#### ABSTRACT

Of the dissertation for the degree of Doctor of Philosophy (PhD) in speciality 6D070700 – Mining

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## Developing Progressive Technological Schemes of Driving and Supporting Mine Workings with Management of Enclosing Coal-bearing Massif Stability

**Relevance of the work.** Among the main factors that determine reliability of the main subsystems of the mine (stope face, ventilation, transport, degassing) functioning is stability of the local development workings.

With the transition of mining operations to great depths of development, the issue of maintaining mine workings, including the use of anchors of increased bearing capacity, has become urgent. At coal mines, to strengthen the support of large-span mine workings, column, mixed and frame support are used. To ensure a stable state of large-span workings and junctions for the entire period of operation, it is most expedient to use a two-level roof bolting, where, in addition to level I anchors are used. The roof bolting, in contrast to the supporting type, immediately after installation provides bonding and strengthening of the rock mass in the roof and sides of the mine and actively counteracts the development of rock displacements and deformations. This advantage makes it possible, with a significantly lower metal content of the support, to provide an increase in the stability and reliability of maintaining the workings.

Comparison of technical and economic indicators for securing workings with a width of 6–7 m showed that the use of two-level roof bolting instead of frame bolting leads to a decrease in: the total cost of fastening the interface by about 1.5 times; labor intensity of work approximately 1.2-1.3 times. The experience of using two-level anchoring of large-span workings and junctions made it possible to draw the following conclusions about the advantages of this support over analogues: low material costs (for example, workings joints, the costs of fastening can be 2.5 times lower in comparison with frame support); low metal consumption, and therefore low labor intensity during delivery and installation; ensuring the bonding and strengthening of rocks immediately after the installation of the support, as a result of which the stratification of the enclosing rocks and the load on the support are reduced.

In this regard, an urgent scientific and practical task is the geomechanical substantiation of the parameters of the technology of securing mine workings, incl. for wide chambers for various technological purposes and interfaces, deep anchors and adaptation of this technology in the conditions of the mines of the Karaganda coal basin. The work was carried out on the topic of R&D: No. AR05135535 "Development of a contour technology for securing workings with control of the technogenic state of the coal-rock massif of enclosing rocks", grant funding for scientific research of the Ministry of Education and Science of the Republic of Kazakhstan for 2018 - 2020.

The purpose of the dissertation is to develop progressive technological schemes of driving and supporting mine workings with control of the enclosing coal-rock massif stability on the basis of geomechanical substantiation of the parameters of the technology of supporting development workings with rope, cable-rope and combined anchors in the zones of interfaces with longwalls, intersections of workings, wide chambers to ensure the efficiency and process safety.

The idea of the work is to use scientifically substantiated parameters of the tools and technology for supporting development workings with rope, cable-rope and combined anchors to ensure the stability of the environment of the "deep anchor system and anchorage bridge - enclosing rocks" at the intersection of workings, junctions, assembly chambers and area widening cross section.

### The tasks of the study:

- analyzing modern domestic and foreign experience in the development and application of technology for supporting mine workings; determining the reasons for decreasing stability of the junctions of the development workings with long wall faces, assembly and dismantling chambers;

- geomechanical substantiating the parameters of the technology of supporting the near-contour massif of development workings with deep anchors in development conditions that differ from the standard ones (interface with longwalls, intersection of workings, wide chambers, etc.);

- manufacturing and bench testing strength and load properties of deep-laid rope and cable anchors, end fittings of steel-polymer anchors and their pilot mining research;

- analytical studying of the near-contour rock massif of mine workings to predict the height of the collapse arch and the depth of the spread of layering in the rock massif of the roof, taking into account manifestations of rock pressure in the zones of interfaces with longwalls, the intersection of development workings, wide chambers of the mines of the Karaganda coal basin;

- developing and implementing at the mines of the Karaganda coal basin the technology of supporting development workings with deep anchors in the areas of interfaces with stoping faces.

**Research methods:** carrying out bench tests of the deep roof bolting elements, mine research of regularities, numerical modeling of the degree of deformation of roof rocks; production experiments.

## The main scientific provisions presented for the defense:

- analytical studies of the rock mass around the workings, forecasting of the arch formation of the collapsed roof rocks, based on the current stress-strain state of the rock mass, with the choice of a rational length of deep anchors;

- the stability of the joints of the development workings of mines is determined by the thickness of the massif anchored with anchors, depending on the size of the destroyed rocks around the mine contour and the mutual ratio of the strength and thickness of the bearing layers of rocks in the roof;

- When arches of natural equilibrium of an increased size are formed, due to geomechanical manifestations of rock pressure, stabilization of the contour of

unstable rocks in the redistribution of the arch is achieved by the formation of a transverse bridge of fixed rocks, and outside the arch by installing deep anchors to create a single load-bearing self-stabilizing structure.

# The main scientific results, conclusions and recommendations are as follows:

1. To expand the scope of application of the roof bolting in conditions that differ from typical conditions, it is recommended for operation rope, cable and combined deep anchors in the rock massif. Substantiation of the parameters (5 - 7 m and more) of the anchors outside the natural balance arch was carried out on the basis of complex bench, mine experimental-industrial research and experiments to determine the working capacity and bearing capacity.

2. Based on the results of bench tests, it was found that the strength characteristic of the AK 19/5 rope anchor was 330 - 340 kN in terms of breaking force. In manufacturing a combined (metal-rope) deep-laid anchor, a reinforcing rope was used as a long flexible part (2/3 of the anchor length). The test results are confirmed by the passport characteristics of the ropes and the reliability of the connection of the couplings with the rope by means of a wedge collet bushing.

