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PERSPECTIVE TRENDS FOR THE DEVELOPMENT OF CYCLE-FLOW TECHNOLOGY IN DEEP QUARRIES TAKING INTO ACCOUNT THE STRUCTURE OF THEIR WORKING AREA

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ПЕРСПЕКТИВНІ НАПРЯМКИ РОЗВИТКУ ЦИКЛІЧНО-ПОТОЧНОЇ ТЕХНОЛОГІЇ НА ГЛИБОКИХ КАР'ЄРАХ З УРАХУВАННЯМ БУДОВИ ЇХ РОБОЧОЇ ЗОНИ

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ПЕРСПЕКТИВНЫЕ НАПРАВЛЕНИЯ РАЗВИТИЯ ЦИКЛИЧНО-ПОТОЧНОЙ ТЕХНОЛОГИИ НА ГЛУБОКИХ КАРЬЕРАХ С УЧЕТОМ СТРОЕНИЯ ИХ РАБОЧЕЙ ЗОНЫ

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Abstract. Over the past 20 years, the parameters of the working zone of deep quarries have changed, which began to consist of sections of inclined and steep sides. At a number of deep iron ore quarries, temporary internal dumps of overburden rocks began to be created in the working area, which influences the choice of schemes for opening deep horizons in cyclic-flow technology (CFT).

The purpose of the study is to substantiate promising directions for the development of CFT in deep iron ore quarries, taking into account the structure of their working area and the use of steeply inclined conveyors (SIC).

It is shown that with certain parameters of a large piece transported by the conveyor belt, contained in the transported rock mass, and its certain kinetic energy, stable operation of the system, widely used steeply inclined and inclined conveyors, is achieved.

The parameters of a steeply inclined conveyor when transporting rocks with a high density were determined. It is assumed that with the same kinetic energy of a piece (ore, rock) contained in the transported rock mass, stable operation of a steeply inclined conveyor will be ensured.

Based on this, the parameters of the transported piece and the parameters of the steeply inclined conveyor are determined. According to the maximum size of the pieces that come after crushing in a cone crusher for coarse crushing on a steeply inclined conveyor, its stable operation is ensured at a density of transported rocks of not more than 2.8 t/m^3. The economical use of SIC is achieved by combining the cyclic-flow technology with SIC and with the technology of pre-enrichment of ore in a quarry. For these conditions, the use of cyclic-flow technology with steeply inclined and inclined conveyors is justified.

The structure of the working zone of a deep quarry with gentle and steep sides is considered. For these conditions, rational schemes for the opening of horizons with steep sides of the open pit and the use of temporary internal dumps was developed.

The depth of the quarry, at which it is necessary to introduce a new opening scheme, was established. It is shown that the time of transition to the next opening scheme is significantly affected by the productivity of the quarry and the rate of decrease in mining operations.

Keywords: working area of a quarry, steeply inclined conveyor, cyclic flow technology, piece size, conveyor speed

Introduction. Since 2000, the technology of ore mining at deep levels of quarries has changed significantly, as well as their parameters in the working area, the slope angles of the sides in the area of railway transport operation when it is used with increased slopes.

In a number of quarries, steeply inclined conveyors (SIC) in cycle-flow technology (CFT) schemes have begun to be used.

Horizons are mined in steep layers with the movement of mining operations along the front in waves. Therefore, the previously used schemes for opening the horizons of deep iron ore quarries to not correspond to the changed conditions. In addition, the use of steeply inclined conveyors for the conditions of deep iron ore quarries and the transportation of high-density ores is requires the justification of the stable operation of the steeply inclined conveyor, the maximum size of a piece in the transported rock mass.

In this regard, the purpose of the study is to substantiate the promising trends for the development of CFT in deep iron ore open pits, taking into account the structure of their working zone and the use of SIC.

Results.

