costs increase with a large working front length. However, it becomes possible to maintain normalized reserves, with a smaller width of the working site, which determines the volume of stripping operations. A reduction in the cost of mining is achieved (the transportation range decreases, the productivity of excavators increases) by reducing the length of the working front, due to the concentration of work in individual sections of the open pit. At the same time, the working site width must be increased in these regions in order to provide normative of ore stocks ready for excavation, which would entail an increase of stripping rates.

Therefore, modeling of the mining operations development must be carried out with such values of the working site width and the working front length, which satisfy the requirements of the normalized reserves for a given ore output productivity of the open pit and at the same time ensure the maximum degree of mining operations concentration in the open-pit mine to achieve the greatest economic effect from the deposit development.

Results and discussion. The width of the working site in the open pit is determined by the standards

$$B_H = B_{\min} + \frac{A_p \cdot \psi}{L_p \cdot h_y}, \text{ m}, \qquad (1)$$

where BH - is the average width of the working site in the open pit, which ensures the presence of a standard ore reserve and the volume of waste rock, ready for excavation, m; Bmin - is the minimum width of the working site in the open pit, m; Ap- is the ore output productivity of the open pit, m /year; ψ - is the normative coefficient of ore stocks ready for excavation (with one and a half monthly ore reserve, this coefficient is 0.125; Lp - is the length of the mining operations active front, m; hy - is the ledge height, m.

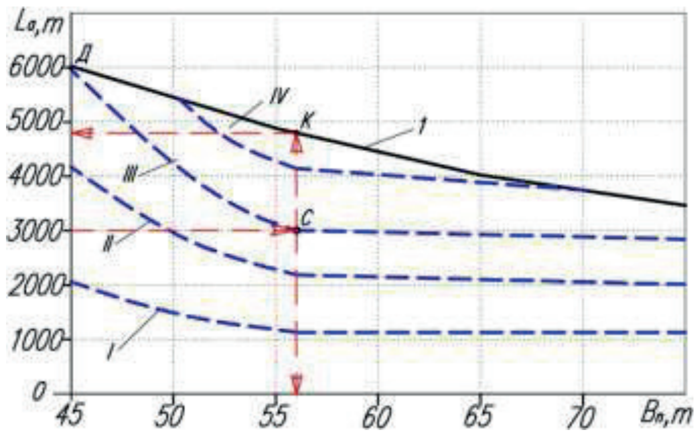
Hence, the length of the mining operations front will be

$$L_p = \frac{A_p \cdot \psi}{(B_н - B_{min}) \cdot h_y}, \text{ m}, \qquad (2)$$

By substituting the values of indicators in (2), we determine the length of the mining operations active front at various values of ore output productivity of the open pit (Fig. 1). Thus, each possible change in the active front length should provide an appropriate value for the open-pit productivity, according to mining capabilities based on the maximum number of mining excavators. Thus, it is necessary to meet the requirement of ensuring the ore output productivity of the open pit based on the arrangement of the maximum number of mining excavators.

The curves (I-IV) in Fig. 1 are the lines of the ore output productivity level, at each point of which a certain productivity level maintains the same value. The curves obtained analytically do not take into account the geometrical parameters of the ore body (shape, strike length, dip angles, etc.). In this regard, for the designed open-pit, it is necessary to perform a geometrical analysis of the open-pit field when deepening with different widths of the working site and to set a change in the length of the active front of mining operations depending on the width of the working site (Fig.1, curve 1). As an example, a conditional quarry with a developing deposit was considered, which is similar to the open-pits of the Kryvyi Rih basin in terms of ore bedding and open-pit mining technology as well as significant deposits of poor ferruginous quartzite. The angle of deposit slope is 65º, the horizontal width is 450 m; the length is 600 m. The parameters of the open pit are as follows: designed pit wall angle is 42°; the target pit depth is 500 m.

Line 1 in Figure 1 limits the range of possible values of the mining operations active front length and the working site width that meet the requirements of the normalized reserves for various options of the ore output productivity in the designed open-pit. Based on the curves (I-IV), it can be seen that the length of the active front of mining operations can be reduced by reducing the length of the ledges involved in mining with an increase in the working site width in order to achieve the required level of productivity. In addition, the position of curve 1 shows that with an increase in the working site width, the maximum possible length of the mining operations active front also decreases if the entire working area of the open-pit is involved in the work.



(1): I - line of the productivity level 2.5 million m^3; II - 5 million m^3; III - 7.5 million m^3; IV - 10 million m^3

Figure 1 – Change in the length of the mining operations front depending on the increase in the normative width of the working site when the entire working zone is involved in the development

In this regard, we can identify the main factors affecting the change in the length of the mining operations active front, which should be considered in determining the parameters of the mining development system:

(1) The reduction in the length of the active front of mining operations occurs when the length of the ledges involved in mining is reduced, i.e. due to the concentration of mining in certain sections of the open-pit working area. In this case, the main condition for reducing the length of the active front is to reduce the length of the open-pit working area section on which mining is carried out.

