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Analytical Modeling of Geomechanical Processes in the Near-Contour Massif of Mine Workings

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Annotation: The development of a progressive technology for workings based on the determination of the stress-strain state (SSS) of the massif and its influence on the parameters of fastening and subsequent maintenance is an important scientific and technical task of mining. In the process of research, the SSS was determined around the mine working: roof, soil and sides; strain rate, delamination zone (crack formation); stresses (compression, tension, shear), displacement from service life (in dynamics). Relatively favorable, medium and difficult conditions for the operation of mine workings, the influence of mining-geological and mining-technical factors on the formation of inelastic deformation zones in the host rocks around the workings were considered. Studies were carried out on the stability of the contours of development workings, taking into account their stress-strain state, depending on mining and geological factors; stress-strain state of excavation workings depending on the influence of technological factors using the finite element method. The boundaries of the region of inelastic deformations were determined by the method of successive loadings.

KEYWORD: progressive technology, fastening, maintenance, stress-strain state, stability of workings, deformations, mining-geological and mining-technical factors.

INTRODUCTION

An increase in the depth of development with a relatively low strength of rocks and the use of supports with insufficient bearing capacity and structural compliance are the main reasons for the unsatisfactory state of mine workings in the Karaganda basin. An important role in increasing the efficiency of production is played by the solution of the problem of improving the technology of fastening and reliable maintenance of workings. Excavation costs are quite high and amount to 15–

20% of the production cost. Sustainable maintenance of development workings also requires significant costs for their repair, both before and after the commissioning of stopes, which reach 15–20% of the cost of mine workings. At the depths of development existing in the basin (600–850 m), it is impossible to achieve non-repair maintenance of workings with modern supports. One of the rational ways to improve the condition of workings and save material resources is the use of a combined lining of metal arch and anchor. To date, the world practice has accumulated sufficient experience in the application of technological schemes for the construction of rock bolts in mine workings. However, as field observations show, the state of mine workings, especially excavation, is not always satisfactory. The weakest link in solving the issues of increasing the efficiency of the use of anchor fastening is the insufficient knowledge of geomechanical processes near mine workings. One of the rational ways to create safe and effective conditions for maintaining mine workings is to manage the state of the near-contour rock mass.

MATERIALS AND METHODS

In this regard, the development of a progressive technology for workings based on the determination of the stress-strain state (SSS) of the massif and its effect on the fastening parameters and subsequent maintenance is an important scientific and technical task of mining.

For the research, development conditions were selected with an assessment of the influence of the following factors:

- cross-sectional shape of the development working;
- type of support: metal arch, anchor and combined;
- maintenance conditions:

About sustainability:

- unstable (fractured mudstones);
- medium stability (argillites);
- stable (siltstones);

About manageability:

- easily manageable;
- average controllability;
- difficult to manage;

Depth of development 600 m 800 m; 1000 m; o by the angle of incidence:

- up to 10º,
- up to 20º,
- Up to 30º and more.

In the process of research, the SSS was determined around the mine working: roof, soil and sides; strain rate, delamination zone (crack formation); stresses (compression, tension, tangential), displacements from service life (in dynamics). Relatively favorable, medium and difficult operating conditions of mine workings were considered.

