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STUDY OF THE RATIONAL STEP OF THE CONCENTRATION HORIZON TRANSFER WITH A STEEPLY INCLINED CONVEYOR AT THE MURUNTAU PIT

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ДОСЛІДЖЕННЯ РАЦІОНАЛЬНОГО КРОКУ ПЕРЕНОСУ КОНЦЕНТРАЦІЙНОГО ГОРИЗОНТУ З КРУТОПОХИЛЕНИМ КОНВЕЄРНИМ ПІДЙОМНИКОМ НА КАР'ЄРІ МУРУНТАУ

Goal. Determination of the rational step of transferring the concentration horizon by installing a steeply inclined conveyor lift at the Muruntau pit.

Methodology. Analytical, statistical, and graph-analytical research methods were used in the work's performance. A feasibility analysis method was used to calculate the effective travel distance of a steeply inclined conveyor.

Research results. The analysis of the application of cyclical flow technology in deep pits using combined road and conveyor haulage was carried out. At the same time, road truck haulage is used as the first link transport in the pit. It delivers the mining rock mass from the excavator faces to the concentration horizons with the overloading of the mining mass on the conveyor elevators. The advantages of using cyclic flow technology with steeply inclined conveyor elevators are given. The influence of the moving step on the concentration horizon on the auxiliary cost of works on its construction has been established. The results show that the most rational step is moving the concentration horizon, based on the initial data for the Muruntau gold pit, which will be 800–1000 m. It is in this range that the cost of the relocation work will be the lowest.

Scientific novelty. The studies that were conducted made it possible to establish the dependence of the moving step of the concentration horizon on the auxiliary cost of works on its construction in the conditions of development of the Muruntau gold pit. Second-order equations describe the resulting dependencies with a high degree of accuracy. It was established that the most rational distance for moving the concentration horizon would be 800–1000 m, according to the available initial data. Using this transfer distance, the work cost will be 2,220–3,469 million USD, which is 4–6.25 times less than the cost from the concentration horizon transfer of 2000 m.

Practical significance. The research results made it possible to justify the rational step of transferring the concentration horizon. The cost of auxiliary works affecting the distance and volumes of mining rock mass haulage to the concentration horizon with its transfer in the Muruntau pit has been established.

Keywords: *deep pits, haulage distance, cyclic flow technology, concentration horizons, steeply inclined conveyor elevators.*

Introduction. The mining industry is a leading branch of Uzbekistan's economy based on a powerful mineral and raw material base of various mineral deposits. Uzbekistan is one of the world's first five countries to have reserves of gold and uranium [1].

These deposits are developed in Navoiinsky mining and metallurgical plant (NGMP). The basis of mineral and raw materials base gold mining and metallurgical plants is more than 13 gold mine deposits [2]. Among them is Muruntau, in the - Kyzylkum district region of Uzbekistan.

The development of a gold ore deposit in Muruntau started in 1967. Design dimensions pit within the limits of the 4th turn as follows: length – 3.5 km; width – 2.5 km; depth – 630 m; volume mining rock mass – 1,500 million cbm. The perspective depth is 900–1000 m above sea level. Pit to this time, more than 1,800 million cbm mining rock mass (up to 110 million tons/year) developed. The general appearance of the Muruntau pit is shown in Fig. 1.

