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Technological conditions for ensuring the stability of the array of enclosing rocks during the fastening of mine workings

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ABSTRACT
Ensuring the stability of the array of enclosing rocks during the fastening of mine workings is possible only if there is a highly efficient technology for conducting and maintaining workings. For fixing the mining, taking into account the technological stratification of coal-bearing massifs, a method using anchor fastening technology is recommended. The effect of the proposed method of fastening workings is that high reliability of fastening is ensured, and the volume of labor-intensive processes to combat the collapse and stratification of rocks is reduced. The stability of the contours of preparatory workings, taking into account their stress-strain state, depending on mining, geological, and technological factors of factors using the finite element method, is investigated. The boundaries of the area of inelastic deformations are determined by the method of successive loadings. The parameters of deformation of the lateral rocks of the mine workings from the angle of incidence of the formation and the depth of anchoring are considered.

Keywords: mining, fastening parameters, geomechanical processes, anchorage, manifestations of rock pressure, technological schemes.

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Introduction

During the mining and development of coal seams due to the violation of the equilibrium of rocks and redistribution of natural stresses in mines, there is mountain pressure and a variety of geological phenomena, realized in deformation, destruction, movement, and shear of their various array. Geological and mining engineering factors have a decisive influence on the development of mining pressure resulting from the interaction of coal-bearing rocks with mine workings.

The deformed state of the array at the time of monitoring should be considered as an integral picture of a multitude of geological processes occurring and overlapping one another.

The wider application of progressive and used in foreign practice anchoring is limited by the insufficient study of geomechanical processes around mine workings. From the analysis of the anchoring application, it was established [[1], [2], [3]] that the main reasons for the decrease in the volume of anchoring of workings are: complications of mining and geological and mining engineering conditions with the transition to the depth of development more than 550 - 700 m. Here, the size of the reference pressure zones in the area around the mine workings and the intensity of rock pressure manifestations in the mine workings inside the minefields have significantly increased. The cross-sectional area of mine workings, especially of longwall mine drifts, and the volumes of non-pillar protection of mine workings on the boundary with the excavated space, i.e. in the zone of shear and collapse of rocks of neighboring excavated faces, increased by 35 - 40% (up to 20 - 22m^2); insufficient study of geomechanical processes in rocks around mine workings at the lower horizons and the performance of anchoring in these conditions. This applies most of all to the size of zones of dangerous deformations (mixing, splitting, and destruction) of rocks of the roof and sides of excavations protected by coal pillars and non-pillar methods.

The current trend towards the use of non-pillar mining technology requires finding reliable means of protecting the development workings, primarily those adjacent to the open pit area.

As the depth of the workings increases, the deformations of the enclosing rocks increase intensively, significantly outpacing the growth of the mining depth. The anchoring, working in tension, keeps the anchored rocks from delamination, shearing, and fracture. In rocks with a layered structure, layers of unstable immediate roof are either anchored to the stable main roof or separate rock layers are anchored to form a single monolithic slab, which is able to absorb the load from the overlying rocks. In unstratified rocks, anchors anchored outside the natural collapse vault resist the tensile forces in the vault rocks, and the anchors are set to resist the tensile forces in the rocks of the vault [[4], [5], [6]].

In connection with the above, the objectives of the research were: to establish the regularities of redistribution of rock pressure and rock shear parameters, the nature of shear of anchored rocks with their diverse structural structure and mining-technological factors; to determine the regularities of manifestation of rock pressure on the support, displacements of rocks of the roof, ground, sides of workings; modeling and establishing the parameters of anchoring of mine workings by means of effective strengthening of weakened zones.

The research of the method justifying the application of a limitedly yieldable anchor support, which influences the development of fracture zones in the contour rocks by binding and hardening them within the initial zones of stratification, formed outside the zone of influence of coal-face works, to create a safety bridge, distributing pressure on the vault heels, and playing in the subsequent in the zone of supporting pressure, the role of redistributing the load from the overlying rocks that have come into shear - figure 1 is established [[7], [8]].

Experimental part

To determine the area of stratification of rocks for predicting the stability and collapsibility of the roof rocks and the displacement of the sides of workings and the choice of rational parameters of their carrying out, the control of the stress-strain state of the array was carried out by devices for controlling the deformation of the array CDA-1 (visual control of stratifications in the array) and CDA-2 (quantitative assessment of the displacement of the array and stratification of the roof rocks) - VNIMI design - Figure 2.

