E3S Web of Conferences **417**, 06007 (2023) https://doi.org/10.1051/e3sconf/202341706007
GEOTECH-2023

Prospects for the use of cyclic-flow technology for the transportation of rocks at the «Yoshlik-1» quarry of JSC Almalyk mining and metallurgical combine

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Abstract. The paper substantiates and proposes a method for selecting mechanization tools for crushing and conveyor complexes as part of cyclic-flow technology in open-pit mining. The proposed methodology justifies the types of means of mechanization of the crushing and conveyor complex used at the Yoshlik-1 quarry of JSC «Almalyk mining and metallurgical combine». The task of developing a methodology for selecting optimal technological parameters of crushing and conveyor complexes equipment for the conditions of the Yoshlik-1 quarry is formulated. Optimal parameters of equipment were selected using complex research methods, including analysis and generalization of research in the field of quarry design, technology and complex mechanization, generalization of production and design practice.

1 Introduction

«Almalyk Mining and Metallurgical Combine» is a huge production complex combining open and closed type deposits, metallurgical and cement plants, extensive mining and processing infrastructure. This plant accounts for 7 percent of industrial production and 15 percent of our country's exports. As a result of the attention paid in recent years, new deposits have been discovered and the volume of production has increased. Among them is the Yoshlik-1 field, the development of which is implementing an investment project worth 4 billion 894 million dollars.

The Yoshlik-1 deposit is located on the northern slope of the Kuraminsky Ridge. It is located just one kilometer from the city of Almalyk and is adjacent to the existing Kalmakir mine. Work on the development of the field was started by Decree of the President of the Republic of Uzbekistan № PP 2807 dated 01.03.2017 "On measures to expand the production capacity of JSC Almalyk MMC on the basis of the Yoshlik-1 field." This colossal project is planned to be launched in 2024 and create a total of 6 thousand jobs [1].

According to statistical data, today the Almalyk project ("Kalmakir" and "Yoshlik-1") ranks 3rd in the world in terms of gold-copper-porphyry reserves, 6th in terms of copper content in ore, 1st in terms of gold content in ore [2].

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The design of the Yoshlik-I quarry will practically be carried out from the zero cycle with the study of the boundaries of the quarry, the opening and the development system, the development of a calendar schedule of testing, the calculation of equipment, etc. The completion of the existing Kalmakir quarry is envisaged in terms of combining the borders in its western part with the contours of the Yoshlik-1 quarry, as well as the use of cyclic flow technology (hereinafter CFT) on it for the transportation of overburden rocks to “Nakpaisai” dumps.

The listed deposits are located in close proximity to each other. At the beginning, their development will be carried out separately, but while maintaining the declared productivity of 100 million tons per year in ore, in 15 years they will be combined on the surface. In this regard, the quarry at these two fields will be referred to as the "Combined quarry based on the Kalmakir and Yoshlik-I fields".

The project provides for both the use of existing copper processing plants (hereinafter CPP) №1 and №2, and the construction of a new CPP-3 with a capacity of 60 million tons/year.

The Yoshlik-I quarry, it is planned to use equipment of large unit capacity – excavators EKG-20, EKG-15, combined mode of transport - dump trucks with a lifting capacity of 220 and 130 tons, CFT for the transportation of ore and overburden rocks (annually 65 million tons of ore and 50 million m3 of overburden rocks).

The efficiency of quarrying depends on the correct choice of technology and equipment in the production of mining operations. Currently, in the development of mineral deposits by the open method, the CFT is widely used, which allows reducing the cost of transporting rock mass by 30-40%, increasing labor productivity by 1.4-2.0 times and reducing the range of transporting rock mass through the use of belt conveyors with tilt angles up to 16-180. The increase in transportation costs and the search for options for more efficient combined methods of delivering rock mass made it possible to intensively switch to mining and overburden excavation [3-23].

In this paper, the analysis and justification of options for ore transportation from the surface of the Yoshlik-1 quarry to CPP-3 is carried out.

2 Materials and methods

Two approaches are possible when designing CFT complexes [7].

