ANNOTATION

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DEVELOPMENT OF INNOVATIVE METHODS FOR AUTOMATED DETERMINATION OF THE STRUCTURAL CHARACTERISTICS OF BLASTED ROCK BASED ON INFORMATION TECHNOLOGIES

Relevance of the topic.

At the mining enterprises of the world, the parameters of the location of explosive charges in the blasted part of the solid are taken on the basis of experimental data and require their experimental confirmation. The preparation of rocks for excavation by explosive means requires scientific substantiation of the adopted technological solutions. One of the main results of drilling and blasting operations at mining enterprises is the structure of the blasted rock mass, i.e. granulometric composition of blasted rocks, placement of their crushing zones, placement of heterogeneous rocks of the broken layer of the solid in the shotpile of the rocks.

Establishment of patterns of formation of structural characteristics of blasted rocks in quarries and their automated determination is an important and urgent task of mining science and production.

Many scientific works are devoted to the solution of this problem. To assess the quality of the blasted rock mass, some authors use the well-known model for the distribution of the granulometric composition of pieces of rock Kuz-Ram by the authors of the same name Kuznetsov and Rozin-Rambler. Other authors (P.H.S.W. Kulatilake, M. Monjezi) try to predict the size distribution of the blasted rock mass based on the use of neural networks. To determine the internal structure of the collapse of rocks, the use of tensor calculus is proposed (Galyanov A.V.). However, such attempts have not been brought to the engineering calculation, because. they do not take into account the real mechanism of destruction of rocks by an explosion.

To solve this problem, this paper uses a different from the known model of destruction of a real rock mass, developed by Academician B.R. Rakishev, which is based on the idea of Academicians M.A. Sadovsky, E.I. Shemyakin, professors G.I. Pokrovsky, V.N. Rodionov about the stage-by-stage development of an explosion of an explosive in a solid medium and the effect of an explosion estimated by the size of the cavity formed by the explosion of an explosive charge. B. Rakishev established patterns of change in the limiting radius of the explosive cavity - the fundamental result of an explosion in a solid medium during the explosion of cylindrical explosive charges, depending on the physical and mechanical properties of rocks, the physical and chemical characteristics of the explosive used and the

conditions for blasting the blasted layer of the rock mass. They form the scientific basis for the selection of effective innovative technologies for blasting in quarries.

The purpose of the study is to identify patterns in the formation of the structural characteristics of blasted rocks and to create innovative methods for automated determination of the granulometric composition of blasted rocks, placement of their crushing zones, placement of heterogeneous rocks in the broken layer of the massif in the shotpile of the rocks.

The idea of the work is to increase the efficiency of mass explosions in quarries using innovative methods for automated prediction of the structural characteristics of blasted rocks based on digital technologies.

Research tasks:

In accordance with the goal set in the dissertation, the following tasks are formulated:

1. Development of an updated analytical method for predicting the granulometric composition of the blasted rock mass, the placement of various rock crushing zones in the shotpile of the rock mass.
2. Creation of new methods for determining the nodal and internal points of the coordinate grid of the blasted block, the placement of heterogeneous rocks of the blasted bench layer in the shotpile of the rock mass.
3. Development of an information experimental platform (IEP) for simulating, visualizing the results of explosions and managing them in real time.

Basic provisions for defense:

1. The formation of the granulometric composition of blasted rocks due to the combined action of stress waves, detonation products of an explosive explosion and collision of large pieces during movement depends on a different combination of physical and mechanical properties of rocks, blockiness of the rock mass, chemical and physical characteristics of the explosive used, and the parameters of the location of charges in the chipped layer of the rock mass breeds.
2. The placement of heterogeneous rocks of the bench in the shotpile of the rock mass is determined by the coordinates of the nodal points of the blasted block of the bench and the internal points of the elements of the coordinate grid of the blasting and blasted blocks. They depend on the coefficient of proportionality of the change in the coordinates of the nodal points and the function of moving the element of the coordinate grid of the blasting and blasted blocks.
3. The set of software modules "Graunulometric composition of natural fragments in a rock mass", "Dimensions of zones of intensive crushing of rocks", "Rational parameters for the location of charges in a bench", "Graunulometric composition of the blasted rock mass", "Participation of heterogeneous rocks in the shotpile" is an information and experimental platform (IEP) for controlling the process of destruction of rocks by the action of an explosion in open pits.