Displacements were measured in near-contour rocks in the conveyor drift 78k10-v of the Saranskaya mine of the Karaganda coal basin at a depth of 450 m in three boreholes (central and two at an angle of 45^o to it) in the roof of the workings - Figure 2.

The immediate mine roof of the formation is represented by medium-stable argillites with thickness from 1 to 5 m and strength of 15-20 MPa with a distance between cracks of 0.5 m and the main hard-to-collapse roof with thickness of 24-30 MPa, composed of sandstone with strength of 65-70 MPa.

Outside the zone of influence of coal-face works, the first delamination contour occurred after 0.3 h at a distance of 1.6 m from the workings, after 20 days at a distance of 2.0 m, and after 3 months. - 2,3 м (Figure 3). The most dangerous are tensile stresses located perpendicular to the strata exceeding the strength limits at the contacts and causing detachment of rocks with the separation of layers from each other, and then their collapse is established [[9], [10], [11]]. Rock foliation slippage occurs under the action of tangential stresses directed along the bedding.

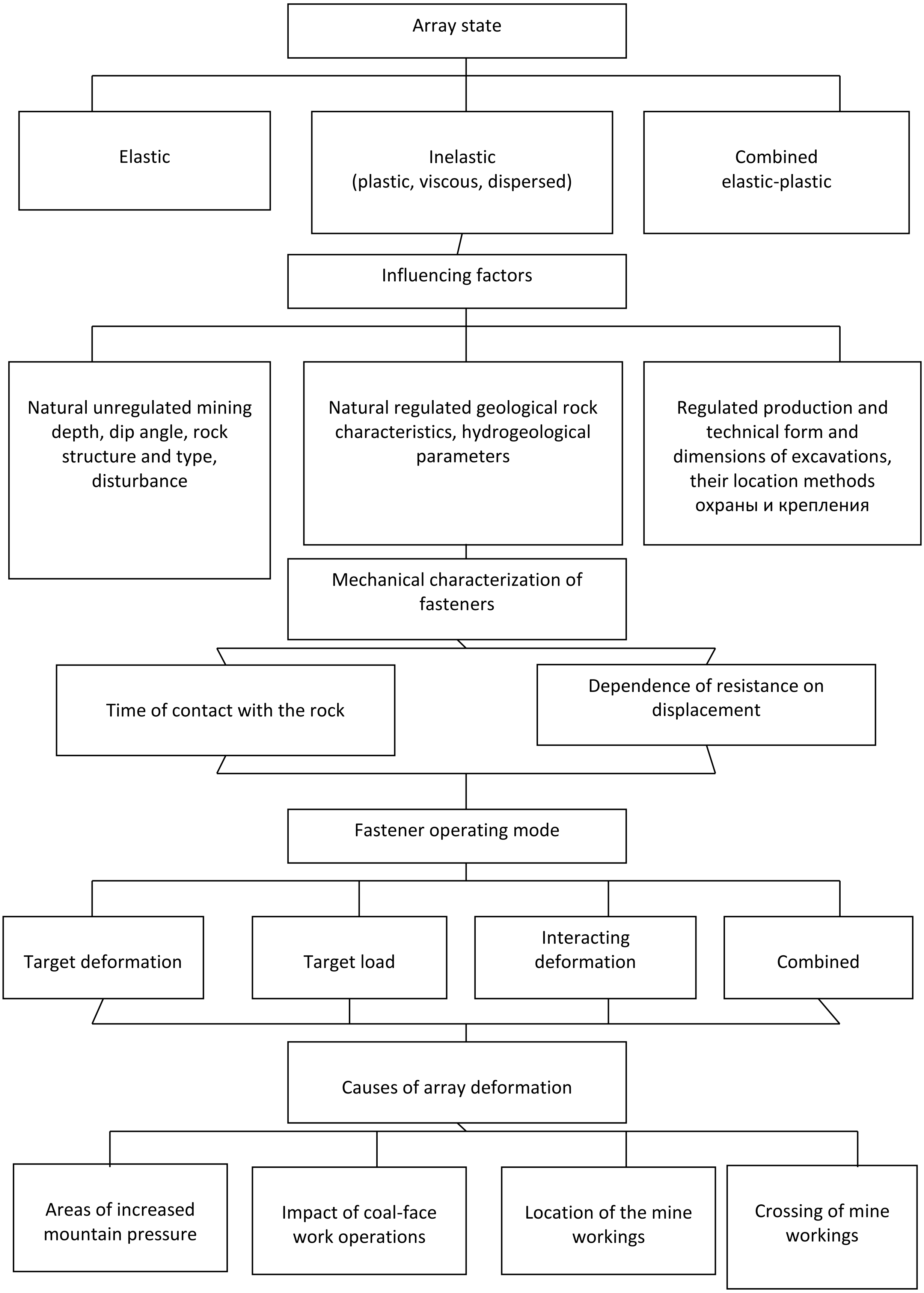
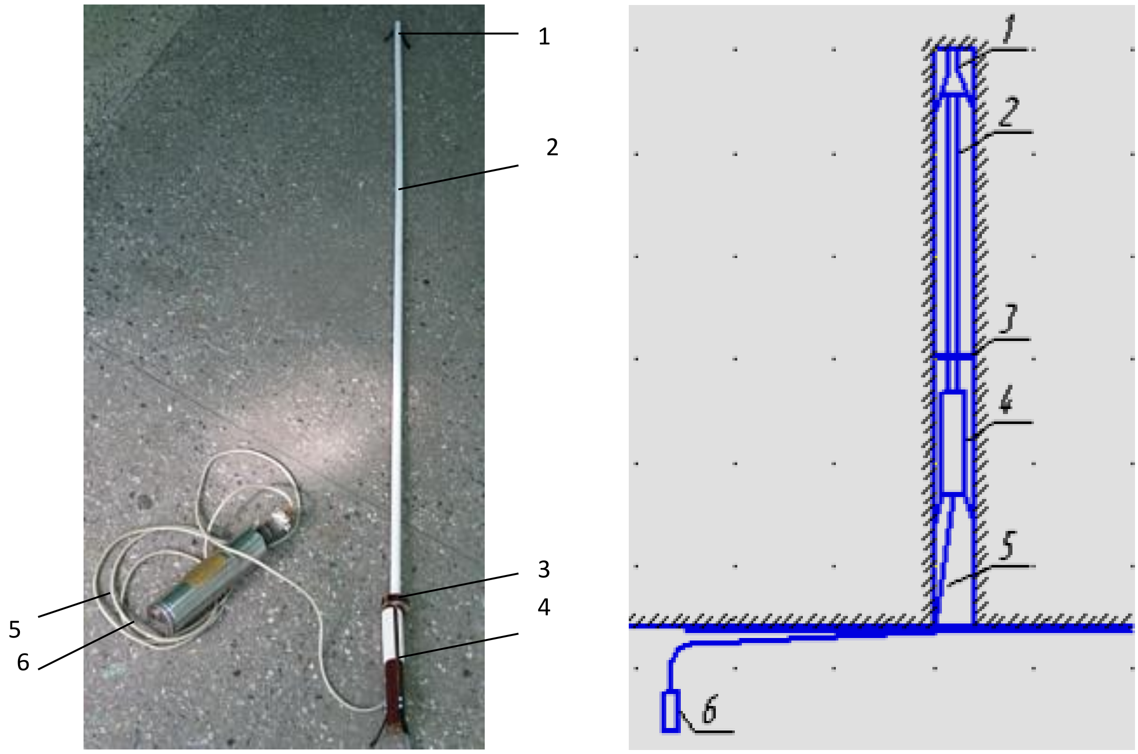


