THE DEVELOPMENT OF INNOVATIVE TECHNOLOGY OF DRILLING AND BLASRING OPERATIONS BY BOREHOLE EXPLOSIVE CHARGES OF DIRECTED ACTION OF DETONATION PRODUCTS USING THE CUMULATIVE EFFECT

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ABSTRACT

Improving the efficiency of mining is inextricably linked with the improvement of explosive technologies. The quality of the rock mass preparation for further processing and obtaining the final product depends on ensuring an increase in the pace and efficiency of economic development of mining countries. The analysis of promising methods for improving explosive preparation of rock mass showed that the main direction is inextricably linked with the use of modern physical fields aimed at intensifying detonation processes. One of these areas is the use of the cumulative effect. The authors developed the design of the borehole explosive charge (EC) using a cumulative effect, which allows to lower the bottom of the ledge and reduce the cost of drilling and blasting. This design of the charge due to the location of the explosive charge directly above the zone of the bottom of the ledge will increase the effect of the explosion on it. The cumulative recess forms a stream, which creates a shock wave directed down and away from the well. In its turn, the stress waves from the cumulative charge directed upward produce additional crushing of the overlying rocks. The direction of the energy of one part of the explosive charge to the lower part of the well increases the time of the explosion on the array and creates two waves of stresses that affect the entire array. The proposed technology also provides for the dispersion of the explosive charge in an inert gap, the lower element of which is made of explosives, corresponding to the strength characteristics of the rocks of the base zone of the ledge, and the upper one should correspond to the exclusivity category of the rocks constituting the ledge. The location of a cumulative funnel in the bottom of the well affects the intensity of explosive destruction of rocks. The effective parameters of the cumulative funnel in the design of the borehole explosive charge are determined.

Keywords: well; design; explosive charge (EC); cumulative effect; ledge sole; penetration depth; height of cumulative facing; action of a detonation wave; numerical modeling; emulsion explosive substances.

FORMULATION OF THE PROBLEM

One of the most energy-intensive processes for the extraction of solid minerals is the explosive preparation of the rock mass, which largely determines the efficiency and cost of production. The results of the entire technological complex depend on the quality of explosive preparation. Intensification of the efficiency of mining due to the improvement of explosive technologies makes it possible to increase the pace and efficiency of economy development of mining countries.

A wide range of changes in physical and mechanical characteristics and a variety of mining and technological properties of rocks of complex structural deposits require an individual approach to the selection of rational technological parameters of mining for each developed section. First of all, this concerns the preparation of rocks for excavation using explosive method.

Drilling and blasting operations (DBO) in the current operating conditions of mining enterprises so far remain practically the only way to destroy strong rocks. Being the initial process of production technology, drilling and blasting operations determine the effectiveness of all subsequent processes: from loading and transportation to mechanical crushing and processing of mineral raw materials.

The uniformity and size of the crushing of the massif, the percentage of oversized output, the working out of the bottom of the ledge, the size of the drill holes, the width of the rock mass collapse - these and other characteristics mainly determine the quality of the blasting operations. In this regard, the research and development of new designs of borehole charges, allowing to ensure the required quality of blasted mass, reduce the number of boreholes and improve the working out of the bottom of the ledge, is an important task, the solution of which will contribute to increasing the economic efficiency of mining enterprises.

When implementing the well-known developed methods for explosive destruction of an array of mixed rocks, uniform crushing of strong layers is not provided [1,2], which leads to a deterioration in the quality of preparation of the rock mass and increased costs for excavation. When studying the processes of explosive destruction of an array of mixed-strength rocks of complex structural deposits using borehole explosive charges, special attention should be paid to identifying the physical features of their destruction depending on the specific structural and strength properties of the blasted rock mass. The existing technology of blasting operations using continuous or dispersed borehole explosive charges implies the presence of an overburden on the underlying horizon to study the bottom of the developed ledge. When this occurs, the destruction of the upper part of the underlying ledge, which leads to the collapse of the mouths of blast holes during subsequent drilling of the underlying horizon. The loss of part of the wells due to

collapse causes technical and economic damage to the mining enterprise, especially developing hard rocks of complex structural deposits, which is the Almalyk mining and metallurgical plant [3].