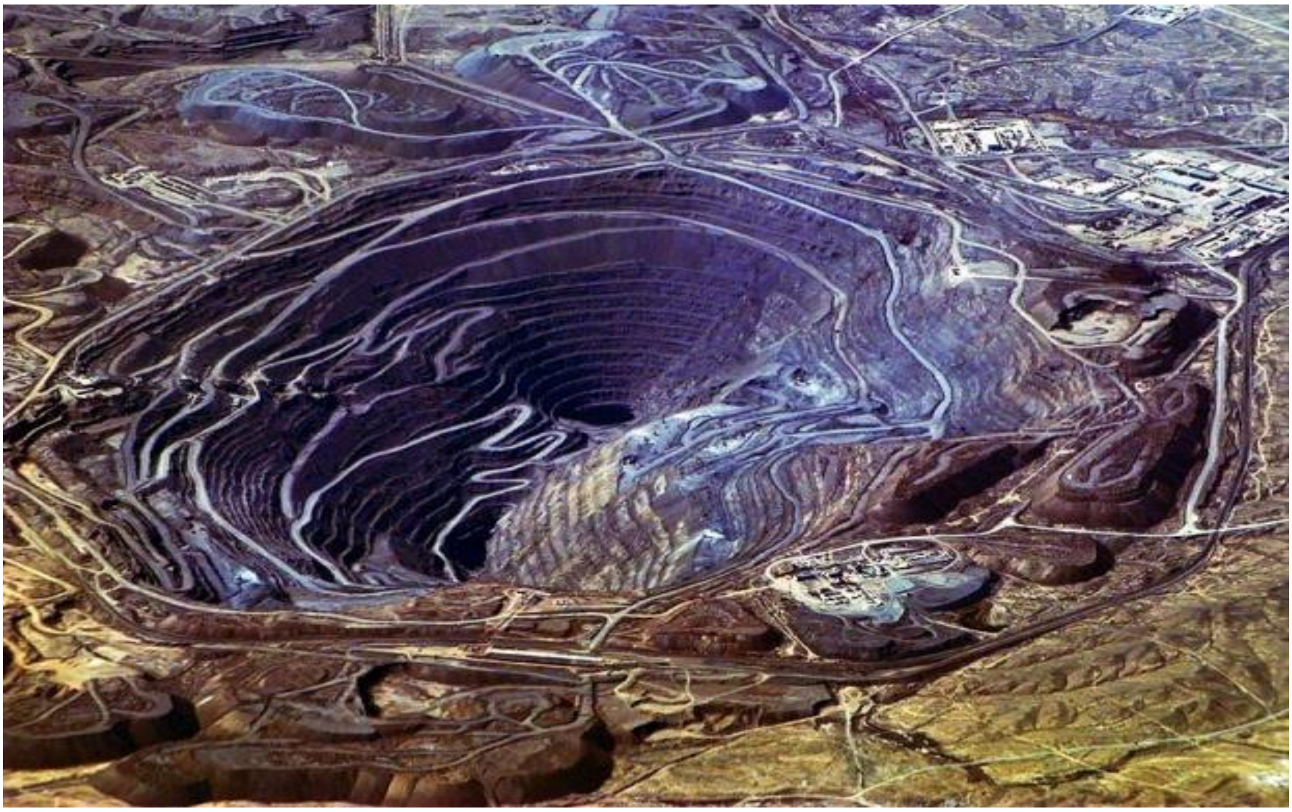

Fig. 1. General view of the Muruntau gold pit

The high concentration of mining operations in the pit and significant volumes of mining rock mass development require the solution of several complex engineering and technical tasks to support the production capacity of the enterprise [3] with the help of the introduction of modern mining and haulage equipment and effective technological development schemes [4].

One effective development of technological schemes in the deep pit is the application of cyclic-flow technologies (CFT) using combined automobile-conveyor haulage [5]. At the same time, road truck haulage is used as the first-line vehicle in the pit.

It delivers mining rock nothing in the mass from excavator mining faces to transshipment points for concentration horizons [6] from weighted average distance haulage of 1–1.5 km.

For the first time, CFT was applied in the Kryvorizky iron ore pool at the quarry and No. 1 NKGZK in 1971. Such technologies are now applied to deep pits: North and Ingulets iron ore mines of Kryvbas [7].

An industrial experience audit of CFT elements for opening rocks and ores was held in 1980-1985 at the Muruntau quarry. The result of such work was the implementation of, in the late 1980s, a complex in the CFT for haulage used in the pit and stacking of dropdowns hard rocks in dumps. The complex consists of two conveyor lines (strip width 2 m), each with two inclined (located in trenches with slope α = 15 degrees), one transfer, main, and dump conveyor with a cantilever dumper on the dump. Productivity for each line is 12.8 million cbm/year. The transshipment point is paved semi-stationary KVKD crushers – 1200/200 [8].