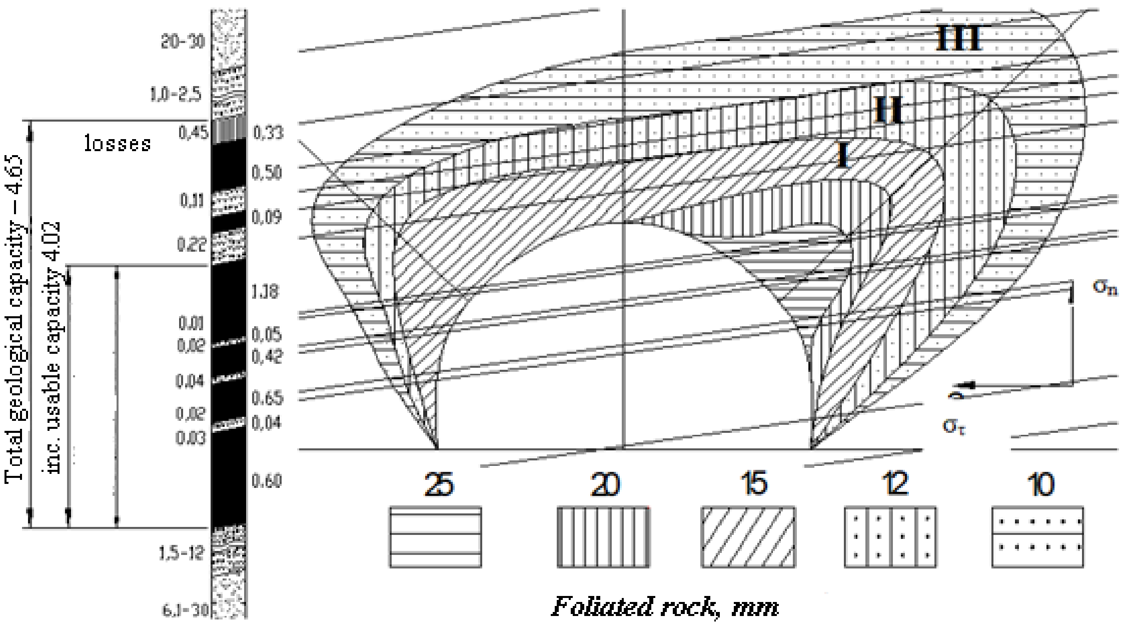
Figure 1 – Complex of basic elements of interaction of underground workings with the rock array