RESULTS AND DISCUSSION

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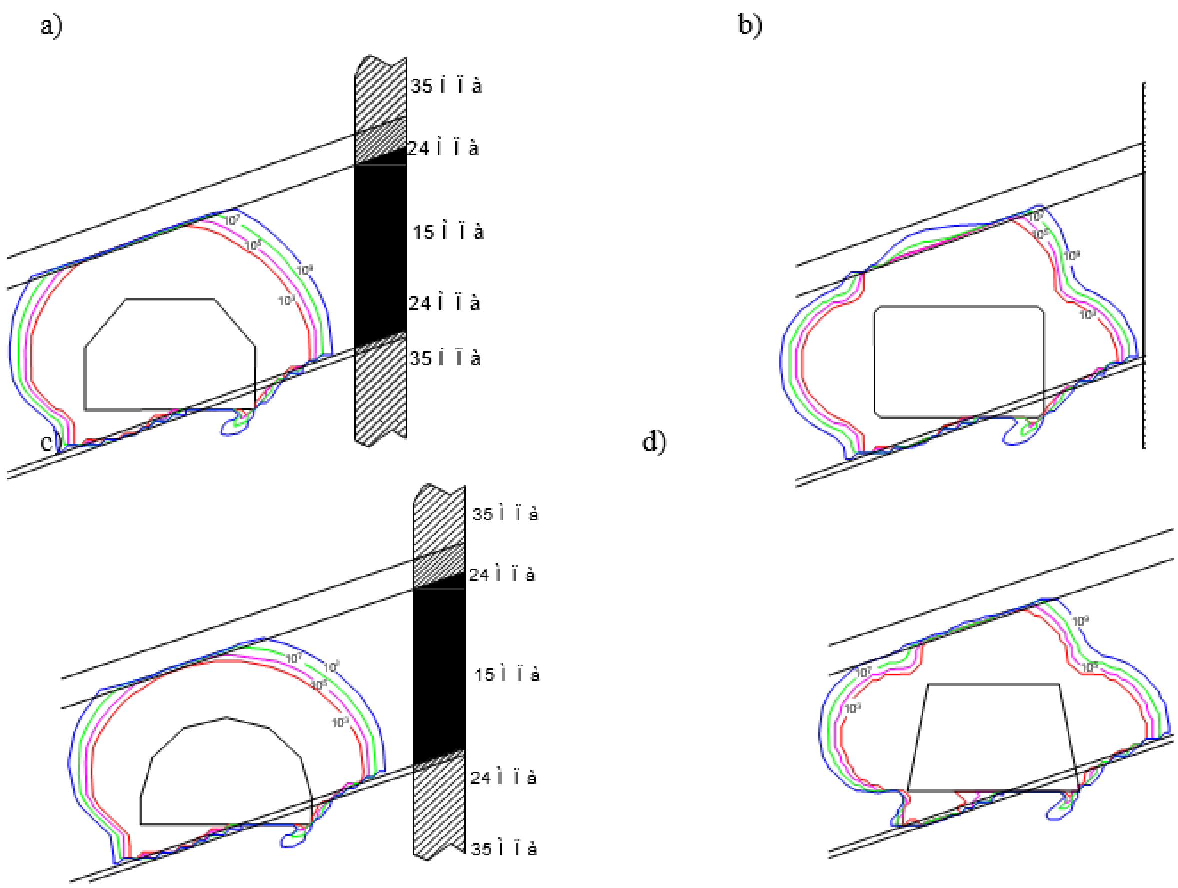
Influence of mining-geological and mining-technical factors on the formation of inelastic deformation zones in the host rocks around the workings. To determine the conditional zones of inelastic deformations, the program "Calculation of stress and durability" was used, created on the basis of theories of elasticity and kinetic strength of solids [1] and allowing to determine the stress-strain state at the considered point of the technogenic space, and then to establish the durability of the object (time to failure) and assess the stability of the rock outcrop for the subsequent adoption of technological measures. For the geomechanical interpretation of the modeling results, a 64k10-z conveyor drift with a cross section of 16.2 m² of the k10 seam of the Abayskaya mine was considered, passed at a depth of 630–640 m.

On fig. 1 shows the isolines of the maximum tangential stresses arising in the lateral enclosing rocks with arched, polygonal, trapezoidal and rectangular cross-sectional shapes of workings.

Comparison of diagrams of mass weakening isolines shows that the shape of workings significantly affects the pattern of distribution of maximum shear stresses τk. The maximum concentrations (τk = 25 MPa) for arched and polygonal supports are located on the soil, including the areas adjacent to the side walls of the working; for a rectangular one - in the same place and in the roof, and with an increase in τk up to 35 MPa - at the side walls of the working. According to the depth of propagation of tangential stresses deep into the massif (τc = 5 and 15 MPa): for a rectangular section of workings - vertical by 5.8 and 0.8 m, horizontal - by 3.5 and 0.9 m; for a polygonal section - vertical at 3.8 and 0.8 m, horizontal - 3 and 0.9 m; for the arched section - vertical 3.3 and 0.8 m, horizontal - 3 and 0.8 m.



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Rice. Fig. 1. Isolines of maximum shear stresses arising in the host rocks with different cross-sectional shapes of excavation workings: a - polygonal, b - rectangular, c - arched and d - trapezoidal

Figure 2 shows the conditional zones of inelastic deformations near the workings in different periods of time, starting from the moment of rock outcrop. An analysis of the durability lines around the working shows that the formation of conditional zones of inelastic deformations begins in the soil of the working, in the corner at the side stand adjacent to the rise line, and after a month covers the entire width of the working, spreading deep into the array by 0.5 width (height) of the section in the light, which leads to heaving of rocks into the cavity of the working. After 0.3 h, the conditional zones of inelastic deformations in the roof, sides and soil from the side of the seam dip were 2.0 m, 30 days - 2.2 m, 4 months - 2.6 m. upon their destruction, is taken in the calculations equal to 1.1.