1. Parameters of the steeply inclined conveyor. With definite parameters of the large piece transported by the conveyor belt, contained in the transported rock mass, and its definite kinetic energy, stable operation of the system of widely used inclined conveyors is achieved. It is assumed that with the same kinetic energy of a piece (ore, rock) contained in the transported rock mass, stable operation of a steeply inclined conveyor will also be ensured. Based on this, the parameters of the transported piece and the parameters of the steeply inclined conveyor are determined. According to the maximum size of the pieces that come after crushing in a cone crusher for coarse crushing on a steeply inclined conveyor, its stable operation is ensured at a density of transported rocks of not more than 2.8 t/m^3.

Let's assume that a large piece of rock with a strength of up to 18 on the Protodyakonov scale is located on the belt of a steeply inclined conveyor (Fig. 1). Due to the use of a conveyor with a deep concave belt in the lifting section, a piece of rock cannot roll down the belt, as it will be clamped in the conveyor belt. In addition, this will be prevented by the rock on the belt, which was submerged earlier. When moving the conveyor belt at a definite speed, forces from the kinetic energy of the piece will act. They will manifest themselves as follows:

I) the impact of a piece of rock (1) on the conveyor belt;

II) the impact of a piece of rock through the conveyor belt on the roller support (2);

III) the impact of a piece of rock through the tape, the roller bearing on the bearing of the roller bearing (3);

IV) the impact of a large piece of rock on the belt, then the idler, then the bearing and the impact of the bearing on the idler rod (4);

V) impact of the roller support rod on the conveyor line (5).

It is necessary to establish at what maximum size of a piece of ore, its density, the speed of the conveyor belt, the angle of inclination of the belt conveyor, the system will work stably within the established standards.

At all quarries in Krivbass, conveyors with the following parameters are used in the schemes of cyclic-flow technology: conveyor belt speed v = 3.15 m/s; the maximum size of a piece of rock transported by the conveyor l =350 mm; conveyor inclination angle α =16 º.

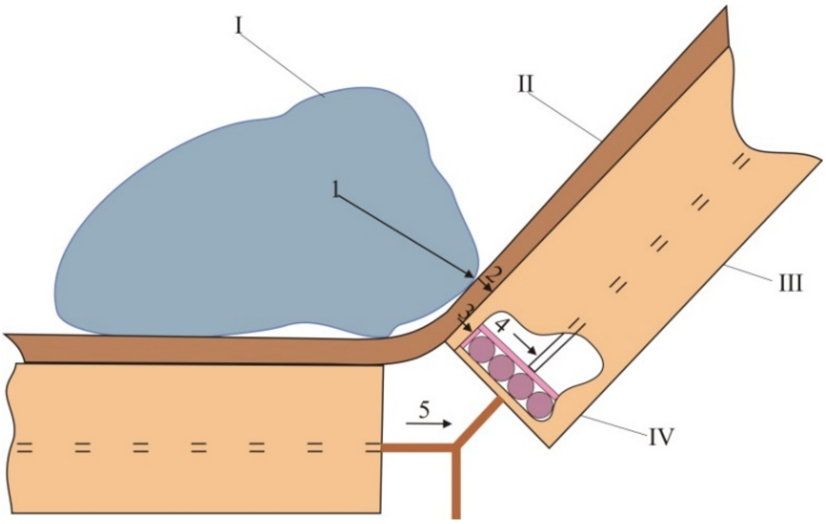


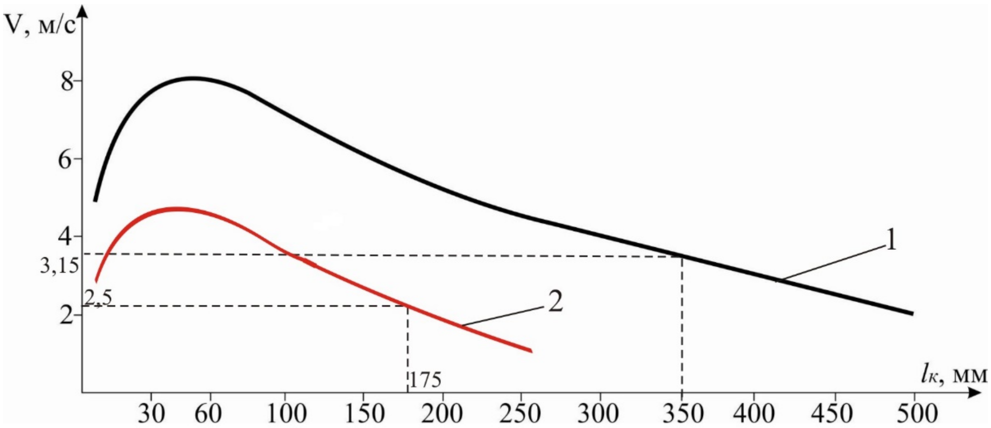
Figure 1 - Forces acting on the system when transporting a large piece of rock