3. Geomechanical substantiation of the design parameters and technology for supporting deep anchors during strengthening the roof of workings at the interface with the longwall was carried out and a technological scheme of supporting development workings with steel-polymer-rope roof bolting at the interface with the longwall was developed.

4. Pilot tests in mine conditions have confirmed reliability of operation and the calculated parameters of the rope anchors in terms of bearing capacity. Geomechanical studies in the experimental section supported with the rope anchors, according to the criterion of roof stratification, is more favorable than in standard sections supported in front of the longwall with an advance support made of two rows of hydraulic props. The magnitude of stratification of the roof rocks along the lower level of the sensors fixed with rope anchors did not exceed the maximum permissible (150 mm), and the maximum load on the anchor did not exceed 26 tons.

## The scientific novelty of the thesis is as follows:

- the dependence of the bearing capacity of steel-polymer-rope roof bolting on the parameters of the borehole (well) and the completeness of filling the borehole has been established;

- the design of steel-polymer-rope roof bolting with an end part in the form of a cutting cutter has been substantiated, which makes it possible to carry out high-quality destruction of ampoules, mixing the components of the composition and supporting the borehole;

- laboratory and mine studies have proved the effectiveness of fixing workings with steel-polymer anchors with an end part in the form of a chisel-shaped cutting mill, the use of which allows you to increase the bearing capacity of anchors by 1.15 times, due to the uniformity of mixing of the fixing composition;

- in the process of interaction of steel-polymer-rope complex roof bolting and near-contour rocks, "self-stabilization" of efforts, stresses and deformations occurs

in the fixed part of the massif with the manifestation of the effect of "stabilization of the cage" and increasing strength of the "support-massif" system.

The author's personal contribution consists s in the formulation of research tasks, carrying out mine tests and analytical studies, developing the main scientific provisions and conclusions, in the development of technology and tools of multi-level supporting the contour rock massif.

The practical significance of the work consists in the fact that based on the results of experimental research, analytical modeling, design studies, progressive innovative solutions have been formed (at the level of patents of the Republic of Kazakhstan) in terms of structural (in length, size, completeness of constituent elements, installation density), technological (locations relative to the contours of and elements of coal seam occurrence, the influence of complicating factors and mining development schemes and supporting parameters) and technical and economic characteristics (reduction of metal and labor intensity of work for supporting mine workings to increase the rate of their implementation and stability; according to the developed prototypes of systems and tools, the active supporting of mine workings and a design study of technological solutions for their layout was carried out; in the development of an effective multi-level technology for anchorage of development workings for various mining and technological operating conditions.

The practical value of the work consists in the development of progressive solutions for implementing the technology of the roof bolting the workings of the rock masifs weakened in strength to ensure the efficient and safe operation of coal mines. The design study and production of pilot batches of supporting devices were carried out with their testing in production conditions at coal mines; developing the technology, methods, systems and tools of anchoring, taking into account the geomechanical state of the massif and mining development schemes (an application for an innovative patent has been submitted); the formation of progressive technological solutions, manufacturing an experimental-industrial batch of tools for contour strengthening of the rock massif and the monitoring of the implemented technologies of supporting the contours of workings (pilot-industrial batches for various purposes).

**Participation in R&D, grant financing as a performer:** R&D on the topic: No. AP05135535 "Developing contour technology of supporting workings with control of the anthopogenic state of the coal-rock massif of enclosing rocks", grant financing of scientific research of the Ministry of Education and Science of the Republic of Kazakhstan for 2018 - 2020.

**Implementation of the work**. Recommendations have been developed for the use of the technology of anchoring workings while supporting development workings at the interfaces of stoping faces, wide workings of coal mines. The research carried out in the dissertation work was introduced in pilot tests of deeplaid rope and cable anchors at the Abayskaya mine, in the form of an Agreement of intent to introduce the technology in mine conditions and in the educational process.

Based on the results of implementing the research projects under targeted grants from the SC of the Ministry of Education and Science of the Republic of Kazakhstan, there were received the acts of testing and implementing supporting devices at the Abayskaya mine of the Coal Department of ArcelorMittal Temirtau JSC, in the educational process of KSTU in the disciplines of bachelor's and master's degrees in specialty "Mining" and the protocol of intent for use in production during mining operations at the Abayskaya mine of the Karaganda coal basin.

Validity and reliability of scientific provisions, conclusions and recommendations are confirmed by the similar results of theoretical studies and experimental tests.

**The dissertation approbation.** The research results are published in 1 scientific article in the edition included in the Scopus database; in 3 articles in the editions recommended by the authorized body (CCES), 6 abstracts of international scientific conferences, 3 SISs. There was submitted an application for a patent of the Republic of Kazakhstan. The results of scientific research obtained in the dissertation have been introduced into the educational process in the disciplines of bachelor's 6B07202 and 7M07203 master's degree specialties "Mining".

As part of implementing the projects for grant funding from the SC of the Ministry of Education and Science of the Republic of Kazakhstan, the Act of Implementation into the Educational Process and the Protocol of Intent to Implement into Production were received.

The main provisions of the work were reported and received approval at scientific seminars of the DMD Department of the KTU NJSC, the Scientific and Technical Council of the KTU NJSC.

The doctoral student thanks the scientific consultants for their recommendations and help in carrying out experiments and performing individual stages of the dissertation work: engineers and technical workers of the Karaganda coal basin mines, employees of the laboratories of Karaganda Technical University, the KLMZ plant and the Russian company Roof Bolting Technologies LLP.

**Structure of the dissertation work.** The dissertation consists of an introduction, 6 sections, a conclusion, a list of references from 88 titles, contains 131 pages of computer text, including 91 figures, 9 tables.