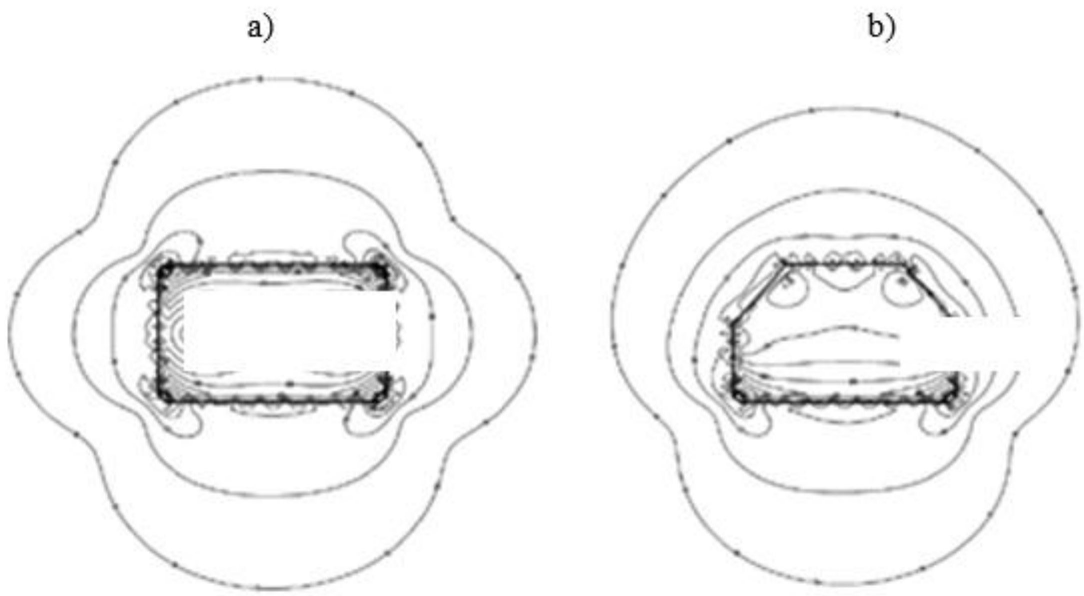

Fig.3. Conditional zones of inelastic deformations near the working in different periods of time from the moment of rock outcrop with different cross-sectional shapes: a – rectangular; b - polygonal

A change in the angle of inclination in the range from 0 to 30º does not lead to a significant change in the load pattern (for example, the arched form of the support of the excavation is taken). The zone of cracking of enclosing rocks, which is maximum for horizontal layers, occurs at a distance of 1.7–1.8 m and approaches the working section by 0.05 m with an increase in the dip angle of the reservoir by 10º (Fig. 3).

An assessment of the degree of influence of the controllability of the roof rocks on the deformability of the rock mass showed that with easily and moderately controllable rocks in the roof, soil and space of the side walls of the plane, cracks form at a distance of 2.5–2.9 m from the working contour, and when hard-to-control rocks - in the roof directly above the working.

Depending on the controllability of the enclosing rocks, the degree of development of the intensity of cracking is considered for a trapezoidal shape of the working section. Crack formation spreads most remotely, and from all sides of the working at a distance of 2.4–2.5 m from the contour, and even less remotely (0.4–0.5 m) at the side posts in the soil near the working - with easy and medium roof.