Main results of the study:

1. On the basis of taking into account the joint destruction of the blasted block of the bench due to the action of stress waves, the action of detonation products and the impact of large pieces during movement, the regularities of the formation of the granulometric composition of blasted rocks depending on various combinations of physical and mechanical properties of rocks, blockiness of the rock mass, chemical and physical characteristics of the applied explosives, drilling parameters. Software has been created for automated determination of the granulometric composition of blasted rocks under various blasting conditions.

2. Using the coordinate grids of the blasting and blasted blocks of the bench, the regularities of the location of heterogeneous rocks in the broken layer of the rock mass in the shotpile and other geometric characteristics that determine the internal structure of the rock shotpile were established. A software module has been developed for automated prediction of the placement of heterogeneous rocks in the shotpile under various blasting conditions.

3. By combining the developed software modules, an information-experimental platform (IEP) has been created that allows for convenient and flexible calculation of blasting parameters, their results for various values of physical and mechanical properties of rocks and physical and chemical characteristics of explosives, parameters of the location of charges in a rock mass and blasting conditions.

Objects of research or development - explosive destruction of rocks in quarries with blasthole charges.

The subject of the study is the structural characteristics of blasted rocks in quarries.

Methodological base of scientific research

When performing scientific research, complex research methods were used, including analysis and generalization of scientific and technical information, theoretical studies, methods of mathematical modeling, methods of mathematical statistics for processing experimental data and a feasibility study of various technology options, correlation and regression analysis, as well as methods of empirical and object-oriented programming to create software modules.

The novelty of the topic lies in the development of an innovative system for automated prediction of the results of drilling and blasting in open pits using the established new patterns of crushing rocks by an explosion of a cylindrical explosive charge in a bench. The fundamental difference between the proposed methods for determining the parameters and results of mass explosions in open pits from the known ones lies in the fact that in mining science, for the first time, the limiting radius of the explosive cavity formed by an explosive explosion in the rock has been adopted as a determining indicator of the results of an explosive explosion in a solid medium. It successfully interconnects the final result of the explosion with the

physical and mechanical properties of the rocks, the physical and chemical characteristics of the explosive used and creates a scientific basis for the development of various software modules for the automated prediction system for drilling and blasting results in open pits.

The practical significance of the work

Using the created IEP, the technological characteristics of the exploded rock mass, the rendering of the development of the explosive cavity during the explosion of a cylindrical explosive charge, the positions of the sizes of zones of intensive crushing under various blasting conditions, the configuration of the shotpile of the exploded rock mass, its internal structure with the allocation of crushing zones are determined. With the help of IEP, it is possible to perform an unlimited number of virtual experiments, simulate various B&D technologies, visualize and predict their results. Properly managing the process of blasting rock masses, it is possible to achieve the necessary technological parameters of the blasted rock mass in quarries.

These procedures are based on proven methods for determining the granulometric composition of the natural parts of the rock mass (blockiness of the rock mass), the strength characteristics of rocks under explosive loading, the relative limiting radius of the explosive cavity, the radii of the fine crushing zones, the rational parameters of the drilling and blasting, the particle size distribution of the blasted rock mass, the internal structure of the shotpile of the exploded rock mass under various production conditions.

Compliance of work with the directions of development of science or state programs

The work was carried out within the framework of the target financing program BR05235618 "Modernization of technologies and production in the mining and processing industries of the Republic of Kazakhstan" (project "Creation of a system for automated design of rational parameters of drilling and blasting and predicting their results in open pits in Kazakhstan (CAD B&D)") 2018-2020. 2018-2019, economic-contractual topic "Implementation of innovative drilling and blasting technologies based on computer-aided design of parameters and results of mass explosions in the quarries of SSGPO JSC" at the Sokolovsko-Sarbayskoye field 2018-2019.

