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Increasing safety at rock preparation by blasting in open pits

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Abstract. The topicality of the present work lies in justification of the means of increasing safety during mass explosions in opencasts. The solution to this problem is possible due to the orientation of downholes in the array, taking into account the angle of incidence and extension of the strata, high-quality stemming and initiation of downhole charges by delay detonators with a minimal deviation from nominal values of their firing time. The most promising way to increase the safety and efficiency of blasting is an integrated approach, including drilling downholes, normal to the strata, and using the design of the downhole charge, rationally distributing the explosion energy in the space of the rock mass due to the use of stemming of a variable density, low-density gap between the parts of the explosive charge and the bottom a downhole compensator based on foam gel and the use of hybrid electronic detonator Iskra-T.

1 Introduction

Kuzbass has very diverse and complex mining and geological conditions for the development of coal opencasts. The seams of coal lie in the form of suites with different angles of incidence. Overburden consists of sandstones, siltstones and mudstones. The structure of rock masses sometimes even within the limits of a single blasting block varies from small-block (with sizes of natural units 200-400 mm) to large-block (with sizes of units 3000-5000 mm and more). In some cases, rock crushing, especially large-block structures, using the existing blasting technology is not enough to ensure productive operation of mining and transport equipment. One of the primary tasks of open cast mining is to improve the quality of rock preparation for excavation by excavator with the creation of safe conditions during blasting.

2 Materials and Methods

An important tendency in improving blasting is to increase the efficiency of the explosion by means of rational redistribution of explosive energy. By changing the spatial arrangement

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of downhole charges in a rock mass, it is possible to rationally distribute the energy of the explosion in the array.

F. A. Baum presented the mechanism of rock destruction by explosion as the combined effect from detonation products, shock waves and rarefaction waves [1]. In time and in the nature of physical phenomena, an explosion is characterized by several successive stages. At the initial stage of the process, the main role is played by expanding products of detonation, which at the first moment are under pressure of about 10^5 kg / cm^2. At this stage of explosion development in the rock array, there occurs plastic flow of the rock, emergence of radial cracks and its crushing. At the charge-rock contact, the compressibility law is applied, which determines the initial parameters and certain patterns of shock wave propagation. The second stage of the process begins after the shock waves exit to the free surface. It is associated with the propagation of the rarefaction wave reflected from this surface and its interaction with the tail of the traveling compression wave. As a result of this process, significant tensile stresses arise in the rock and, consequently, new cracks appear. The intersection of these cracks and the natural micro- and macrocracks present in the rock with the system of radial cracks arising in it at the previous stage of the explosion leads to the formation of a spatial network of cracks, the nature of which to a certain extent determines the possible size and number of rock pieces, crushed during the explosion. The third, final stage of the process is reduced mainly to the effect on the rock of already expanded products of detonation. By the time of its full expansion, detonation products still contain about 50% of the explosion energy of its total amount. Under the influence of this energy, various types of rock destruction occur during the penetration of gases into cracks, separation of individual pieces from the array, etc., displacement of the destroyed mass of rock and scattering of individual pieces of the array.

In the works of G. I. Pokrovsky [2], who considered the principle of self-similarity of the shock wave propagation during an explosion and main energy dependences, physically deeply substantiated representations of a qualitative picture of the effect of an explosion on a medium, established the parameters of a shock wave arising in a medium during the explosion of a spherical explosive charge.

A. N. Hanukaev [3] adheres to the theory according to which the process of destruction occurs under the action of elastic waves. Basing on the theory of rock destruction by the reflected wave, a proposition is put forward that the process of rock destruction largely depends on their acoustic rigidity.

G.P. Paramonov [4] shows that the destruction mechanism of a fractured array depends on what the cracks are filled with. If the cracks are filled with solid material, then the destruction occurs mainly due to stress waves. When cracks are filled with air, the stress wave destroys only the part, in which the charge is located, further destruction occurs due to the products of detonation.

Adhering to the classical ideas about the mechanism of destruction of rocks with a layered structure, explosive preparation of rocks for excavation by the method of downhole charges includes drilling parallel rows of vertical or deviated downholes, loading them with explosive followed by stemming, assembling blast pattern and short-delay blasting.

Downholes are drilled at a calculated distance according to a rectangular or checkerboard pattern. Moreover, in the array downholes are located so that the longitudinal axis of each well on the plane of the ledge slope is designed as a perpendicular to the generators of the upper and lower edges of the ledge. In this position, the axis of the well intersects the bed plane at a certain angle. In most cases, the most favorable conditions for crushing the array occur when the fracture load from the blast of an explosive charge in the rock layer is strictly perpendicular to the bedding or when the bedding extends parallel to the charge [5, 6].

At present, the design of explosions does not take into account the relationship of shear stresses in the direction of layering and the direction of fracturing of the array. If the angle of incidence of the strata is between 35 and 65 degrees with the downhole axis, then the stress wave attenuates in a separate part and the quality of the array fragmentation deteriorates. Therefore, for uniform crushing of the array with an unfavorable location of the charge relative to the strata, an increased specific consumption of explosive is required. Charges with the same specific explosive consumption on one block without taking into account the structure of the array crush it with unpredictable results.

3 Results and Discussion

In order to study the possibility of uniform crushing of the rock within the entire ledge, before designing drilling and blasting operations at one of the casts, the array was surveyed using the OKO-2 georadar with a screened collapsible antenna unit AB-9. Analysis of radarograms and photos of the slope of the ledge showed that the angle of incidence of the strata surface was 10-22 degrees, and the azimuth of their fall 120-140 degrees. At a certain distance from the inspection site, the surfaces of the strata flatten out, and after another 85-100 m the angle of incidence of the strata changes to 146 degrees.