At present, Almalyk Mining and Metallurgical Plant is one of the leaders in the development of open pit mining and is actively paying attention to improving the progress of science, as well as innovative projects. The development of the Sary-Cheku porphyry copper ore deposit was begun in 1974. Geologically, the Sary-Cheku deposit of the Lower Devonian volcanogenic formations is divided into three horizons (bottom to top): andesitic porphyries', quartz porphyries and andesite-dacitic porphyries with coefficient of fortress on a scale prof. M. M. Protodyakonova f = 14-15, but has significantly smaller sizes. The ore of this quarry is processed at the copper processing plant and copper processing plant No. 2. for further increase of productivity and output of non-ferrous and precious metals, the implementation of which increased its design capacity to 5 million tons of ore per year. The design capacity of the quarry before the reconstruction was 4 million tons of ore per year.

THE ANALYSIS OF EXISTING TECHNICAL SOLUTIONS

The presence of an explosion of blast holes requires an additional consumption of drilling and explosives and, as it has been noted, breaks the underlying horizon during an explosion, which reduces the efficiency of drilling and blasting operations. In addition, the explosion of part of the charge in the drill causes a seismic wave, which can negatively affect the safety of protected objects [4-6]. This is especially true for high-density emulsion explosives [7–9]. Previous theoretical and laboratory studies [10, 11] and analysis of existing technical solutions showed that the shape of the bottom of the charge has a significant effect on the surface condition and the level of the bottom of the ledge after the explosion. Various forms of the bottom part are proposed to be performed using cumulative funnels, which are a cone made of an inert material. With certain geometric parameters of the cumulative funnel, an increase in the zone of enhanced dynamic loading on the bottom of the well is provided and the effect of the reflected shock wave on the stemming material is reduced.

The creation of a camouflage recess in the lower part of the borehole charge is possible due to the polyethylene borehole gates (PES) of the design of the IHD named after A.A. Skochinsky [12], which are elastic cones, to the base of which are mounted supports with thrust bearings. Installation of PES in wells at a given depth is carried out by means of a rigid and strong support, which are used as wooden rods or industrial pipes made of polyvinyl chloride (PVC). The length of the support is equal

to the length of the air gap. Upon receipt of the first portion of explosives in the well, the elastic cone opens, forming a camouflage recess and reliably overlapping the section of the well. Using physical modeling of the action of the explosion of borehole explosive charges in a multi-strength rock mass [13], a technology was developed for blasting a borehole explosive charge with a cumulative recess in its lower part, which makes it possible to increase the fragmentation efficiency of the massif under conditions of a wide range of geological and geological properties of rocks, providing a compact homogeneous in fractional composition of the collapse. Thus, using the obtained results, the construction of charge was developed where a cumulative funnel is located at the bottom of the well. This will reduce the magnitude of the borehole charge overhead, reach the design level of the bottom of the ledge and provide the necessary granulometric composition of the blasted mass. The charge construction due to the location of the explosive charge directly above the zone of the bottom of the ledge will increase the effect of the explosion on it. The cumulative recess forms a stream, which creates a shock wave directed down and away from the well. In turn, the stress waves from the cumulative charge directed upward produce additional crushing of the overlying rocks. The direction of the energy of part of the explosive charge to the lower part of the well increases the time the explosion acts on the array and creates two waves of stresses that affect the entire array. The formation of this design is as follows (Fig. 1).

A polyvinyl chloride or wooden cylinder 1 is lowered to the bottom of the well, which serves to create a focal length, a cumulative funnel 2 is placed over it, an explosive 3 is poured, an intermediate detonator 4 is lowered, the rest of the explosive 3 is charged, and jamming 5 is formed.