With increased mining depth deposits, complicated engineering conditions are deteriorating technical-economic indicators of mining work in general. It leads to an increase in the distance haulage hard rocks, the increase in the number of haulage equipment and workers, deterioration of environmental working conditions, and harmful impact on the environment [9].

Experience operation of the CFT complex on excavation works in the pit Muruntau showed a decline in its efficiency at depth career 350–400 m due to extensive mining capital volumes during the construction of trenches for accommodation inclined conveyors, additional capital expenditures for the increased productivity pits on the mining rock mass, the rest of the entire reserves beneficial minerals under concentration horizon and by conveyor track [10].

An effective technical solution for these conditions was the application of a steeply inclined conveyor with the possibility of hauling mining rock masses at an angle of more than 30 degrees and his placement on supports built on the pit slope's berms.

For this, on the north-eastern side of the Muruntau pit, a transshipment complex was created by the concentration horizon from the point +286 m with the reception point of the mine rock masses and a crusher, steeply inclined conveyor (SIC) for lifting mining rocks to a height of 270 m (elevation +550) and further load ores in railway transport (Fig. 2). During the work of SIC (since 2000) there, it was established that with the maximum conditions of the Muruntau pit, the economic effect is 60–70% by a combination of a motor vehicle and conveyor achieved due to decreasing road truck haulage work by 30–40%. The specific application efficiency of SIC implementation is approximately – 0.4 $/cbm.

Currently, the essential problem consists of developing blocks of valuable minerals that remain on the concentration horizon. Questions about its dismantling and transfer to another pit slope along the SIC track arose.

In touch with at this moment, the installation of rational places arrangement concentration horizon (step transfer) and tracks of SIC in the Muruntau pit are relevant and timely crucial scientific tasks.

Fig. 2. Steeply inclined conveyor at the Muruntau gold pit

It is necessary to note that during the development of steep fall deposits and deep pits, periodic transfer of haulage communications is inescapable since the development of pit faces occurs practically along every pit's perimeter.

The condition determines the choice of the location of the transshipment points:

– Economic use of road haulage is ensured first, with minimal haulage distances.
– Availability of sites for placement of transshipment points.
– Costs for moving transshipment points during operation.

The parameters of the deposit mining system with a combination of road truck haulage and inclined conveyor elevators are set, taking into account the features caused by the presence of concentration horizons serving a group of benches. They include the preparation of new horizons for development, setting the optimal step transfer concentration horizon, defining places, and arranging concentration horizons for the group benches, among others. Besides this, preparing a new concentration horizon is related to the arrangement of its receiving and overloading equipment [11].

Preparation of new horizons has provided a mining plan from developments both revealing and mining works.

The complete preparation of bench groups, which will provide a concentration horizon of mining rock mass, creates a consistent passage of separate trenches on the benches below. At the same time, the width of the lowest prepared horizons will be equal to the width of separate trenches. The width of the upper horizon depends on the number of benches in the group and the width of sites (berms) that remain and can reach 200–300 m [12].

Partial preparation subordinate bench groups consist of conducting preparatory works not by all pit field benches but only its parts bench areas. The length of the pit field that is in preparation depends on the receiving and transshipment device and necessary conditions for average development mining works. Such preparation allows for reduced mining preparation works in less favorable conditions, thus decreasing haulage in-pit space expenses and mining masses in preparation for a new concentration horizon.

A partial method of preparing horizons for development allows for the planned development of mining operations immediately after moving the concentration horizon to a new site.

Costs from delivery of mining rock masses by motor vehicle with an increase in step transfer are increasing; the costs related to installation equipment at the concentration center horizon decrease. Therefore, the optimal step transfer will be determined as the minor total expense for haulage of 1-ton rock mass.