1. Having previously set the parameters of the mass-produced conveyor equipment (production link), determine the annual transport capacity of the crushing and conveyor complex (hereinafter CCC).

$$Q_t = Q_{h.c.}\mathrm{T}_w \tag{1}$$

where, $Q_{h.c.}$ - is the passport hourly productivity of conveyor equipment, t/h; $\mathrm{T_w}$ - is the net working time, h.

Then, based on the hourly productivity of the CCC, select the necessary equipment of cyclic links and develop a mining technology that ensures the processing of the planned annual volume of rock mass.

2. Based on the mining capabilities and the necessary volumes of the output of rock mass from the quarry, determine the appropriate annual productivity of the CFT complex. According to a given volume of rock mass, calculate the required hourly productivity of CCC, t/h

$$Q_{h.CCC} = Q_{a.CFT}/\mathrm{T}_w \tag{2}$$

where $Q_{\mathrm{a.CFT}}$ - is the annual productivity of the CFT complex, t.

By the value of $Q_{\mathrm{h.CCC}}$ the parameters of conveyors, crushers and equipment of cyclic links of the CFT complex should be selected.

The second approach is certainly preferable with a limited variation in the standard sizes (parameters) of the manufactured equipment. In addition, even with a significant number of conveyor sizes, it is not always possible to choose conveyors with parameters that meet the specific operating conditions of the CFT complexes. As a rule, they require custom-made equipment, which is confirmed by the practice of designing a central processing plant at quarries.

Duration of effective work (net work time) CCC in CFT systems with a continuous working week is determined by the expression.

$$\mathrm{T}_{nw} = (\mathrm{T}_a - \mathrm{T}_m - \mathrm{T}_{d.cl} - \mathrm{T}_{d.tech} - \mathrm{T}_{d.org} - \mathrm{T}_{d.ex})\mathrm{K}_a \text{, h} \quad (3)$$

where $\mathrm{T}_{\boldsymbol{a}}$ - is the annual fund of time, h; $\mathrm{T}_{\boldsymbol{m}}$- is the time for maintenance and repairs of DKK equipment, h; $\mathrm{T}_{\boldsymbol{d.cl}}$ - is the downtime of equipment for climatic reasons, h; $\mathrm{T}_{\boldsymbol{d.tech}}$ and $\mathrm{T}_{\boldsymbol{d.org}}$ - are the duration of in-shift incompatible system downtime for technological and organizational reasons, h; $\mathrm{T}_{\boldsymbol{d.ex}}$ is the duration of incompatible in–shift emergency downtime of the excavator link, h; $\mathrm{K}_{\boldsymbol{a}}$ – the availability coefficient of the CCC equipment.

The CCC includes the following sequentially connected links: the crushing unit, conveyor staves in the line and reloading units between them. Taking the same readiness coefficients of the same type of elements, we get

– coefficient of readiness of the conveyors in the line

$$k_{\mathrm{r.l}} = \frac{1}{\frac{n}{k_{\mathrm{r.cs}}} - n + 1} \quad (4)$$

– coefficient of readiness of transshipment points

$$k_{\mathrm{r.tp}} = \frac{1}{\frac{n}{k_{\mathrm{r.tp.bcs}}} - n + 1} \quad (5)$$

– coefficient of readiness of readiness of the crushing unit

$$k_{r.cu} = k_{r.c} \quad (6)$$

where $k_{\mathrm{r.cs}}$, $k_{\mathrm{r.tp.bcs}}$, $k_{r.c}$ - are, respectively, the readiness coefficients of the conveyor stave, transshipment point between conveyor staves, crushers; n -is the number of conveyor staves or transshipment points in the line.

The choice of equipment for CFT complexes refers to the tasks of comparing options with slightly different, and often the same, production capacity and duration of construction [3-17].