Under these parameters, rock conveyors operate stably. Let us assume such a situation that steeply inclined conveyors with the same piece energy as with gently inclined conveyors will work stably. Then

$$l = \sqrt[3]{E_{pu}/0{,}06} \cdot v^2 cos\alpha$$

where E_{pu} – is the energy of the maximum piece of rock transported by an inclined conveyor.

In the work [1] the dependence of the speed of the conveyor belt of an inclined conveyor on the maximum size of a piece in the transported rock mass is shows, and also it in Fig. 2 as curve 1 is shown. Based on the above studies and the article [1], the dependence for a steeply inclined conveyor (SIC) on the maximum size of a piece in the transported rock mass at its density in the pillar is 3.7 t/m^3 was determine and in Fig. 2 as curve 2 [2] it is shown.



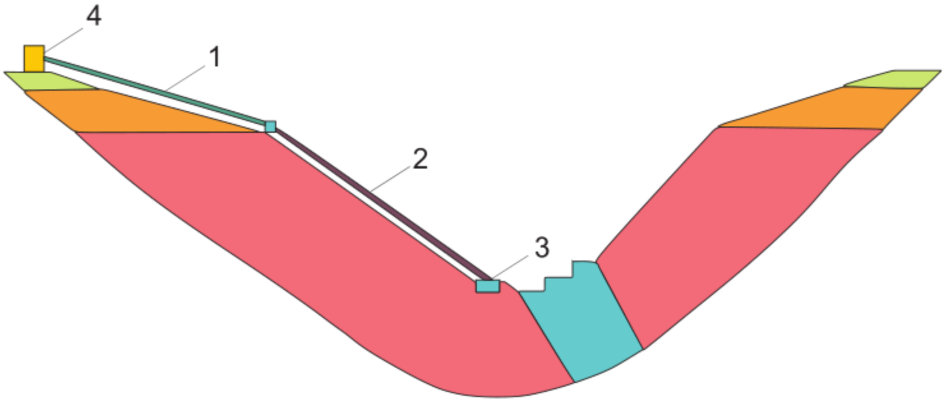
1 - inclined conveyor (according to [1]) and 2 - steeply inclined conveyor (SIC)

Figure 2 - The dependence of the speed of the conveyor belt from the maximum size of a piece in the transported rock mass at its density in the pillar of 3.7 t/m^3

Thus, for stable operation of a steeply inclined conveyor at a rock density of 3.0 - 3.7 t/m^3, the speed of the conveyor belt should be no more than 2.5 -1.5 m/s, and the maximum size of a piece in the transported ore should not exceed 200 mm. From this it follows that the second stage of crushing is necessary for the iron ores of Krivyy Rig and the use of SIC. In this case, it is necessary to lengthen the conveyor and relocate the transfer unit.

2. Opening horizons with cyclic-flow technology and the use of inclined and steeply inclined conveyors.

The working area of a deep quarry consists of gently sloping and steeply sloping sides. On the side of the quarry, in areas with a side slope of 10–18º, it is effective to use inclined conveyors, and in areas with a side slope of 30–36º- steeply inclined ones (Fig. 3).



1 - inclined conveyor, 2 - steeply inclined conveyor, 3 - crushing and transfer station in a quarry, 4 - transfer point on the surface

Figure 3 - Application of cyclic-flow technology in a deep quarry with using an inclined conveyor at the upper levels and a steeply inclined one at the lower ones

The complexity of the functioning of such a complex lies in the regulation of its parameters to ensure a given performance. After crushing the ore in the first and second stages of crushing, the maximum size of a piece in the rock mass entering the steeply inclined conveyor will be 175-200 mm. Therefore, an inclined conveyor can have a higher conveyor belt speed and a smaller width.

