ABSTRACT

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

Khalikova Elvira Ravilovna

Development of effective mine - working technology on the basis analytical models of geomechanical processes

Relevance of the work. The world experience of leading coal-mining countries (USA, Australia, China, etc.) shows that efficient and reliable supporting of capital and development workings can be achieved using steel-polymer anchors with the bearing capacity of at least 100 - 130 kH. Monitoring the use of the roof bolting in coal mines shows that, in accordance with the existing regulatory documents, it is used as primary and secondary support in combination with a metal frame pliable support. The existing methods of determining the roof bolting parameters are based on supporting mine workings by means of developing an anchor bridge or "suspension" of relatively weak layers to the thick one in the strong zone of stable rocks.

The task of developing efficient supporting mine workings in mines has not been completely solved due to the fact that the currently used method of supporting winning workings with frame metal arch supports with strengthening props is very labor-intensive and metal-intensive, and in the presence of coal seams in the immediate roof there are layered fractured rocks with the thickness of more than 3 - 4 m, and in the main roof there are hard-to-break rocks, there is not provided a repair-free condition of the workings during the service life of the workings.

Therefore, one of the current trends in the coal mining industry is developing a technology of supporting winning workings, taking into account the anthropogenic state of the contour massif in the areas of increased displacement due to various types of disturbances in the occurrence of enclosing rocks and changes in the occurrence of coal seams.

The goal of the dissertation consists in developing technological schemes of strengthening the weakened rock zone at the intersection of the geological disturbance with a development mine working (including at the entrance and at the exit from it), which increase stability of the rocks surrounding the mine.

To achieve the goal, in the doctoral dissertation the following tasks have been solved:

- there have been evaluated the mining conditions for the use of technological schemes of supporting mine workings in mining operations;
- there have been conducted mine observations to establish the defectiveness of the development workings in coal mines driven in the zone of the geological disturbance effect;
- there have been found the dependencies of the zones of destruction and reduction of the rock strength along the perimeter of the mine on the geological and technological parameters in the vicinity of the contours of the mine workings;

- there have been found the patterns of developing deformation processes in mine workings, including those in undisturbed and weakened by disturbances enclosing rocks;

- there have been established the regularities and quantitative indicators of stresses of destruction and displacement of rocks in the roof of the workings to develop methods of their effective support;

- there have been proposed systems and tools of the roof bolting during the operation of the workings, taking into account the geomechanical state of the contour massif;

- pilot batches of multi-level and multi-purpose hardening systems for the rock mass have been manufactured and the implemented technologies of supporting the mine working contours have been monitored; the results of research on the improvement and implementation of technological schemes of driving workings have been introduced;

- industrial experiments have been carried out at the Abayskaya mine of the CD ArcelorMittal Temirtau JSC to strengthen the roofing of the mine workings;

- there have been developed progressive methods of supporting when driving workings in the areas of geological disturbances.

- the technological schemes have been developed for the effective support with the pillarless protection of the mine workings in the disturbed enclosing massif.

Idea of the work consists in ensuring stability of the mine working contour when crossing the zone of unstable rocks due to stabilization of the bearing rock layer by means of developing an advance enclosing contour of an inclined overlapping roof bolting with the system of metal rods with the helical surface mounted in the roof and the working sides in drilled holes (or wells) in a certain order: by density, location angles and length, with chemical fixation with resin.

Methodology of the work. A comprehensive research methodology was used in the work, including generalization, assessment and analysis of specialized information contained in industrial practice, literature and patent sources; numerical simulation; development of technological solutions aimed at solving assigned tasks; pilot industrial, experimental mine research.

Main scientific provisions to be defended are as follows:

- the proposed system of metal rods with the helical surface mounted according to the contour diagram with the length of 1.8–2.4 m with the density of 0.8–1.2 anchor/m^2, chemically fixed in the roof and sides of the mine working, contributes to the developing of a single monolithic plate working as a single system "rock-support", and provides repair-free maintenance of development mine workings;

- the obliquely mounted injection discharge anchors 2.0–2.5 m long through 0.8–1.2 m, fixed with pumping under pressure of 0.6–1.0 MPa, accompanied by forced resin injection into the weakened massif with the mounting step 1.0 - 1.5 m, alongside with the main roof bolting, develops a bearing layer of rocks that can absorb loads from overlying deformed roof rocks that arise in the zone of disturbed rocks; the bearing capacity of bonded rocks depends on the value of the coefficient of the massif structural weakening (0.25-0.37: the coefficient of reduction in the

enclosing rocks strength) and the angles of inclined rods 55 - 85°;

- the advanced strengthening of the weakened zone of loose rocks with advance contour guarding support in the zone of disturbance, unstable enclosing rocks around the mine allows increasing the rock stability when tectonic disturbances intersect with development workings at the distance of 10 m from the entrance, at the exit from the disturbed zone and immediately in it;

- the stresses obtained in the massif as a result of geomechanical simulation for various roof stability conditions with an estimate of the degree of the rock massif disturbance through the Young's modulus in the range of 7 (coal) - 35 (sandstone) MPa and Poisson's ratio of 0.2–0.23 are close in nature and the dynamics of changing to the inverse parabolic law and are favorable in terms of stresses and the technology of mounting an injection roof bolting in the disturbed zone in the range from 60 to 70° from the front of the axis in the roof of the mine workings driven in geologically and technologically disturbed rocks.