The main provisions of the choice of CCC equipment are as follows:

1. Preparation of initial data to determine the parameters of conveyor equipment, select the type and parameters of equipment of adjacent links, calculate capital and operating costs for moving 1 ton of rock mass and other indicators in accordance with the selected criteria for evaluating the effectiveness of the CFT complexes.
2. The choice of conveyor line equipment is carried out taking into account the mutual influence of adjacent technological links of the CFT systems. At the same time, it is sufficient to take into account the influence of excavator-automobile and crushing-conveyor complexes on the efficiency of their mutual functioning and the system as a whole. The influence of adjacent technological links is estimated by the value of the average daily loss of productivity, based on equipment downtime due to emergency, technological and organizational reasons.
3. The mode of operation of crushing and conveyor complexes should be considered decisive when calculating the duration of operation of equipment in CFT systems. The work of adjacent links should ensure the operation of crushing and conveyor complexes in the mode of maximum use of their technical capabilities by creating an optimal reserve of equipment for the implementation of appropriate technological processes. The required hourly productivity of the CFT system is

determined based on a given annual volume of rock mass transportation and the most likely time of effective operation of the crushing and conveyor complex.

4. According to the required hourly productivity, taking into account the uneven loading of conveyors in crushing and transshipment points, the equipment of the complex is selected with parameters that ensure the unconditional fulfillment of the annual volume of traffic.
5. Due to the varying complexity of manufacturing and durability of elements of conveyor systems (drive station, rollers, linear support structures, belts), when calculating capital costs, their cost is taken into account separately. Operating costs are determined taking into account the service life of the most rapidly wearing elements, since their durability is significantly lower than the depreciation period of the conveyor as a whole.

3 Discussion

Comparative technical and economic indicators for the options for the delivery of ore from the quarry to the concentrator are presented in Table 1.

Table 1. Technical and economic indicators for ore delivery options from the quarry to the concentrator.

Indicators (units)	Option 1	Option 2
	(with priority development of road transport)	(with priority development of conveyor transport)
Mountain mass (thousand tons)	-	-
- ore	65 000	65 000
- highways (km)	6.5 with overpass	-
- conveyor lines (km)	-	3.4*2
Display of working transport (million tons*km):	-	-
motor transport	422	-
conveyor lines	-	221
Average delivery distance:	-	-
auto (km)	6.5	
conveyor (km)	-	3.4
4. Operating costs (dollars USA):	-	-
motor transport	97 060 000	
conveyor transport	-	44 200 000
5. Equipment	-	-
motor transport	46 dump trucks with a capacities of 130 tons	-
conveyor transport	-	Crushing and handling plant with a crusher MMD-1300 - 2 pcs. $\Sigma N=2\times1400$ kVt Conveyor lines – 2 pieces .

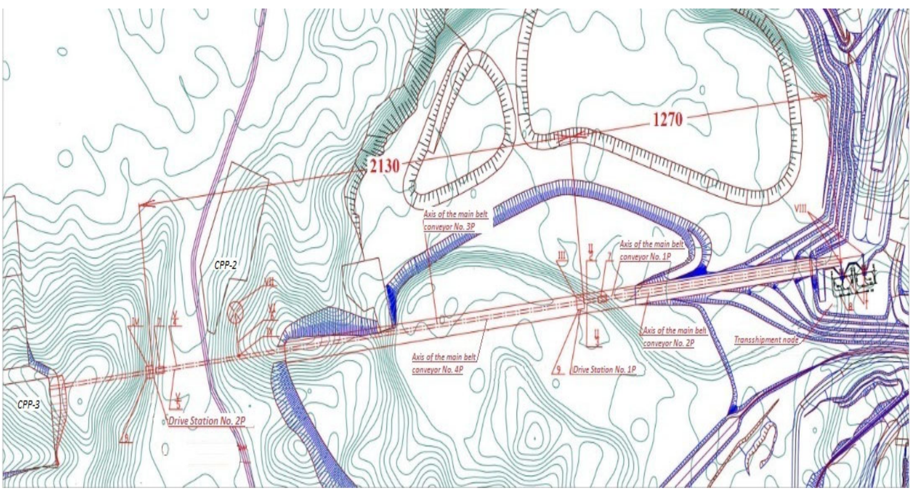
		Width of the tape – 2000 mm; ΣL=6800 m; ΣN=16000 kVt

In the mining and transport scheme for the development of the Yoshlik-1 deposit, the use of conveyor transport for the delivery of ore to the newly designed CPP-3 processing plant is envisaged (Figure 1).