a b

1, 2 - the base checkpoint and its bunch; 3- thrust collar; 4 – strainmeter;
5 – connector cable; 6 – gear CDA - 2.

Figure 2 – Device design (a) and measurement scheme (b)



a b

Figure 3 – Structural column of the formation and the zone of technological stratification of the near-contour rock array of the conveyor drift 78k10-in of the Saranskaya mine

Figure 3, b shows that three foliated contacts of weak rocks (zones I - destructive deformations, II - inelastic, III - elastic) were formed with corresponding zones of technological foliation of the near-contour rock massif.

Discussion of the results

The conducted mine instrumental observations allow us to make the following conclusions established [[12], [13], [14]]:

- activation of rock displacements in the roof and sides of the workings occurs almost immediately, after the face moves 8-10 m away from the measuring sensor;
- destruction of rocks in the sides of the workings leads to the development of roof deformation processes; displacements of rocks on the contour on the side of the workings are at least 1.8 times higher than displacements on the side of the roof;
- the smallest deformations of the roof rocks, within the inelastic deformation zone formed around the workings, outside the anchored thickness, were observed in the sections of the workings with lower values of the loosening coefficients in the sides;
- destruction (extreme deformation) of the roof rocks occurs in the borehole sections located at a distance of at least 1.8 m from the workings contour (no more than 25% of the anchored area of rocks is destroyed).
- the well section located within the anchoring zone is displaced as a single block without significant foliation;
- the zone of the most intensive destruction of rocks in the mine roof is located at a distance of 3.5m or more from the contour and is confined to the place of interlayer contact;
- in the sides of the workings, the rock deformation zone usually has areas of zonal disintegration (at a distance of 0.5 - 1.0 m and 2.0 - 2.5 m from the contour, destruction occurs in the first two days of observation with subsequent development of destruction within the initially undisturbed area of 1.0 - 2.0 m);
- roof rock fractures within the anchoring zone and directly on the workings contour were recorded in the areas of workings with intensive deformations of the side enclosing rocks (lateral displacements exceed vertical displacements by 4-5 times and more), as well as in case of violations of work technology (when the gap between the borehole walls and the anchor rod is exceeded, which leads to incomplete gluing of the anchor in the borehole), in areas with water dripping from the roof and in areas with increased fracturing caused by the presence of small-amplitude geological disturbances.

Determination of the area of initial rock foliation makes it possible to predict the stability and collapsibility of the rocks of the roof and sides of the workings in order to select rational parameters of their conduct. Figure 4 shows the dependences of rock pressure fracture spacing (*l*, cm) on the ratio of geostatic pressure (*γH*, t/m^2) to the compressive strength of rocks (Rcc , $\frac{кН}{см^2}$), and Figure 5 shows the dependences of fracture modulus (*L*, pcs./m) on the layer thickness (*h*, m) and tensile strength (Rp, $\frac{кН}{см^2}$), fracturing due to the presence of small-amplitude geological disturbances.