The authors of [12] proposed a formula for the determination of a step transfer concentration horizon:

$$l = 20\sqrt{\frac{C_d}{C_a k_{tr} S}}\text{, } t,$$

where C_d is the auxiliary costs associated with the installation of the loading point (concentration horizon), USD; C_a is the cost of 1 t·km when using mining vehicles for the delivery of mining rock mass from pits to the concentration horizon, USD; k_{tr} is track development coefficient; S is the weighted average area of the working benches on the concentration horizon, m^2; p is the volumetric weight of mining rock mass, t/m^3.

An important parameter in determining the transfer step of the concentration horizon and the steeply inclined conveyor elevator route is the cost of auxiliary costs associated with dismantling and installing the load point – C_d.

Let's transform the formula for determining the step of transferring the concentration horizon through C_d and get the following expression:

$$S_d = \frac{S_a k_{tr} S l^2}{400}\text{, USD.}$$

This parameter depends on the costs associated with a change in the distance of mining rock mass haulage, changes in the development of the quarry roads route, the weighted average area of the working benches on the concentration horizon, and the concentration horizon transfer step.

A part of the general plan of the Muruntau quarry with a selected mineral block preserved in connection with the placement of the PDA above this block is shown in Fig. 3.

Fig. 3. The general plan of the Muruntau gold pit with a preserved ore block highlighted

The volume of the noted block is more than 100 million cbm (Fig. 4), which is expedient to develop with the lowest costs of mining and haulage operations. This cost reduction is connected with the occurrence of rocks on the upper horizons of the pit's slope and the insignificant transportation distance to overload ore for further movement and processing to obtain the final product.