The location of the CPT-ore is shown on the situational plan in accordance with the adopted technological solutions, taking into account the location of the CPP-3 site. The CFT-ore route passes through the territory of the existing Almalyksai dumps, taking into account the use in the future for the transportation of ore to CPP-2 (Figure 1).

3.1 Coarse crushing complex - ore of the Yoshlik-I quarry

The coarse crushing complex is located in accordance with technological solutions in the area of the south-western side of the quarry, taking into account the CFT route. When mining operations decrease, the «Coarse crushing complex-ore» will change its location starting from 2032.



Statement of projected buildings and structures		
№	Name	Quantity
I	Crushing and reloading plant with screw-toothed crusher	2
II	Main conveyor overpass №1P, (2P)	2
III	Drive station №1P	1
IV	Drive station №2P	1
V	Main conveyor overpass №3P, (4P)	2
VI	Main conveyor overpass №5P	1

Specificatio			
№	Name	Quantity	Note
1	Crushing and reloading plant equipment		
2	Conveyor belt trunk №1P L=1270 m, H=110 m,v=5 m/s, B=2000 mm, N=4*1000 kVt	1	1 line
3	Conveyor belt trunk №2P L=1270 m, H=110 m,v=5m/s, B=2000 mm, N=4*1000 kVt	1	2 line
4	Conveyor belt trunk №3P L=2130 m, H=70 m, v=5m/s, B=2000 mm, N=4*1000 kVt	1	1 line
5	Conveyor belt trunk №4P L=2130 m, H=70 m,v=5m/s, B=2000 mm, N=4*1000 kVt	1	2 line
6	Conveyor belt trunk №5P L=40 m, v=5m/s, B=2000 mm, N=315 kVt	1	1 line; ore sampling unit on CPP-2

VII	Cone Crushed Ore Warehouse	1
VIII	Transshipment node	2
IX	Ore selection node on CPP-2	1

7	Complex of equipment for replacing conveyor belts of main conveyors №1P, №2P, №3P,№4P	4	
8	Dump truck load capacity 130 t	1	
9	Fire fighting equipment	2 set	

Fig. 1. Scheme of the complex of cyclic-flow ore technology CFT-ore.

3.2 Operating mode and performance

According to the design assignment and the mining schedule, the productivity of the Yoshlik-1 quarry of Almalyk MMC for ore extraction is 65 million tons of ore per year, of which 5 million tons will be transported to the existing CPP-2, and 60 million tons of ore per year to the new CPP-3.

The operating mode of the "CFT-ore" complex is adopted year-round, corresponds to the operating mode of CPP–3 and is: the number of working days per year is 365; the number of shifts per day is 2; the duration of the shift in hours is 12.

The calendar working time is 365×2×12=8760 hours per year. The estimated hourly productivity of the "CFT-ore" complex for the selection of equipment is determined by the formula

$$Q_{complex} = \frac{Q_{\text{year}}\, k_u}{\text{T}_{n.o} k_{r.s}} \qquad (7)$$

where, Q_{year} – annual productivity, t/ year; k_u = 1.15 – the coefficient of uneven ore supply; $\text{T}_{n.o}$ = 7400 hours per year – the net operating time of the equipment, taking into account the loss of working time; $k_{r.s}$ = 0.92 – the coefficient of readiness of the system according to the norms of technological design.

When calculating the net operating time of the equipment of the "CFT-ore" complex, the normalized loss of working time for the following activities is taken into account:

- carrying out mass explosions in a quarry – 310 h/g.;
- carrying out current repairs of equipment (if possible, it is necessary
- to combine with auxiliary technological works) – 380 hours /year;
- performing scheduled preventive repairs - 590 hours/year;
- organizational downtime – 80 hours/year.

The total loss of working time will amount to 1,360 hours per year.

As a result of the calculations carried out, as well as taking into account the experience of similar enterprises, the net operating time of the equipment of the "CFT-ore" complex is 7400 hours per year.