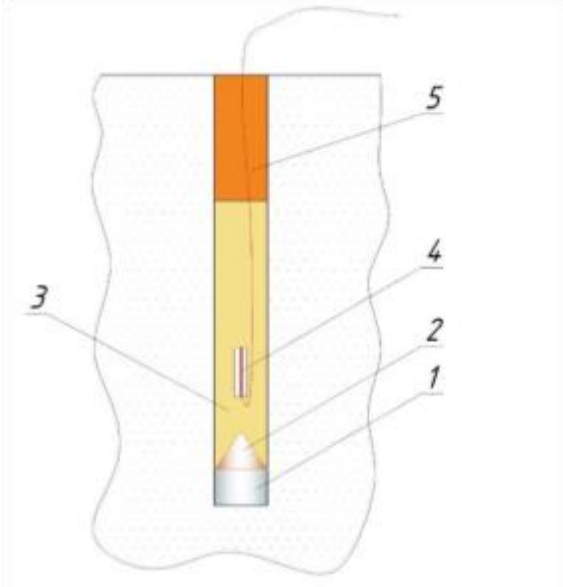


Fig. 1. The design of the borehole explosive charge using the cumulative effect 1 -

a wooden cylinder; 2 - cumulative funnel; 3 - explosive charge; 4 - intermediate detonator; 5 - stemming

The diameter of the lining is equal to the diameter of the well, and its height for wells with a diameter of 250 mm should be 210 ÷ 280 mm. It was experimentally determined that the optimal angle between the walls of the cladding should be 40-500. The wells are charged with the same explosives that are accepted at this enterprise. In the presence of solid inclusions in the base zone of the explosive ledge, it is recommended to use explosives with a higher detonation speed and increased brisance. To select these explosives, the tensile strengths of the enclosing rocks and rocks of solid inclusion are preliminarily determined. In this case, the choice of explosives for the bottom of the wells is carried out by the value of the detonation velocity of the explosives, determined from the ratio

$$D_{\partial} = D_0 \sqrt{2\frac{\sigma_{\text{р}}^{\text{вкл}}}{\sigma_{\text{р}}^{\text{вм}}} - 2\sqrt{\frac{\sigma_{\text{р}}^{\text{вкл}}}{\sigma_{\text{р}}^{\text{вм}}} + 1}}$$

where D_{∂} – detonation speed of explosives for well bottom charging, m/s;

D_0 – detonation speed of explosives for main wells charging, m/s;

$\sigma_{\text{р}}^{\text{вкл}}$ – breaking strength of tensile, Pa;

$\sigma_{\text{р}}^{\text{вм}}$ – tensile strength of host rocks, Pa.

The proposed technology also provides for the dispersion of the explosive charge in an inert gap, the lower element of which is made of explosives, corresponding to the strength characteristics of the rocks of the base zone of the ledge, and the upper one should correspond to the explosively category of the rocks constituting the ledge. This technology is protected by the RF patent [14].

INDUSTRIAL TEST OF THE DEVELOPED METHOD OF THE ROCK MASS DESTRUCTION BY BOREHOLE EXPLOSIVE CHARGES WITH A CUMULATIVE EFFECT

To conduct semi-industrial tests of the proposed design of the explosive borehole charge according to the approved program, a site with a coefficient of strength on the scale of prof. M. M. Protodyakonova f = 14-16 on the horizon 1160-1145 of the Sary-Cheku AGMK quarry, and an experimental blasting block No. 8 was prepared with drilling wells SBSh-250MN with a diameter of 250 mm, the distance between wells 7x7 m, between rows 8x8 m, the block consisted of 21 wells with a depth of 16 m with a 2 m reduction in spillage compared to the base method; an ANFO type explosive used in the base method of blasting at Sary- Cheku quarry was used to charge the wells.



Fig. 2. Experimental site for pilot testing of the developed crushing method

At the site of the experimental block, wells were drilled in rocks identical to the basic method with a coefficient of fortress on the scale of prof. M.M. Protodyakonova f = 14-16. The well depth was 16 m, and at the base it was 18 m. The charge design was adopted by a continuous core with reverse initiation by one intermediate detonator.