Main scientific results are as follows:

- the second-level enclosing roof bolting mounted in the unstable immediate roof with a slope of 60–70° to the bottom face of the working with an overlap of 1.0–1.5 m to ensure roof rock displacements of up to 150 mm, after mounting the main roof bolting develops a supporting barrier layer of supported rocks 1.7–2.0 m thick, perceiving loads from overlying deformed roof rocks that arise in the zone of disturbed contour rocks;

- after the formation of the bearing rock-anchor structure 2.4 m wide in the vicinity of a mine, there begins stratification of the rocks beyond its boundaries at the distance of inelastic deformation action of up to 3.6–4.0 m, at which the rock-anchor system not only accepts the load from loosening rocks in the fracture zone, but also inhibits the development of fracture in the direction of the working, and also prevents the displacement of rocks within the zone of inelastic deformation, in the direction of the working cavity, which forms a rock-anchor structure in the massif of enclosing-holding support of the working with the overlapping the volume of action zones mounted every 1.0–1.5 m injection anchors;

- there have been developed technological schemes of mounting the developed sopport, which provides reducing the cost of supporting the mine workings in the disturbed rock massif, comparable in amplitude with the removed thickness of the seam;

- the results of the work have found application in the development of passports of mine workings by design organizations and are used in the educational process, which is reflected in the act and intentions for implementation and in educational and methodological developments in the mining profile.

S**cientific novelty** of the work consists in that:

- there has been proposed a progressive technological solution that ensures when driving mine workings, through mounting anchors across the supposed fault lines of the rocks of the immediate roof, a "contour rigid" monolithic structure (with displacements of up to 150 mm) that works as a single rock-support system when driving workings; moreover, at the meeting angle not larger than 90°, increased stresses are characteristic at the entrance to the disturbed zone, and at

meeting angles larger than 90°, at the exit from the geological disturbance with the treatment zone exceeding the daily movement of the face to the excavation cycle (1.0 m advance supporting).

Scientific significance of the work consists in establishing the parameters and developing the technology of supporting mine workings in weakened enclosing rock massifs based on numerical experimental studies of rock deformations around the mine working contour.

Practical value of the work lies in the possibility of the efficient use of the technology of strengthening a support around the mine, development of technological schemes of driving mine workings and supporting unstable rocks surrounding it.

Defender's personal contribution is scientific justification of developing an efficient design of enclosing systems for supporting in the areas with unstable (disturbed) rocks in mining and tunneling operations.

Practical significance of the work consists in the fact that the mine working driven along the damaged formation, is supported ahead of the working face by contour guarding injection anchors mounted in the roof and the sides at the entrance, along the entire length of the zone and at the exit of the violation, which forms zones of strengthened support and gives the working the needed stability. Advance strengthening of the weakened rock zone is carried out at the intersection of the tectonic disturbance zone by the development working to form a stable rock layer and the roof bolting within the supported contour.

Reliability and validity of scientific provisions, conclusions and recommendations are confirmed by the use of the proven analytical and experimental methods, a representative amount of data obtained in natural conditions, good convergence of the calculated and actual parameters of the roof bolting operation in the workings.

Subject of the research: The mine workings driven in the areas weakened by geological disturbances and with deviations from bedding elements (in terms of thickness, structure of the coal-rock massif, dip angle and hypsometry) of coal seams at mining enterprises.

Theoretical and practical significance of the work consists in justifying and determining, based on the assessment of the stress-strain state of the enclosing rock massif, the parameters for the formation of an effective and low-cost method of enclosing contour strengthening with unstable rocks ahead of the face of the mine working.

The economic efficiency of the preventive two-level supporting ahead of the reference pressure zone is: 5,527,200 tenge – 2,535,700 tenge = 2,991,500 tenge per month or 35,898,000 tenge per year without taking into account production losses in the face (if production is carried out in unstable rocks).

Structure of the work. The dissertation consists of an introduction, 5 sections, a conclusion and contains 121 pages of text, 62 figures, 13 tables, a list of references containing 101 items.

Implementation of the work. The main conclusions and recommendations obtained in the doctoral dissertation were recommended when driving mine

workings at the mines of the Karaganda coal basin in the areas with unstable enclosing rocks: in 1 monograph, in 7 scientific articles, in 8 theses of scientific conferences and 1 invention.

Approbation of the work. The main provisions of the work were reported and received approval: at the scientific seminar of the DMD Department of KSTU in May 2020; at the meeting of the Scientific and Technical Council of KSTU (June 2020). The results of scientific research obtained in the dissertation have been introduced into the educational process in specialized disciplines of bachelor's 6B07202 and master's degrees 6M07202 - Mining specialties.

Participation in research, grant financing as an executor:

- R&D on the topic: No. AR05135535 "Developing a contour technology for supporting workings with controlling the anthropogenic state of the coal-rock massif of the enclosing rocks", grant funding of scientific research of the Ministry of Education and Science of the Republic of Kazakhstan for 2018-2020;
- R&D on the topic: No. AR05135203 "Developing intelligent information systems for calculating the technological parameters of mining processes", grant funding of scientific research of the Ministry of Education and Science of the Republic of Kazakhstan for 2018-2020;
- R&D on the topic: "Developing and implementing the technology, systems and tools of active supporting mine workings, taking into account the stress-strain state of an contour rocks massif," program-targeted funding of scientific research for 2018-2020 with KazNITU n.a. K. Satpayev.

As part of the implementation of grant funding projects with the Ministry of Education and Science, the Act of Implementation in the Educational Process and the Statement of Intent to implementing into production were received.

The doctoral student thanks the Kazakh and foreign scientific advisers for their recommendations and assistance in carrying out experiments and performing certain stages of the dissertation.