Thus, the hourly productivity of the "CFT-ore" complex for the calculation and selection of equipment is:

$$Q_{\text{complex}} = \frac{65000000*1{,}15}{7400*0{,}92}\text{=10980 t/h}$$

To ensure this performance, it is proposed to build two conveyor lines with a capacity of 5500 t/h each. With this scheme, the stable operation of the CPP-3 is more reliably ensured, since stopping one line does not have a critical impact on the operation of the complex and factories as a whole (with a single-line scheme, the risks of a complete shutdown of the ore processing plant significantly increase and, despite the presence of storage warehouses, possible disruptions of the processing plant).

For the use of conveyor transport, the initial ore with a size of 0-1200 mm must be refined to a size of 0-350 mm in crushing and reloading plants (CRP).

The location of the CRP site was chosen taking into account the contours of the first stage of the quarry construction and the location of the CPP-3 processing plant. The most convenient location of the CRP is the western side of the quarry in the immediate vicinity of the automobile exit, which ensures the minimum distance of ore delivery from the quarry to the receiving devices.

Based on the technological requirements for the crushing operation (the size of the initial ore and its physical and mechanical properties, the specified size of the crushed ore), the feasibility study considers the use of two types of crushers - screw–toothed and gyration cone with an hourly capacity of 5500 t/h.

3.3 Selection of crushing equipment

Stationary and semi-stationary intra-barrier crushing transfer station (CTS) are currently equipped with jaw and cone crushers for large crushing of processing and processing plants. The costs of their construction are very high, only construction and installation work accounts for about 50-60% of the total costs, and the construction time takes up to 2 years. CTS have a height of over 30 m when using cone crushers and about 25 m when using jaw crushers. They also require the performance of special, very time-consuming work on the penetration of deep trenches and chambers for their placement. The transfer step of the CTS reaches 120-150 m, while the distance of transportation by dump trucks increases (more than 2.5 km) and the economic efficiency of the CFT decreases.

The initial ore with a size of 0-1200 mm must be crushed to a size of 0-350 mm (380 mm) for the possibility of using conveyor transport.

The analysis of the operation of crushing equipment on ores is carried out taking into account their physical and mechanical properties, as well as taking into account the productivity of the crushing and reloading plant 5500 t/h.

Commercial offers have been received from the following manufacturers:

- FLSMIDTH (Great Britain) crushing complex Sizer – screw crusher MMD1300;
- METSO (Finland) – semi-stationary crushing plant with gyration cone crusher Superior 60-110E;
- KRUPP (Germany) - semi-stationary crushing plant with gyration cone crusher KV 63-130;
- KRUPP, TAKRAF (Germany) - Semi-stationary crushing plant with screw crusher 1250;
- KANEX (Russia) - crushing complex Sizer – screw crusher.

Based on the data received from potential suppliers of crushing equipment, a comparative analysis of the types of crushers was performed. The technological characteristics of crushing equipment are given in Table 2.

As a result of the analysis of the technological characteristics of crushing equipment, two options are proposed for further consideration:

- option 1 – a semi-stationary crushing plant based on a screw-toothed drill;
- option 2 is a semi-stationary crushing plant based on a gyration cone crusher.

Table 2. Technological characteristics of crushing equipment.

Manufacturer company	Name of the crusher	Type of Crusher	Efficiency, t/h	Engine power, kVt	Number of unloading places	Operating costs, dollars a year
FLSmidth	FLS ABON 13/300	Roll	6500	710	3	795060
	FLS TSU 1600x3000	Gyration	6500	1200	2	1318000
KANEKS	ДШЗ 1500.400	Roll	6000	1120	3	1932300
	-	Gyration	n/d	n/d	n/d	n/d

Thyssenkrupp	-	Roll	n/d	n/d	n/d	n/d
	KB 63-89	Gyration	6500	1200	3	n/d
Takraf	TCS14.35	Roll	6000	1120	3	2405970
	Metso 69-89	Gyration	6000	1000	2	n/d

Option 1 - CRP based on a screw-toothed crusher

The copper ores of the Yoshlik-1 deposit have an average Protodiakonov hardness of 8-12 units. Taking into account the physical and mechanical properties, for large crushing we consider the use of a screw-toothed crusher in the form of a semi-stationary crushing plant.