а)

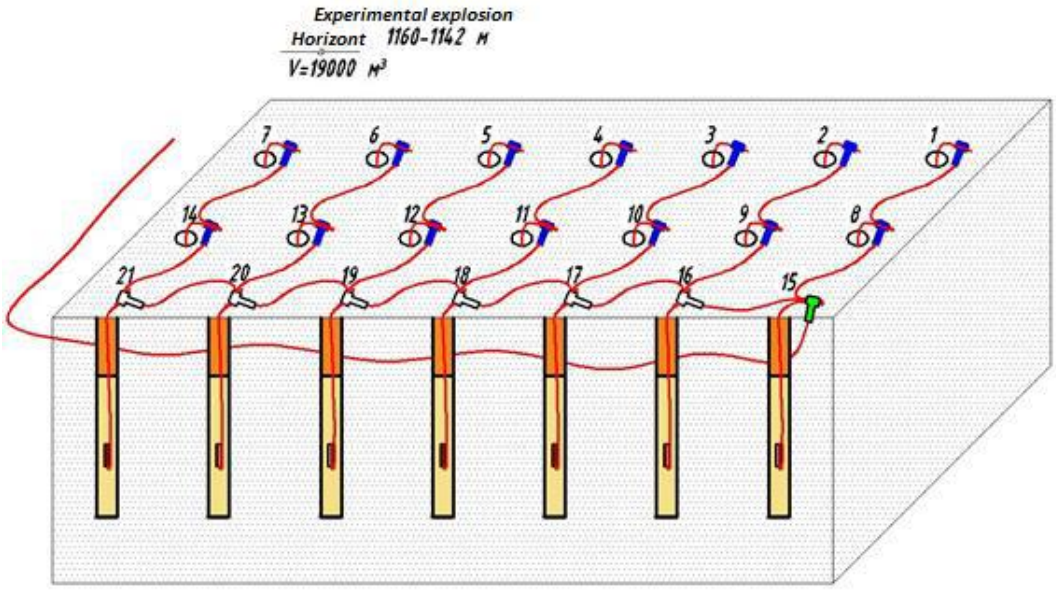


Fig. 3. Non-electric blasting circuit in the usual way

б)