Quality analysis of the explosive preparation of the rock for excavation at Kuzbass coal opencasts allowed us to obtain a pattern of change in the size of the piece in the broken rock disintegration depending on the spatial location of the downholes in the layered array (Fig. 1).

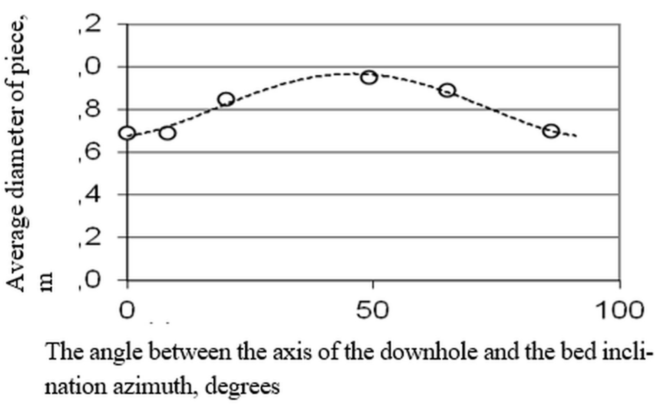

Fig. 1. Change in piece size in broken rock disintegration depending on the angle of the downhole charge with the bedding of the array.

Analysis of the graph shows that a good quality of overburden preparation for excavation was obtained when drilling downholes relative to the bedding plane at an angle of 85-90 degrees and if the drilling direction coincides with the bedding plane.

Since [7] allow the drilling rig to be installed at any angle with respect to the slope of the ledge, downholes can be drilled at an angle close to normal with respect to the bedding azimuth.

All other things being equal, the material and stemming quality play a significant role in the design of the downhole charge. Stemming of downholes is designed to increase the momentum of detonation products due to the duration of their impact on the array. In Kuzbass coal opencasts, as a rule, drill cuttings are used as a stemmer. It is recommended that the magnitude of the stemming from drill cutting be proportional to the diameter of the downholes. Drill cuttings and other high-density materials used as stemming during mass explosions have high inertial characteristics, so they fly out of the downhole without properly locking the detonation products.

The greatest effect is obtained by stemming, which ensures the locking of detonation products due to clamping of the downhole channel. These properties are possessed by a variable density stemming consisting of a combination of a low-density porous material and a layer of drill cuttings. The property of low-density porous stemming to enhance the explosive effect of an explosion on an array in combination with the possibility of dust suppression.

The mechanism of this stemming construction is as follows. After the downhole is loaded with explosive, the space above the charge is filled with foam gel in the sleeve, the top of the sleeve is filled with a drill cuttings to the level of intense fracturing of the rock array from the previous explosion.

The effect of clamping the downhole channel in the upper part is explained by the fact that the propagation velocity of the stress wave has a finite value, and, depending on the blockiness of the array, amounts to 800–3000 m / s in the rock, 330 m / s in air, and 1500 m / s in water, and in the low-density composition only 30–50 m / s.

In addition to low-density stemming, the design of the downhole charge may consist of a low-density gap dispersing the downhole charge. This is carried out using a sleeve with its filling with foam gel [8].

Blasting of downhole charges is usually carried out by short-delayed blasting with non-electric initiation systems with shock tubes.

The main technological drawback of non-electric initiation systems is the low accuracy of the moment of charges initiation, which does not always allow achieving the desired results of a mass explosion.

When using short-delay blasting with non-electric initiation systems the main contribution to the deviation from nominal delay time is made by downhole detonators with a long delay time (1000-2000 ms). “Novosibirsk Mechanical Plant “Iskra" developed and is launching a new generation of initiation means - hybrid electronic detonators ISKRA-T [9].

Unlike pyrotechnic initiation systems in hybrid electronic detonators ISKRA-T, instead of the delay composition, where the deviation of the delay time reaches ± 7% of the nominal value, an electronic micromodule is used which provides an accuracy of ± 1 ms with any specified delay time in the range from 0 up to 2000 ms and with a programming step of a delay time of 1 ms (Fig. 2).

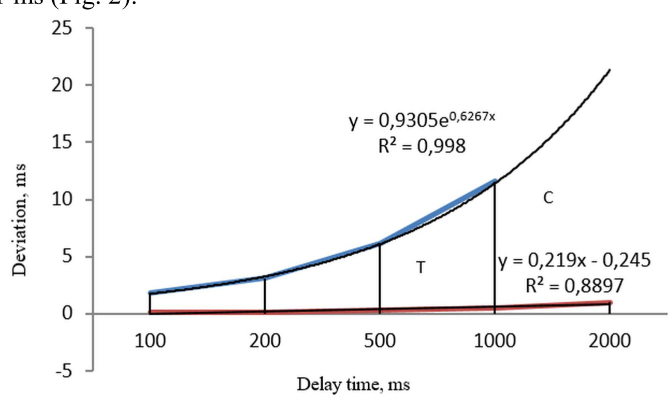

Fig. 2 Delay time deviation depending on the delay time.

4 Conclusion

As the experimental results show, the use of ISKRA-T downhole detonator caps with electronic delay is more preferable from the point of view of seismic effects of industrial explosions.

Thus, an integrated approach to the design and conduct of mass explosions with the above measures will improve the safety of blasting in coal opencasts.

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