The screw-toothed crusher passes small classes without crushing. The woven gear design of the rotor allows the lower crushing product to be freely sifted through the constantly appearing cracks formed during the slow rotation of the crusher shafts.

The spiral arrangement of the teeth forces the larger pieces to move to one of the ends of the machine and distributes the incoming material along the entire length of the rotors.

This property is used to remove pieces of material from the crusher that exceed the permissible dimensions.

In addition, there are no plates in the crushed material, the presence of which complicates transportation by conveyors.

The main advantages of the screw-tooth crusher are:

- compact overall dimensions that favorably affect the design and layout solutions of the CRP. The height (H = 2195 mm) allows you to have a retaining wall height of no more than 15 m;
- the insignificant weight of the crusher (160 t) allows the use of stationary lifting equipment 50/5 t or mobile cranes when repairing the crusher of integral parts of the crusher.

The working body of the screw-toothed crusher are the teeth located on the rotors in a spiral. Crowns are put on the teeth, which are bolted to the teeth. The plant manufactures crowns taking into account the hardness and abrosivity of the material coming for crushing.

Semi-stationary crushing plants based on screw-tooth crushers are manufactured by the firms "Sizer" and "FL SMIDTH" Great Britain, the firm "KRUPP" Germany (Table 1).

Option 2 - CRP based on a gyration cone crusher

According to option 2, the use of semi-stationary crushing plants based on a gyration cone crusher is considered for large crushing of the initial rock mass.

To ensure the fineness of the crushed material 0-350 mm, the optimal discharge gap should be 180 mm. Gyratory cone crushers as part of a CRP with a maximum capacity of 180 mm are manufactured by Metso Finland – crusher "Superior 60-110E", and KRUPP Germany – crusher type KB 63-130, the productivity of crushers is 6500 t/h and 7900 t/h, respectively, weight 553.4 t and 490 t, the height of the crusher, taking into account the rollout of the hydraulic cylinder, is 11832 mm and 9678 mm, respectively.

Considering the overall size of cone crushers in height, the required volume the receiving hopper, as well as the hopper for crushed material, the height of the retaining walls will be 28.6 m and 26.5 m.

The crusher works under the blockage. Uniform loading of the conveyor line is provided by plate feeders or a belt feeder, which are installed under the hopper for crushed material.

Taking into account the sieve composition of the initial ore mass entering the crushing, a large number of small classes (sometimes clay) leads to the pre-pressing of the cone. This fact is a significant disadvantage for the use of crushers of this type.

To maintain the crusher, it is necessary to install a bridge crane with a lifting capacity of 160/32 tons, given the large weight of the integral part of the crusher. It is necessary to have a large repair area with stands for the installation of removable parts of the crusher in the area of operation of the crane.

Characteristics of screw-toothed and cone gyration crushers as part of crushing plants are given in Table 1.

Comparison of crushing equipment options 1 and 2

The comparative analysis of the technical parameters of the equipment has shown that roller crushers have a number of significant technological advantages over gyration types of crushers, namely:

1. The possibility of obtaining a large degree of reduction of the crushed piece from 2:1 up to 10:1 for one crushing stage. If an oversized piece hits, this type of crushers will ensure their operation, and on a gyration crusher it can lead to suspension of work.
2. Roller crushers have smaller oversized dimensions compared to gyration crushers similar hourly performance. The height from the installation level of the main conveyor to the dump truck unloading point is up to 30m for a cone crusher, and 12.5-15m for a roller crusher, which entails an increase in the length of the main conveyors by 160-200m, or an increase in their lifting height by 15-17m, followed by an increase in drive power by 9-10%. Taking into account that the main conveyor CFT-1 passes under the "Novoporodnaya" station, lowering the start mark of the conveyor will lead to a significant increase in the volume of excavation work.
3. A significant multiple reduction in the volume of concrete work. The gyration crusher requires a high (up to 30 m) retaining wall to install two entrances for dump trucks. The roller crusher does not need foundations, and the wall is much smaller (up to 15m).
4. Less equipment weight. The mass of the complex of one crushing plant with a gyration crusher is about 2000-2200 tons, and the mass of the complex of one crushing plant with a roller crusher is 800-900 tons.