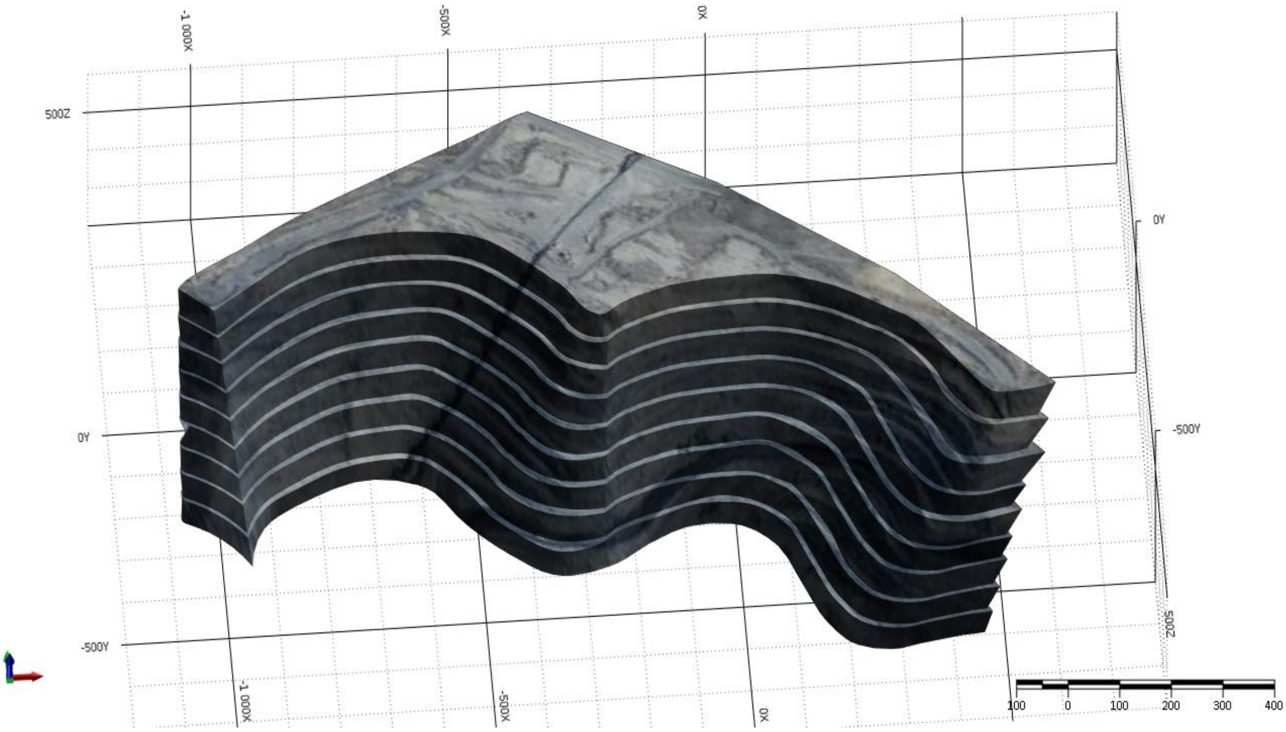

Fig. 4. A preserved gold ore block in a three-dimensional image

In this case, it is essential to conduct a study of the rational step of transferring the concentration horizon and the new platform for placing the steeply inclined conveyor lift on the pit slope.

In this regard, the work carried out research on establishing the dependence of changes in costs C_d on the transferring step of the concentration horizon in the pit. Figure 5 shows a graphical interpretation of the obtained dependencies.

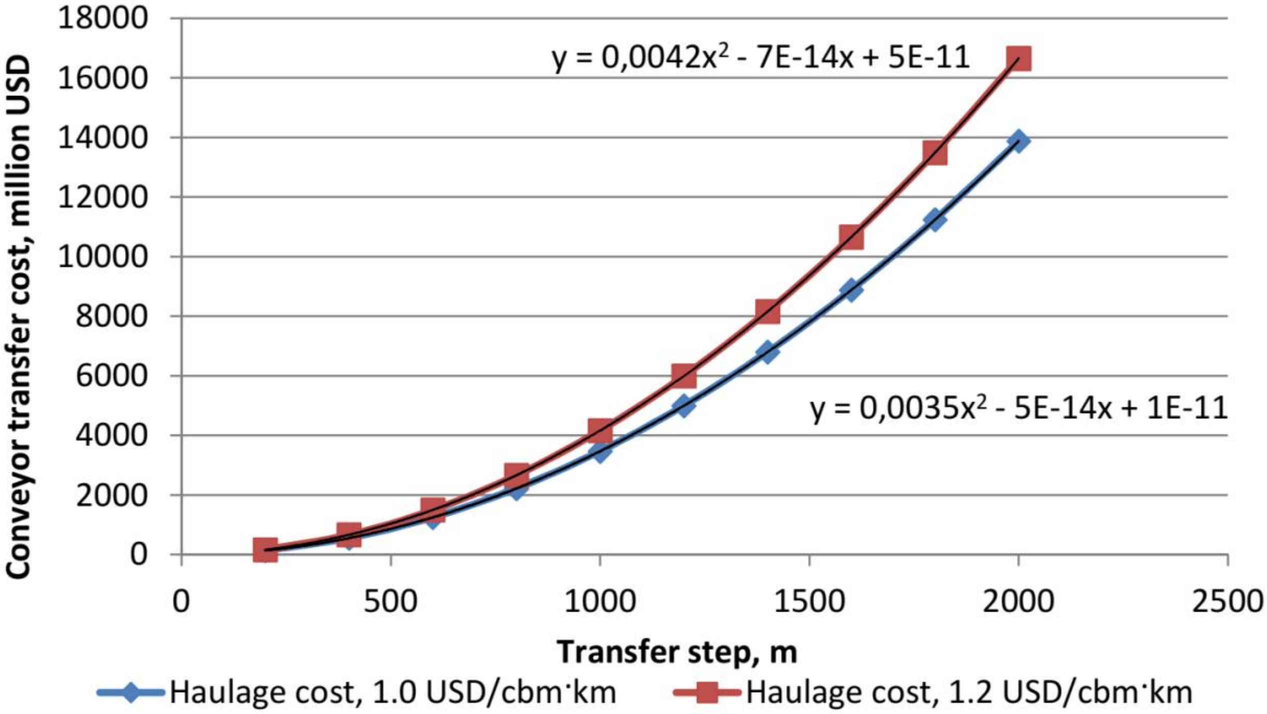

Fig. 5. The influence of the concentration horizon transfer step on the auxiliary cost of works for its construction at the haulage cost 1.0–1.2 USD/cbm·km