With definite parameters of the large piece transported by the conveyor belt, contained in the transported rock mass, and its definite kinetic energy, stable operation of the system of widely used inclined conveyors is achieved. With the same kinetic energy of a piece (ore, rock) contained in the transported rock mass, stable operation of the steeply inclined conveyor will also be ensured.

When designing the transition to the next horizon opening scheme with cyclic-flow technology and putting it into operation, a some period of time passes from the beginning of design to start-up. In most cases, during this time, the depth of the quarry can increase significantly, relative to the one at which it was supposed to be introduced according to the project. This leads to an increase in the distance of trucking to the transshipment point and a decrease in the economic efficiency of the designed scheme for opening the quarry horizons, and the cyclic-flow technology as a whole. Let's assume that the introduction of the next scheme for opening deep horizons according to the project was supposed to be carried out at a quarry depth H_p, but in fact it was introduced at a greater depth of the pit H_{to}. This leads to an increase in trucking distances

$$L_i - (H_{to} - H_p)i + L_g, \text{ м.}, \quad (1)$$

where i – slope of roads; L_g - distance of truck transportation of ore in horizontal sections, m.

The transition time from the existing horizon opening scheme to the introduction of the next one consists of the time during which some stages of the design and construction of facilities are performed.

The time for design and construction consists of the following stages:

t_s - development and approval of technical specifications for design, months;

t_p - is the duration of the project, months;

t_{ap} is the duration of the project approval, months;

t_e - the duration of the project expertise, months;

t_{mo} - duration of equipment manufacturing, months;

t_c - the duration of the construction of facilities corresponding to the opening scheme, months.

Then

$$H_{to} = (t_s + t_p + t_{ap} + t_e + t_{mo} + t_c) \cdot h, \text{ м.}, \quad (2)$$

where h - rate of decrease in mining operations, m/year, which can be determined by the expression

$$h = G / S\,(H) \quad (3)$$

where G- quarry productivity in terms of minerals, mln.m^3; $S\,(H)$ - is the area of the deposit, which changes with the decrease in mining operations in accordance with the increase in the depth of the quarry, m^2.

Then, taking into account expression (3), the depth of the quarry, where it is necessary to introduce the next opening scheme (2), can be written as

$$H_{to} = (t_s + t_p + t_{ap} + t_e + t_{mo} + t_c) \cdot G / S\,(H), \textit{ м.} \quad (4)$$

Determining the difference between H_{to} and H_p, the effectiveness of the adopted opening scheme and the possibility of the timing of the transition to it are established.

At the time of transition to the next opening scheme is significantly affected by the productivity of the open pit and the rate of decrease in mining operations.

Conclusion.

1. A promising trend in the development of cyclic-flow technology is the combined use of inclined and steeply inclined conveyors.

2. To ensure stable operation of the steeply inclined conveyor when transporting ore with a bulk weight of 3.7 t/m^3, the maximum piece size should not exceed 175 mm at a conveyor belt speed of 2.5 m/s. These parameters are determined based on the density of the ore, which is typical for the conditions of Krivbass. If the volumetric weight of the transported piece of ore is lower, then the maximum size of the piece in the transported mass can be increased, which does not require a second stage of crushing.

3. Under the condition of pre-enrichment of ore in a quarry and the provision of large and medium crushing, it is possible to effectively use steeply inclined conveyors.

4. On board a deep quarry with a complex structure of the working area, it is effective to use inclined conveyors in areas with a side slope of 10 - 18º, and steeply inclined conveyors in areas with a side slope of 30 - 36º.

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Анотація. За останні 20 років змінились параметри робочої зони глибоких кар'єрів, яка стала складатись з ділянок похилих та крутопохилих бортів. На ряді глибоких залізорудних кар'єрів почали створювати в робочій зоні тимчасові внутрішні відвали розкривних порід, що впливає на вибір схем розкриття глибоких горизонтів при циклічно-потоковій технології.