This factor significantly and directly affects:

- costs associated with the delivery of equipment from manufacturers to installation sites;
- the cost and timing of preparatory and construction and installation works;
- the procedure for conducting scheduled preventive repairs.

5. To carry out repair work and maintenance of the roller crusher, a cantilever or automobile crane with a lifting capacity of 32t is sufficient, and a bridge crane with a lifting capacity of 160t with a crane trestle is required for a gyration crusher.
6. The possibility of processing sticky and plastic products. Roller crushers are equipped with special devices for cleaning teeth from stuck material during operation without stopping.
7. The possibility of processing frozen products.
8. Combining the functions of screening and crushing, when the material that is not subject to crushing freely passes through the roller crusher.
9. Ease of installation of roller crushers and less dynamic loads on structures, whereas gyration crushers have large dynamic loads on supporting structures from swinging parts.
10. Compactness, simplicity of design of roller crushers, quick replacement of working tools, the possibility of production of replaceable teeth not from foreign companies, and at the Novoi Machine-building Plant.

The experience of operating gyration crushers with higher hourly productivity (more than 3500t/hour) in the world is limited due to their small number, whereas roll crushers of various manufacturers on similar materials are successfully operated worldwide in significant quantities.

Analysis of the economic efficiency of two types of crushing equipment he showed that with the existing cost of capital and operational costs, as well as the cost of construction and installation work, it is economically feasible to use roller (screw-toothed) crushers.

4 Results

The main technical solutions for the complex of cyclic-flow technology of ore transportation on the Western side of the "CFT-ore" quarry are as follows.

CFT-ore includes two conveyor lines, which include: 1 conveyor line: CRP-1, main belt conveyors № 1P, № 3P, belt conveyor on CPP-2; 2 conveyor line: CRP-2, main belt conveyors № 2P, № 4.

Technological sequence of ore delivery:

- delivery of the initial ore by road from the face to the receiving devices of the crushing and reloading plant (CRP);
- crushing of the initial rock mass with a size of 0-1200 mm to a size of 0–350 mm for the possibility of using conveyor transport;
- transportation of crushed material by main belt conveyors №1P, №2P from the mark of +595.0 m to the mark of +700.0 m;
- material reloading from main belt conveyors №1P, №2P to main belt conveyors №3P, №4P in the drive station №1P;
- transportation of crushed material by main belt conveyors №1P and №2P from the +700 m mark to the +630 m mark.

The location of the CFT-ore was chosen taking into account the optimal mileage of vehicles, delivering the source ore to the receiving devices of the CRP, as well as taking into account the location of the newly designed CPP-3 processing plant and the choice of a route with a minimum of interruptions with transport communications. The distance between the conveyor lines is due to the location in the drive station №1 (№2) of two drive stations of belt conveyors with a capacity of 4× 1000 kW each. In this documentation, the drives of the Syzran Heavy Machinery Plant (SHMP) with cylindrical gearboxes are taken as a prototype. The distance along the axes of the conveyor lines is 12.5 m (according to the results of a competitive selection for the supply of equipment from another manufacturer, the size can be changed). The main structural and layout solutions for the CFT-ore are shown in Figure 1.

The following structures and equipment are part of the projected CFT-ore complex:

- two crushing and reloading plants with unloading platforms for vehicles at +610.0 m;
- belt main conveyor No. 1P;
- main belt conveyor No. 2P;
- main belt conveyor No. 3P;
- main belt conveyor No. 4P;
- conveyor belt No. 5 on CPP-2;
- drive station No. 1P;
- drive station No. 2P;
- conveyor belt replacement equipment complexes, on all conveyors.

4.1 Crushing and reloading plant (CRP)

In this work, the choice of crushing equipment was made according to two options:

- option 1 – CRP based on a screw-toothed crusher;
- option 2 – CRP based on a gyration cone crusher.

When choosing, the following were considered: the composition of crushing plants in two variants, the technical characteristics of crushers, the main structural and layout solutions

CRP, manufacturers of semi-stationary crushing plants, evaluated the advantages and disadvantages of each option. For further consideration, option 1 – CRP based on a screw-toothed crusher of the MMD 1300 type is recommended.