(2) The reduction in the length of the active front of mining operations occurs only by increasing the width of the working site. In this case, the main condition for reducing the length of the active front is to reduce the number of working ledges in the open-pit working area. Thus, the length of open-pit, the section where the mining operation is underway, remains constant.

Therefore, for a given ore output productivity of the open-pit, if mining concentration areas are identified in the open-pit, when determining the parameters of the development system, it is necessary to consider not only the reduction in the length of the ledges involved in mining, but also the decrease in the maximum possible length of the active front of mining operations with an increase in the width of the working site. To confirm this, let's consider an example. Let's assume that the ore output productivity is accepted at the level of 7.5 million m^3/year (Curve III, Fig. 1). The minimum width of the working site is 35 m. The width of the working sites in the open-pit is 45 m, the length of the mining operations active front is 6000 m. From the length of the mining operations active front (point D, Fig.1) it follows that mining is carried out throughout the working area of the open-pit. In the case of the allocation of two sections of the mining operations concentration in the open-pit, a given amount of ore extraction can be concentrated on a shorter ore front. Thus, mining operations front will be 3000 m, and the width of the work platform – 56 m (point C, Fig.1). However, based on the maximum ore front with a working site width of 56 m (point K, Fig. 1), which is 4800 m, it can be argued that if two equal concentration sections of mining operations are allocated in the open-pit, the length of the ore front in each section will not exceed 2400 m, which is 600 m less than the required length to achieve a given productivity. From this, it follows that when determining the parameters of the mining development system in the case of allocation of mining concentration sections in the open-pit, it is necessary to consider the decrease in the maximum possible length of the mining operations active front with an increase in the width of the working site. For this, it is necessary to determine the change in the mining operations active front length, depending on the working site width while reducing the active area of the open-pit working zone (Fig. 2). The active area of the working zone refers to the part of the open-pit working zone, which is involved in mining development during the planned period [27, 28]. In addition, on this graph, it is necessary to display a line of the ore output productivity level of open-pit (Fig. 3). For the given conditions, the maximum possible open-pit productivity in terms of mining capabilities is 12.5 million m^3/year (point A in Fig. 3). In this case, the entire working zone of the open-pit is involved in the work, the parameters of the mining development system are: the width of the working site is 56 m, the length of the active ore front is 4800 m.

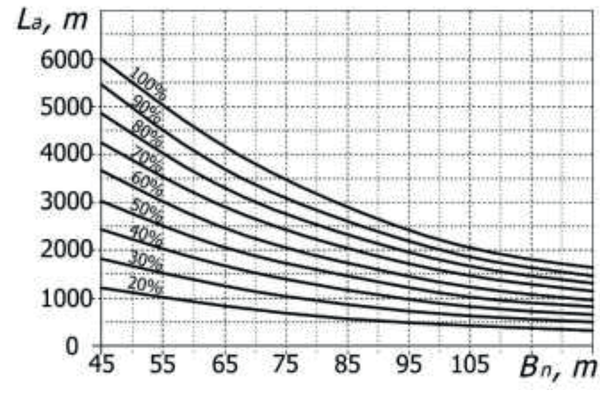
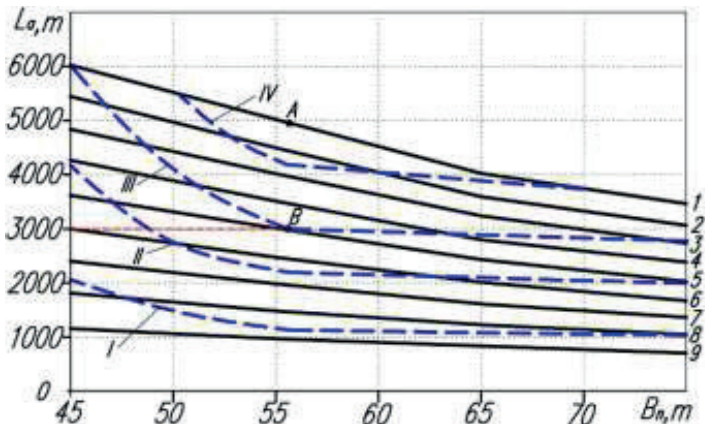


Figure 2 – The mining operations active front length, depending on the working site width with a decrease in the active area of the working site of the open-pit

Thus, in order to ensure the ore output productivity of open-pit of 7.5 million m^3/year with reducing the mining operations active front length to 3000 m, the active area of the working zone in which mining operations are concentrated should be at least 60% of the total area of the working zone (point B, Fig. 3). At the same time, the line (line 6) characterizing the involvement in the development of 50% of the open-pit working zone does not intersect with the line of the ore output productivity level of 7.5 million m^3/year. This suggests that if two equal sections of mining operations concentration are allocated in the open-pit (the active area of the working zone should be 50% of the total area of the working zone), it is impossible to achieve a given ore output productivity of 7.5 million m^3/year. In this case, the ore output productivity will be 6 million m^3/year. From this, it follows that the determination of the optimal parameters of the mining development system, which satisfy the requirements of reserves normative ready for extraction for a given ore output productivity must be determined considering the dimensions of the active part of the open-pit working zone.