When establishing the rational distance of the concentration horizon transfer with a steeply inclined conveyor, the following parameters were taken into account: the area of the pit part slope (the benches that are worked out to the concentration horizon) is 1.26 million cbm; road track coefficient is 1.1; the cost of haulage rock mining mass was taken for the cases of using various heavy-duty pit dump trucks (on average 1.0–1.2 USD /cbm·km).

According to the established dependencies (see Fig. 4), the auxiliary cost of the work on the concentration horizon transfer in the Muruntau pit development conditions is 138.8–16,651.6 million USD. At the same time, a 10-fold increase in the transfer distance from 200 to 2000 m will lead to a 100-fold increase in costs from 138 to 13,876 million USD at a transportation cost of 1.0 USD/cbm·km. The obtained results allow us to state that the most rational distance for moving the concentration horizon is, based on the available initial data, should be 800–1000 m. In this range, the cost of transfer works will be 2220–3469 million USD, which allows 4–6.25 times to reduce the cost of work on the transfer of the concentration horizon compared with the transfer step of 2000 m.

It should be noted that the research did not consider the direct costs of dismantling and installing the steeply inclined conveyor. These costs are considered to be conditionally constant at different steps of transferring the concentration horizon.

To determine the new location of the concentration horizon in a group of benches, you can use the work equation to haul the mining rock mass when the concentration horizon is located on one of the ledges. The formulas can determine the rational location site:

– with reduced volumes of mining rock mass on benches:

$$n=\frac{\frac{k_c}{t_c}(1-3q)+\frac{k_n}{i_n}(2M+1+q)}{2\frac{k_c}{i_c}(1-q)+2\frac{k_n}{i_n}(1+q)},$$

– with constant volumes of mining rock mass on the benches:

$$n=\frac{\frac{k_c}{i_c}+\frac{k_n}{i_n}(2M+1)}{2\left(\frac{k_c}{i_c}+\frac{k_n}{i_n}\right)},$$

where n is the serial number of the ledge on which it is necessary to place the concentration horizon (calculating from top to bottom); M is the number of benches that worked out for one concentration horizon; q is the relative value ot increasing volumes mining rock masses on benches; k_s, k_n are mode coefficients operation of dump truck vehicles, respectively, during descent and ascent:

$$k_П=k_c\frac{i_n}{i_c}a,$$

where i_n, i_c – the slope of the road, respectively, on the rise and descent, ‰; α is the coefficient of comparison of the operation of truck vehicles on uphill and downhill slopes with equal road gradients.

Lowering the place of transfer concentration horizons allows for an increase in road transport costs when using truck-conveyor transport.

Receiving and transshipment platforms on concentration horizons may have different designs, depending on the type of combined haulage. In the case of automobile-conveyor combination, it can be used from dump trucks to belt conveyors through crushing or screening devices. Receiving and transshipment sites must provide the necessary production capacity of the enterprise and minimal additional volumes of overburdened work.

The rational parameters of receiving sites are determined by the performance of receiving and handling devices (grinders), type, load capacity, dimensions, and turning radius of pit dump trucks.

Necessary pass ability applied devices depending on the concentration horizon from their productivity and carrying capacity of motor vehicles is possibly determined by the formula:

$$P_{a.d} = \frac{Q_{n.y} k}{Q_a \gamma}, \text{ truck/hour,}$$

where $Q_{n.y}$ is the hourly productivity of the receiving transmission point, t; Q_a is the loading capacity of dump trucks, t; k is the coefficient of dump truck delivery unevenness; γ is the coefficient of the carrying capacity utilization of the rolling stock of dump trucks.

The following formula can determine the necessary unloading points number:

$$m = \frac{Q_{n.y} t_p k}{Q_a \gamma 60},$$

where t_p is the unloading time of dump trucks.