The estimated hourly productivity of the CFT-ore complex for the selection of equipment is 10980 t/h. Delivery of ore to the receiving devices is carried out by motor transport with a load capacity of 130 tons. Based on operational experience, we believe that in 60 minutes. one BelAZ performs 15 unloading operations. We determine the required number of unloading points at a given performance:

Therefore, in order to organize 6 unloading points, it is necessary to provide two crushing and reloading installations. The manufacturing plants provide a constructive opportunity to organize 3 unloading points per one CRP. In the feasibility study, a decision was made – two CRPs with 3 unloading points, the distance along the axes of the CRPs is ~ 90 m.

4.2 Belt conveyors

The structure of the conveyor tract of the TST-ore complex includes 4 belt conveyors: mainline No. 1P, mainline No. 2P, mainline No. 3P, mainline No. 4P. The total length of the conveyors is 6800 m.

The hourly productivity of the CFT-ore complex for calculating equipment is determined based on the annual productivity of the quarry for extraction, the net operating time of the equipment, the coefficient of uneven material supply, the system readiness coefficient, and is 10980 t/h. The capacity of each of the two conveyor lines of 5500 t/h is assumed.

To determine the power of the drives and the choice of the type of tape in the feasibility study, preliminary traction calculations of all belt conveyors. According to the norms of technological design and the calculation methodology of the Syzran HMP, the calculation of the conveyor drive consists in determining the values of:

- the power required to move the belt at idle;
- the power required to move the material in the horizontal direction;
- the power required to lift the material.

Then the power on the drive drum shaft is determined for steady motion mode, then the rated power of the electric motor is determined.

The results of the calculations of the drive power and the characteristics of the conveyors are given in Table 3.

The route of the two conveyor lines of the CFT-ore has the minimum required length and includes the smallest number of conveyors, therefore, the smallest number of transshipment stations. This reduces capital and operating costs. Taking into account the terrain and existing transport communications to ensure the passage of the main belt conveyors No. 3, No. 4 over the existing railway, the section of the conveyor route L.K. No. 3, No. 4 with a length of 600 m passes along the overpass. The height of the overpass is determined by the condition of the location under in complexes for replacing the conveyor belt and is 15 m.

Bulk devices (funnels) from one conveyor to another provide the lowest drop height of the material, there are "pockets" that contribute to changing the trajectory of the flow of material, if necessary, and reducing its speed. This helps to increase the durability and reliability of the tape.

Table 3. Technical characteristics of the equipment of the CFT-ore complex.

Name of the equipment	Productivity, t/h	Horizontal length, m	Width of the tape, mm	Lifting height, m	Tape speed, m/s	Drive power, kW
1-conveyor line						
CRP (including feeder)	6500	n/d	n/d	n/d	n/d	2×600+ 200
Main belt conveyor No. 1P	5700	1270	2000	110	5	4×1000
Main belt conveyor No. 3P	5700	2130	2000	-70	5	4×1000
2-conveyor line						
CRP (including feeder)	6500	n/d	n/d	n/d	n/d	2*600+200
Main belt conveyor No. 2P	5700	1270	2000	110	5	4×1000
Main belt conveyor No. 4P	5700	2130	2000	-70	5	4×1000
Total						**18800**

5 Conclusion

Thus, the paper substantiates and proposes a method for selecting mechanization tools for crushing and conveyor complexes as part of cyclic-flow technology in open-pit mining. The proposed methodology selected the types of means of mechanization of the crushing and conveyor complex used at the Yoshlik-1 quarry of JSC Almalyk Mining and Metallurgical Combine. The location of the CFT-ore is justified in accordance with the adopted technological solutions, taking into account the location of the CPP-3 site. The CFT-ore route passes through the territory of the existing Almalyksai dumps, taking into account the use in the future for the transportation of ore to CPP-2. The technical solutions providing the possibility of achieving the annual productivity of "Yoshlik-I" for the extraction of ore of 60 million tons per year are substantiated.

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