Publications and approbation of work.

The main provisions of the dissertation work were reported at the XXVII-XXVIII International scientific symposia "Miner's Week-2019", "Miner's Week-2020" (Moscow, 2019, 2020), the international scientific and practical conference "Rational use of mineral and technogenic raw materials in conditions of Industry 4.0" (Almaty, 2019), scientific and practical conference "SATPAEV READINGS - 2020" (Almaty, 2020).

Approbation of the created analytical methods and software was carried out within the framework of the economic contract theme "Implementation of innovative drilling and blasting technologies based on computer-aided design of parameters and results of mass explosions in open pits of JSC SSGPO" at the Sokolovsko-Sarbaiskoye field.

On the topic of the dissertation, 8 publications were published. Of these, one in the journal included in the 2nd quartile according to the Scopus database, 4 - in the journals included in the 3rd quartile according to the Scopus database, 1 - in the journal recommended by the CQASES MES RK, from 3 of them are in the materials of conferences. A worthy contribution was made to each published article by the doctoral student, they reflect the provisions submitted for defense, the results obtained by the doctoral student in the course of the research.

Obtained 2 copyrights for the developed software.

1 methodical manual has been issued.

Scope and structure of work.

The dissertation consists of an introduction, three sections, a conclusion, a list of references and applications. The volume of the dissertation is 130 pages of typewritten text, 17 tables, 109 figures, a list of references, including 94 titles and 2 appendices.

Conclusion

1. Taking into account the fact that the destruction of the exploding ledge block is carried out due to the action of stress waves and reflected waves (stage I of the explosion), due to the action of detonation products (explosive action of the explosion) (stage II of the explosion) and collision of large pieces during movement (stage III explosion). Regularities were established for the formation of the granulometric composition of blasted rocks depending on a different combination of physical and mechanical properties of rocks, blockiness of the massif, chemical and physical characteristics of the explosive used, and parameters of the drilling and blasting. Based on them, a theoretical method for determining the granulometric composition of blasted rocks has been developed. Software has been created for automated determination of the granulometric composition of blasted rocks under various blasting conditions. Examples of using the program are given. Comparison of the actual data of the granulometric composition of rocks with the calculated one, found using the developed computer program, confirms their complete identity.

2. In order to determine the internal structure of the shotpile of rocks, the concept of coordinate grids of the blasting and blasted bench blocks was introduced. Their joint use makes it possible to determine the location of the fixed elements of the bench in the shotpile, its configuration and other geometric characteristics. Based on the joint consideration of the analytical method for determining the granulometric composition of rock masses and the graph-analytical method for determining the

zones of fine, medium and coarse crushing, analytical methods have been developed for determining the nodal and internal points of the coordinate grid of the blasted block, the sizes of various rock crushing zones in the shotpile of the rock mass. They served as the basis for creating a software product for determining the internal structure of the shotpile of rocks. Examples of using the program under the conditions of exploding model ledges are considered.

3. 3. The developed software modules "Graunulometric composition of natural fragments in a rock mass", "Dimensions of zones of intensive crushing of rocks", "Rational parameters for the location of charges in a ledge", "Graunulometric composition of the exploded rock mass", "Participation of heterogeneous rocks in the shotpile" in the complex can be be considered as an information and experimental platform (IEP) for controlling the process of destruction of rocks by the action of an explosion. Using the platform, the technological characteristics of the exploded rock mass are determined, the development of the explosive cavity is drawn during the explosion of a cylindrical explosive charge, the position of the sizes of zones of intensive crushing under various blasting conditions, the configuration of the collapse of the exploded rock mass, its internal structure with the allocation of crushing zones. Thus, with the help of IEP it is possible to perform an unlimited number of virtual experiments, simulate various B&D technologies, visualize and predict their results. Properly managing the process of blasting rock masses, it is possible to achieve the necessary technological parameters of the blasted rock mass in quarries.