Determination of the area of initial rock foliation makes it possible to predict the stability and collapsibility of the rocks of the roof and sides of the workings in order to select rational parameters of their conduct established [[15], [16], [17]]. Figure 4 shows the dependences of rock pressure fracture spacing (*l, cm*) on the ratio of geostatic pressure (*γH*, t/m^2) to the compressive strength of rocks (Rcc , $\frac{кН}{см^2}$), and Figure 5 shows the dependences of fracture modulus (*L*, pcs./m) on layer thickness (*h*, m) and tensile strength (Rp, $\frac{кН}{см^2}$).

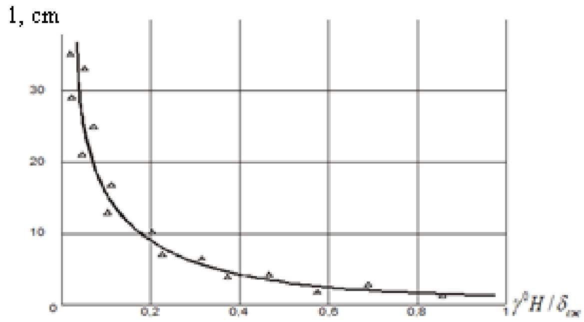


Figure 4 – Dependence of the distance between rock pressure cracks on the ratio of geostatic pressure to the compressive strength of rocks

The obtained results on foliation of rocks allowed to create an effective method for fixing the mine workings taking into account the technological foliation of coal-rock massifs with the use of anchor fixing technology. In this case, the anchors are installed perpendicular to the force lines of pressure (technological foliation) occurring in the rocks in the contour massif of the workings.

Increasing the load-bearing capacity of the rock anchor is achieved by improving the operational condition of the anchor, ensuring stability, and reducing the displacement and delamination of the enclosing rocks [[18], [19], [20]]. Figure 6 shows the deformation patterns obtained on the basis of analytical modeling using the finite element method with the application of the ANZIS software package for the technology of arch and anchor fixing of the mine workings.

Figure 7 shows the force lines of rock pressure at the anchoring of the mine workings (side view).

When anchoring the workings, anchors are fixed perpendicular to the force lines of rock pressure acting in the rock massif.

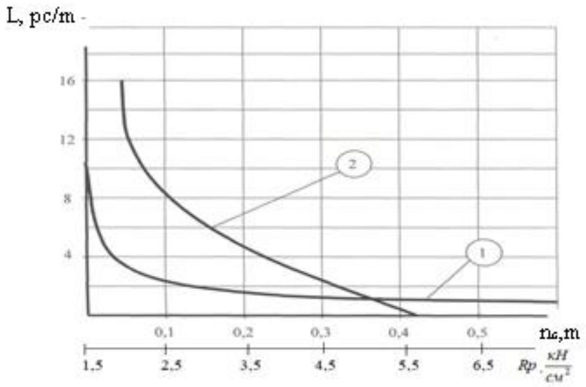
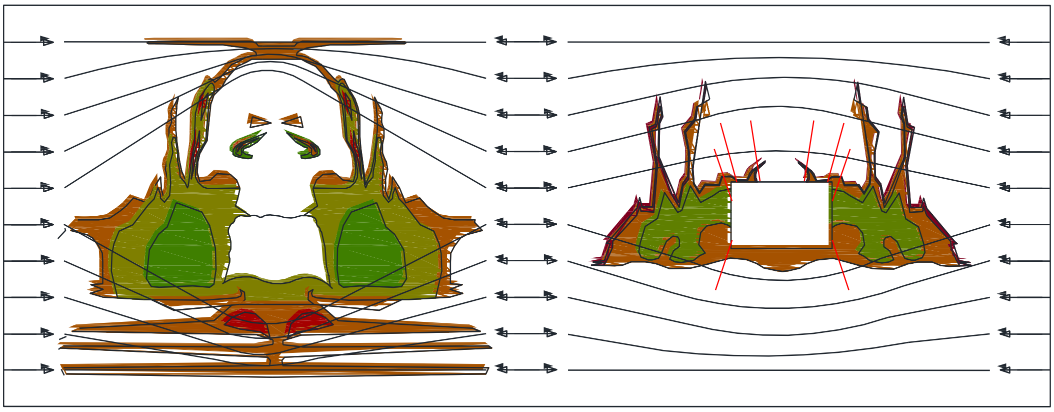
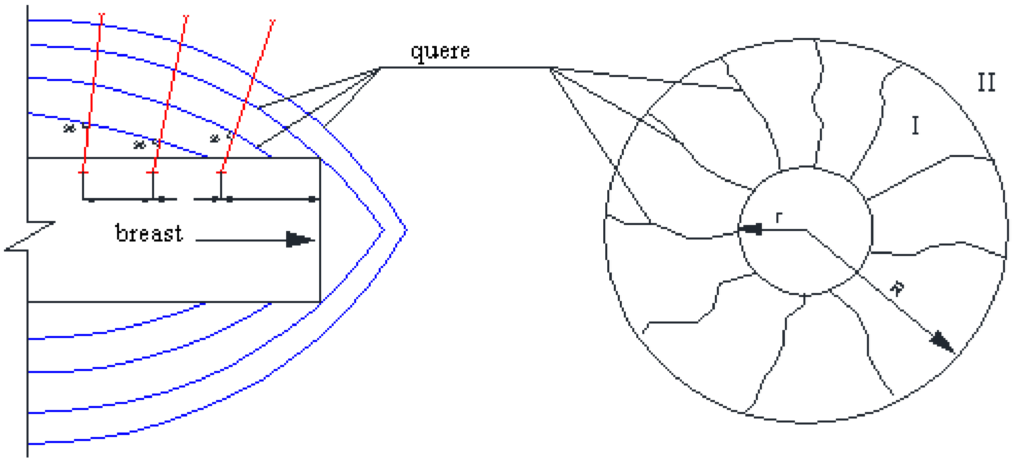