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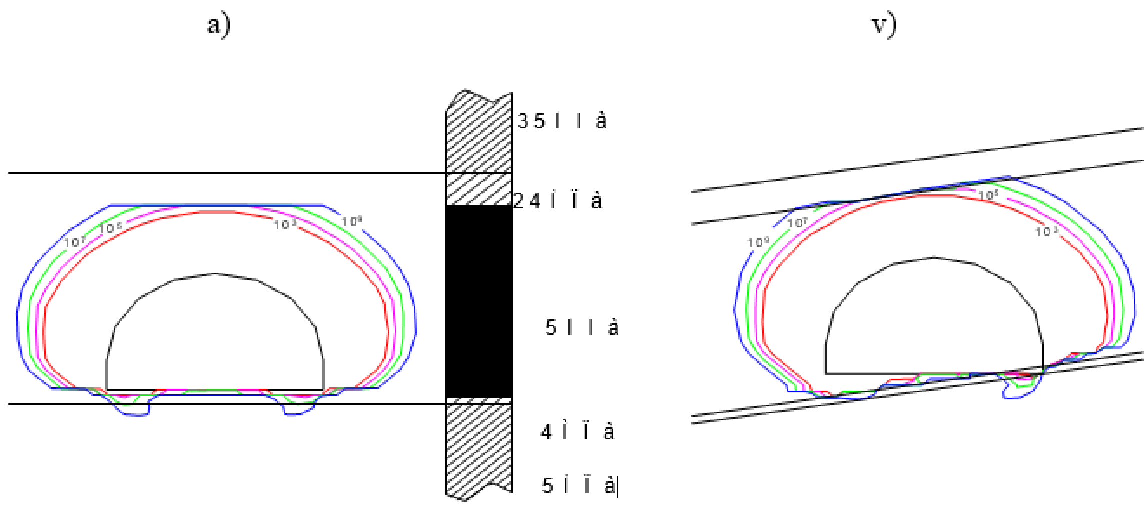
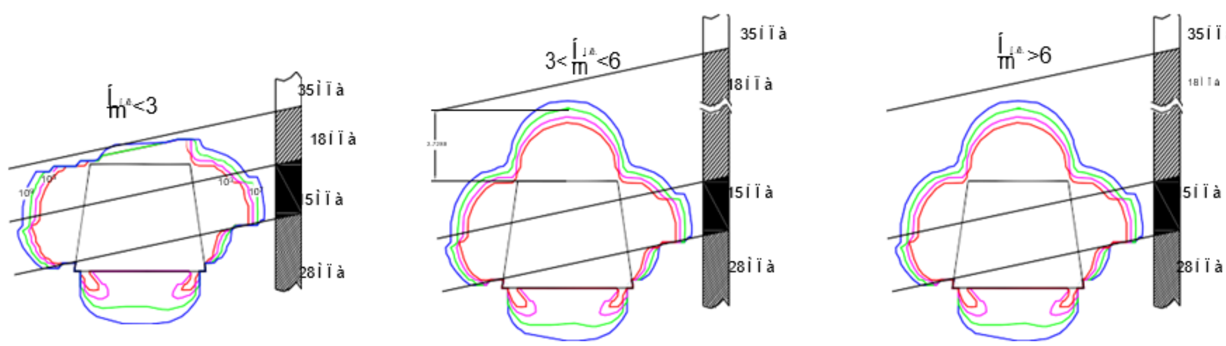


Fig.3. Influence of the angle of dip of the coal seam on the distribution of maximum tangential stresses around the development workings a) - 0o; b) - 10o

With a hard-to-control roof, cracks in the roof are close to the working and are located at a distance from the working section, not exceeding 0.5 m.

Thus, the characteristics of the controllability of the host rocks are manifested to a greater extent by the proximity of newly formed cracks to the contour of the working only with a hard-to-control roof (Fig. 4).



Cracking in the roof and sides differs insignificantly from the depth of location (for example, an arched shape) of a working of 600 and 700 m; , 15 and 150 days, propagates with a step of 0.2 m deep into the massif. In the soil, the trend of crack propagation is similar to crack formation in the roof with the same parameters, but at an initial distance of 1.5 m from the working contour.

CONCLUSION

The mechanism of deformation, displacement and collapse of rocks in a structurally disturbed heterogeneous rock mass, its influence on the functioning of the subsystem "mining operations" was studied using computer programs to assess the stress-strain state of the rock mass around mine workings.

The conducted comparative studies of the manifestations of rock pressure in workings with different types of fastening made it possible to establish the nature of their operational performance. At the same time, deformations of workings with combined anchor-frame support are 3–4 times less than with metal-frame support.

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The influence of mining-geological and mining-technical factors on the formation of inelastic deformation zones in the host rocks around the workings is determined. The stability of the contours of development workings was studied, taking into account their stress-strain state, depending on mining, geological and technological factors, using the finite element method. The boundaries of the region of inelastic deformations are determined by the method of successive loadings. The parameters of deformation of side rocks of a mine working are considered depending on the dip angle of the seam and the anchoring depth.

With a small depth of development (400 m), the minimum stresses are inherent in the rectangular shape of the working section. For the average level of development depths (600–700 m), the arched shape of the working cross section is quite acceptable. Changing the angle of inclination in the range from 0 to 30º does not lead to a significant change in the load pattern. The controllability characteristics of host rocks are manifested to a greater extent by the proximity of newly formed cracks to the working contour only with a hard-to-control roof (5 times) and are located at a distance from the working section not exceeding 0.5 m. With an increase in the development depth (from 600 to 1000 m) crack formation increases by 1.5 times. At the same time, an increase in the diameter of the holes (up to 0.05 m) negatively affects the emerging stresses and leads to their doubling over the entire range. The first diagrams of conditional zones of inelastic deformations from the working contour are located at a distance of 1.6–2.0 m.

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