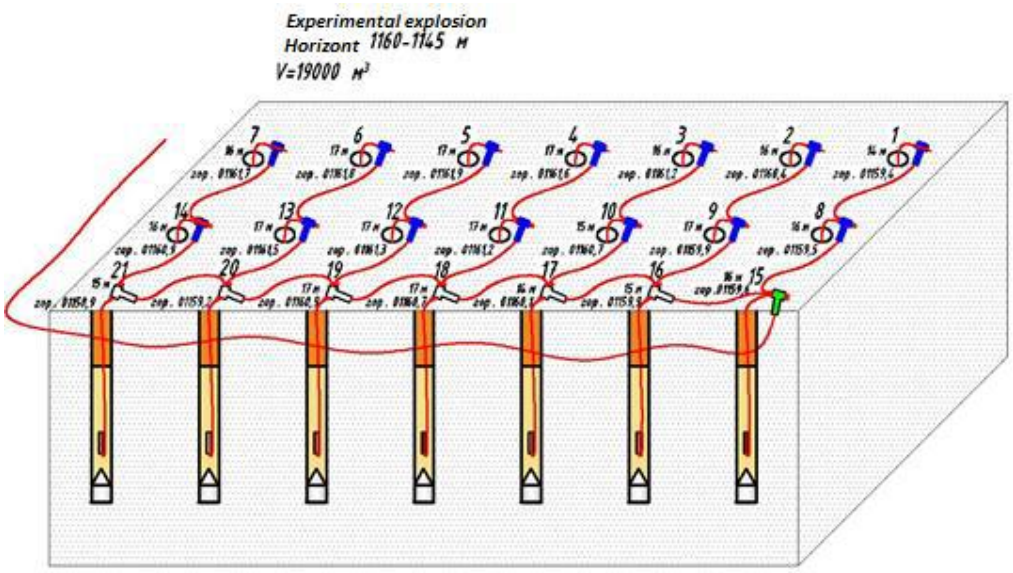


Fig. 4. Cumulative non-electric blasting circuit

The weight of the main charge of the ammonium nitrate explosive of the ANFO type was 400 kg for each well with a specific consumption of explosives of 0.44 kg / m3, with a base load of 550 kg, with a specific consumption of explosives of 0.61 kg / m3. To initiate the main charge, an intermediate detonator from an explosive substance Ammonite 6ЖВ was used, with a diameter of 90 mm and a mass of 2 kg. The blasting of borehole charges was carried out using the non- electric spark initiation system. To create the design of the borehole explosive charge with a cumulative effect, a metal cone made of steel 2 mm thick was used. The diameter of the cone was 220 mm, which is 30 mm less than the diameter of the well. Next, a explosive charge (ANFO) weighing 2 kg was laid. Above the conical lining, together with the explosive charge, an intermediate detonator of the KD-Iskra S-16, VV Almanit brand was installed. The charge design was adopted by a continuous column with reverse initiation by one intermediate detonator. During industrial tests of the developed design of the borehole explosive charge with a cumulative effect, a rock mass of 19,000 m3 was blown up. The main factors determining the effectiveness of the proposed new blasting method with respect to the base method are the granulometric composition of the blasted rock mass and the quality of the working out of the bottom of the ledge. The determination of the granulometric composition of the blasted rock mass and the development of the bottom of the ledge, based on surveying surveys, showed that the use of the developed design of the explosive borehole charge with a cumulative effect allowed to reduce the average size of a piece of blasted rock mass, as well as to achieve a satisfactory quality of the development of the bottom of the ledge with a decrease in the number of wells by 2 m.

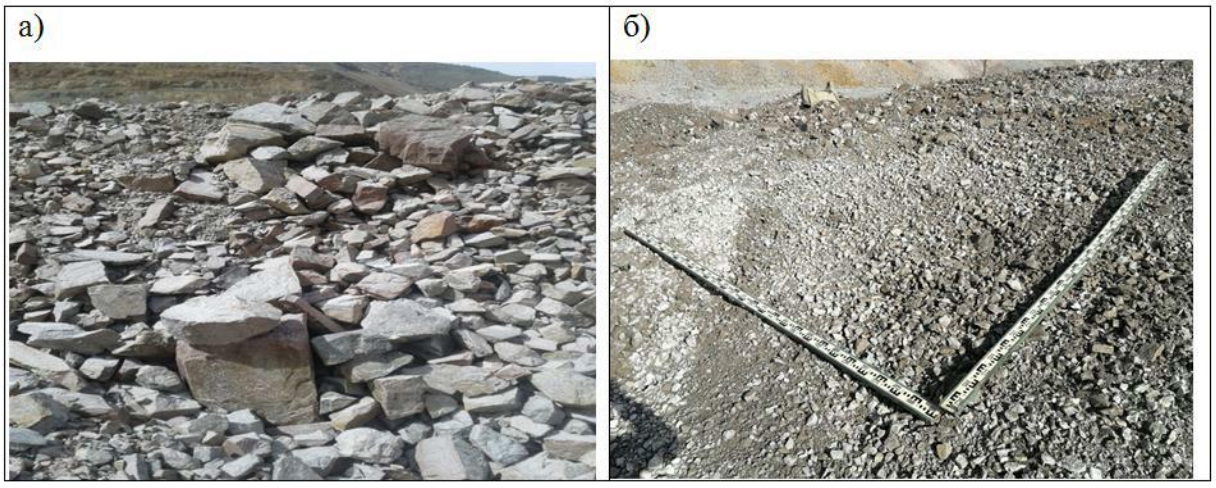


Fig. 5. The average size of the pieces when using the basic (a) and developed (б) methods of crushing a rock mass

After each explosion in the process of shipment, the granulometric composition of the blasted rock mass was also analyzed. Comparative data on the distribution of particle size distribution with the basic and developed methods of crushing different-strength rocks are given in table. 1. and in fig. 6. With the number of wells equal to 21, a reduction of drilling by 42 linear meters was achieved. m., which allowed to reduce the consumption of explosives ANFO by 3150 kg. Based on the results of an industrial test, it was determined that a decrease in the cost of drilling wells amounted to 8 thousand rubles, with a cost of drilling of 1 m 190 rubles. The reduction in the cost of explosives is 38.5 thousand rubles, with the cost of explosives ANFO 12,000 rubles / t. Reducing the volume of drilling made it possible to reduce the consumption of auxiliary materials (roller cone bits, drill rods, basic salary, depreciation, general workshop expenses) by 21.7 thousand rubles. The total cost reduction when exploding 21 borehole explosive charges and using the developed method exceeded 67 thousand. rub. To carry out blasting operations, 21 cones were made, worth 959 rubles. each, the total cost of the cones was 20 thousand rubles. In this respect, the economic effect of exploding 19,000 m3 of rock mass is 47 thousand rubles, and the cost savings per 1 m3 of blasted mass was 2.5 rubles. (table 2)

To determine economic indicators, the cost of materials and work were obtained from the Kalmakyr mine administration.