1 – with a decrease in the active area of the working site by 0%; 2 – 10%, 3 – 20%, 4 – 30%, 5 – 40%, 6 – 50%, 7 – 60%, 8 – 70%, 9 – 80%; I – is the line of productivity level for 2.5 million m^3; II – 5 million m^3; III – 7.5 million m^3; IV - 10 million m^3

Figure 3 – Determination of the mining development system parameters providing a given ore output productivity

An analysis of Figure 1 shows that the same value of open-pit ore output productivity can be achieved with different values of the working site width and the length of the mining operations active front due to an increase in the mining operations concentration. At the same time, with an increase in the degree of mining operations concentration, there is an appearance and interaction of two factors that influence on the cost price of marketable mineral productsin the opposite way: an increase in the stripping ratio (Table 1) and a decrease in the distance of rock mass transportation. Therefore, when determining the optimal values of the working site width and the length of the mining operations active front that meet the requirements of standardized reserves, it is necessary to consider the effect of the mining operations concentration on the cost price of marketable mineral products.

Table 1– Initial indicators for determining the optimal values of the working site width and the length of the mining operations active front

Working site width, m	Stripping ratio, m^3/m^3	Ore output productivity of the open pit, million ton/year			
		2.5	5	7.5	10
		Range of transportation, km			
45	0.59	1.56	1.83	2.05	-
55	0.66	1.57	1.76	1.95	2.02
65	0.72	1.57	1.72	1.86	1.97
75	0.8	1.6	1.71	1.82	1.93

For these purposes, we will construct a graph of the dependence of the specific semi-variable costs of ore extraction and the mining operations front length on the working site width for various values of the ore output productivity of the open-pit with a depth of 210 m (Fig. 4). The values of the initial data for the calculations are based on the economic indicators of a number of Kryvyi Rih open-pit mines.

The position of the curves that characterize the specific semi-variable costs of ore mining indicates the presence of optimal values of the working site width and the length of the mining operations active front with various options for the ore output productivity. The parameters of the mining development system that meet the minimum specific semi-variable costs of ore mining are considered optimal for the projected open-pit. The parameters of the mining development system corresponding to the minimum value of its specific conditionally costs are optimal for the designed open-pit mine.

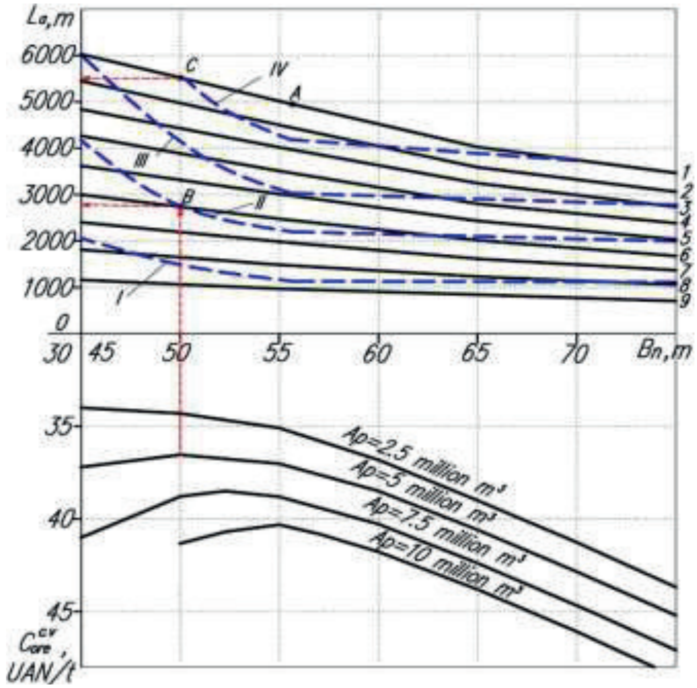


Figure 4 – The dependence of the specific semi-variable costs of ore extraction and the mining front length on the working site width at various values of the ore output productivity

From Fig.2 it is clear that the optimal width of the working site should be 50 m (point B) and the length of the mining operations active front should be 2800 m to achieve open pit ore output of 5 million m3/year. Given that the maximum possible length of mining operations active front is 5600 m (point C) for the working site width of 50 m, then it is advisable to allocate two areas of mining operations concentration in the open pit working area, which can provide the required level of open-pit productivity by ore. Therein the active working area will be at least 50% of the overall working area.

Conclusions. As a result of the study, it was found that the determination of mining development system parameters, which meet the requirements of rate reserves for a given open pit mine productivity should be carried out considering the size of the active part of the open pit working area. A method for determining the optimum values of the working site width and the length of the mining operations active front, which meet the requirements of rate reserves for various options for open-pit mine productivity has been developed.

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