Мета дослідження – обґрунтування перспективних напрямів розвитку ЦПТ на глибоких залізорудних кар'єрах з урахуванням будови їх робочої зони та застосування крутопохилих конвеєрів.

Показано, що при певних параметрах транспортованого стрічкою конвеєра великого шматка, який міститься в гірській масі, що транспортується, і певної його кінетичної енергії досягається стійка робота системи, широко експлуатованих крутопохилих і похилих конвеєрів.

Визначено параметри крутопохилих конвеєрів при транспортуванні порід з великою щільністю. Прийнято, що за такої ж кінетичної енергії шматка (руди, породи), який міститься в гірській масі, що транспортується, буде забезпечуватися стійка робота крутопохилого конвеєру.

Виходячи з цього, визначені параметри шматка, що транспортується, і параметри крутопохилого конвеєра. За максимальною крупністю шматків, які надходять після дроблення в конусній дробарці великого дроблення на крутопохилий конвеєр, стійка його робота забезпечується при щільності порід, що транспортуються, не більше 2,8т/м^3. Економічне застосування КНК досягається при суміщенні циклічно-потокової технології з КНК та з технологією збагачення руди в кар'єрі. Для цих умов обґрунтовано застосування циклічно-потокової технології з крутопохилими та похилими конвеєрами.

Розглянуто будову робочої зони глибокого кар'єру з пологими та крутими бортами. Для цих умов розроблено раціональні схеми розтину горизонтів при крутих бортах кар'єру та застосування тимчасових внутрішніх відвалів.

Встановлено глибину кар'єру, за якої необхідно вводити нову схему розкриття. Показано, що на час переходу до чергової схеми розкриття істотно впливає продуктивність кар'єру та швидкість зниження гірничих робіт.

Ключові слова: робоча зона кар'єру, крутопохилий конвеєр, циклічно-потокова технологія, розмір шматка, швидкість конвеєра

Аннотация. За последние 20 лет изменились параметры рабочей зоны глубоких карьеров, которая стала состоять из участков наклонных и крутонаклонных бортов. На ряде глубоких железорудных карьеров начали создавать в рабочей зоне временные внутренние отвалы вскрышных пород., что оказывает влияние на выбор схем вскрытия глубоких горизонтов при циклично-поточной технологии.

Цель исследования - обоснование перспективных направлений развития ЦПТ на глубоких железорудных карьерах с учетом строения их рабочей зоны и применения крутонаклонных конвейеров.

Показано, что при определенных параметрах транспортируемого лентой конвейера крупного куска, содержащегося в транспортируемой горной массе, и определенной его кинетической энергии достигается устойчивая работа системы, широко эксплуатируемых крутонаклонных и наклонных конвейеров.

Определены параметры крутонаклонного конвейера при транспортировании пород с большой плотностью. Принято, что при такой же кинетической энергии куска (руды, породы), содержащегося в транспортируемой горной массе будет обеспечиваться устойчивая работа крутонаклонного конвейера.

Исходя из этого, определены параметры транспортируемого куска и параметры крутонаклонного конвейера. По максимальной крупности кусков, которые поступают после дробления в конусной дробилке крупного дробления на крутонаклонный конвейер, устойчивая его работа обеспечивается при плотности транспортируемых пород не более 2,8т/м^3. Экономичное применение КНК достигается при совмещении циклично-поточной технологии с КНК и с технологией предобогащения руды в карьере. Для этих условий обосновано применение циклично-поточной технологии с крутонаклонными и наклонными конвейерами.

Рассмотрено строение рабочей зоны глубокого карьера с пологими и крутыми бортами. Для этих условий разработаны рациональные схемы вскрытия горизонтов при крутых бортах карьера и применения временных внутренних отвалов.

Установлена глубина карьера, при которой необходимо вводить новую схему вскрытия. Показано, что на время перехода к очередной схеме вскрытия существенно влияет производительность карьера и скорость понижения горных работ.

Ключевые слова: рабочая зона карьера, крутонаклонный конвейер, циклично-поточная технология, размер куска, скорость конвейера.

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