Table 1 Comparative data on the distribution of particle size distribution in the basic and developed methods of crushing rock mass

Linear fraction size, d, мм	The content of fractions depending on the method of crushing, n, %	
	basic	Developed
0-300	21,1	41,1
301-400	11,1	31,2
401-500	10,3	17,0
501-600	11,9	7,2
601-700	11,4	1,9
701-800	6,2	0,9
801-900	7,1	0,5
901-1000	10,7	–
more 1000	10,2	–

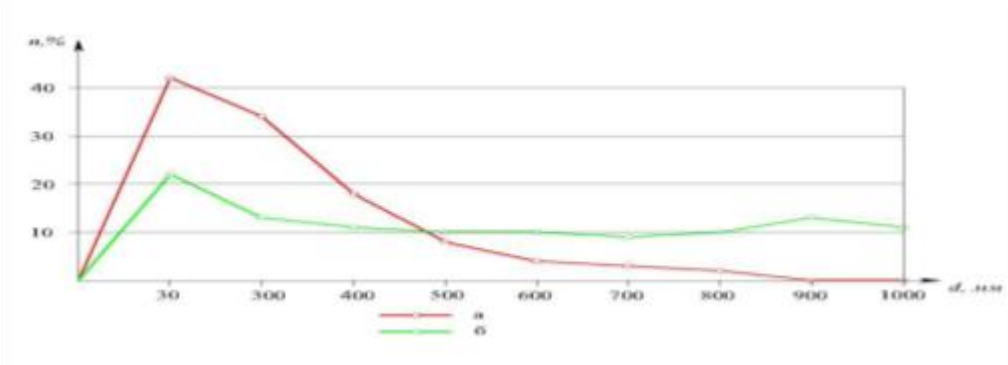


Fig. 6. The distribution of fractions of particle size distribution in the basic (a) and (б) developed methods of crushing rock mass

Table 2

Economic indicators of the developed method of crushing rocks by borehole explosive charges with a cumulative effect

Indicators	Method of crushing rocks	
	basic	New
1	*2*	*3*
Ledge height, m	15	15
Depth of main wells, m with perebour	18	-
Depth of main wells, m without perebour		16
Well diameter, mm	250	250
Blast hole grid, m	7,0x7,0	7,0x7,0
The number of main blast holes in the block,	21	21
The weight of explosives in the main well, kg	550	400

General weight of explosives in the wells kg	11550	8400
Well charge length, m	11	8
Volume of blasted rock mass, m^3	19000	19000
Specific explosive consumption, kg/m^3	0,61	0,44
The cost of 1 ton of explosive charge, rub.	12000	12000
Expenses on explosive charges, rub	138000	116300
The price of auxiliary materials used per 1 meter of wells, rub.	5170	
- cone chisel		
- drill rods		
- oil		
- industrial oil		
- basic salary		
- deductions		
-amortization		
- general shop expenses		
- electric energy		
- electronic computer services		
- cone cladding (21 things.), rub.	-	20000
Actual economic effect on 19000 $м^3$ of blasted rock mass is (according to 10.04.2019 г.), rub.	-	47000

MAIN CONCLUSIONS

1. A new method of explosive destruction of a rock mass in open-cast mining using borehole explosive charges with a cumulative effect has been developed, which allows for uniform crushing of rocks due to the directed use of explosion energy in the bottom zone of the ledge, to reduce the specific explosive consumption by 10% and the cost of drilling by increasing the grid of wells by 20-30%.

2. The effective parameters of the cumulative funnel in the design of the borehole explosive charge are determined. 3. A methodology has been developed for calculating the parameters of drilling and blasting operations when crushing rocks with charges located on a ledge without an overhead, which allows to optimize the cost of drilling and blasting.

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