Conclusions. The studies that were conducted made it possible to establish the dependence of the transfer step of the concentration horizon on the auxiliary works cost on its construction in the Muruntau pit's development conditions. The obtained dependencies are described by equations of the second degree with sufficient accuracy.

At the same time, the cost of auxiliary works affecting the distance and volumes of mining rock mass haulage to the concentration horizon with its transfer in the pit is in the range of 138.8–16,651.6 million USD.

It was established that increasing the distance (step) of transfer by 10 times from 200 to 2,000 m will lead to a 100-fold increase in costs from 138 to 13,876 million USD at a transportation cost of 1.0 USD/cbm·km.

The obtained results allow us to state that the most rational distance for moving the concentration horizon, based on the available initial data, will be 800–1000 m. In this range, the cost of transfer works will be 2,220–3,469 million USD, which allows for a 4–6.25 times reduction in their cost from the transfer of the concentration horizon compared to the transfer step of 2000 m.

To establish the final option for the placement of a new site for the concentration horizon and the construction of a point for reloading rocks into a steeply inclined conveyor, it is necessary to conduct a study to establish the weighted average distance of haulage mining rock mass by dump trucks from the pits to the concentration horizon, and direct costs for the dismantling of the existing PDA and its installation in a specified place for Muruntau gold pit conditions.

In the work, the proposed method allows us to determine the location of the concentration horizon in the group of benches and the throughput of the used concentration horizon machines, depending on their productivity and the carrying capacity of dump truck vehicles.

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АНОТАЦІЯ

Мета. Визначення раціонального кроку переносу концентраційного горизонту з облаштуванням крутопохиленого конвеєрного підйомника на кар'єрі Мурунтау.

Методологія. При виконанні роботи застосовані аналітичний, статистичний, графоаналітичний методи досліджень. Метод техніко-економічного аналізу був використаний для розрахунку ефективної відстані переміщення круто похилого конвеєра.

Результати досліджень. Проведений аналіз застосування на глибоких кар’єрах циклічно-потокової технології із використанням комбінованого автомобільно-конвейєрного транспорту. При цьому автомобільний транспорт застосовується як транспорт першої ланки у кар'єрі та доставляє гірничу масу від вибоїв екскаватора до на концентраційних горизонтів з перевантажуванням гірничої маси на конвеєрні підйомники. Наведено переваги застосування циклічно-потокової технології з використанням круто похилених конвеєрних підйомників. Встановлено вплив кроку перенесення концентраційного горизонту на допоміжну вартість робіт на його спорудження. Отримані результати дозволяють стверджувати, що найбільш раціональним є крок переміщення концентраційного горизонту, за наявних вихідних даних для золоторудного кар’єру Мурунтау, що складатиме 800–1000 м. Саме в цьому діапазоні вартість робіт з перенесення буде найменшою.

Наукова новизна. Проведені дослідження дозволили встановити залежності впливу кроку перенесення концентраційного горизонту на допоміжну вартість робіт на його спорудження в умовах розробки кар’єру Мурунтау. Отримані залежності описуються рівняннями другого порядку з високим ступенем точності. Встановлено, що найбільш раціональна відстань для переміщення концентраційного горизонту складає 800–1000 м, за наявними вихідними даними. При такій дальності вартість робіт з переміщення концентраційного горизонту становитиме 2220–3469 млн дол. США, що в 4–6,25 разів менше, ніж вартість від перенесення горизонту концентрації на 2000 м.

Практичне значення. Результати досліджень дозволили обґрунтувати раціональний крок перенесення концентраційного горизонту. Встановлено вартість допоміжних робіт, що впливають на відстань та об’єми перевезень гірничої маси до концентраційного горизонту з його перенесенням в кар’єрі Мурунтау.

Ключові слова: *глибокі кар’єри, відстань транспортування, циклічно-потокова технологія, концентраційні горизонти, крутопохилі конвеєрні підйомники.*