Figure 5 – Dependence of fracture modulus on layer thickness and tensile strength



a b

Figure 6 - Deformation patterns at arch (a) and anchor (b) fastening of the mine workings



I – technological foliation zone; II – sustainable zone of the rock massif

Figure 7 – Anchoring of the mine workings, installed perpendicular to the lines of acting mining pressure

Conclusions

The use of the technology of anchoring the mine workings, installed perpendicular to the force lines of the acting mining pressure, provides for the reduction of displacements and delaminations of the roof rocks and sides of the workings, the possibility of roof collapse and extrusion of the rocks of the sides and ground. The effect of the proposed method of workings fastening is that the high reliability of fastening is provided, and the volume of labor-intensive processes to combat the collapse and separation of rocks is reduced.

The stability of the contours of preparatory workings with regard to their stress-strain state depending on the mining-geological and technological factors was investigated using the finite element method. The boundaries of the inelastic deformation region were determined by the method of successive loading. The parameters of deformation of the lateral rocks of the mine workings from the angle of incidence of the formation and the depth of anchoring are considered.

Limited yielding support is characterized by an elastic-plastic model with unstrengthening. The installation of such anchors in weak rock will result in the activation of the yielding knot at the formation of the nearest fracture zone in time. The formed arch-bridge redistributes the impact of vertical mining pressure from the shear of overlying rocks to the heels of the arch-adjacent side rocks, which stops the process of formation of vertical loading from the fracture zones to the support of the working. The effect of roof rock management is that a load-bearing plate with strong bonds between blocks and increased stability of rock outcrops is formed in the mine roof, preventing the formation of rock foliation cracks (rock pressure cracks) and cross-cutting process cracks.

Conflict of interest. On behalf of all authors, the correspondent author declares that there is no conflict of interest.

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Кен қазбаларын бекіту кезінде тау жыныстары сілемінің орнықтылығын қамтамасыз етудің технологиялық шарттары

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Сараптамадан өтті: *26 қазан 2023*
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ТҮЙІНДЕМЕ
Тау-кен қазбаларын бекіту кезінде сыйымды жыныстар массивінің тұрақтылығын қамтамасыз ету қазбаларды өңдеу мен қолдаудың жоғары тиімді технологиясы болған жағдайда ғана мүмкін болады. Көмір жынысты сілемдердің технологиялық стратификациясын ескере отырып, тау-кен қазбаларын бекіту үшін анкерлі бекіту технологиясын қолдану әдісі ұсынылады. Қазбаларды бекітудің ұсынылған әдісінің әсері-бекітудің жоғары сенімділігін қамтамасыз етеді және тау жыныстарының құлауымен және стратификациясымен күресу үшін көп уақытты қажет ететін процестердің көлемі азаяды. Соңғы элементтер әдісін қолданып, тау-кен геологиялық және технологиялық факторларға байланысты олардың кернеулі – деформацияланған күйін ескере отырып, дайындық қазбалары контурларының тұрақтылығы зерттелді. Жүйелі жүктеу әдісімен серпімді емес деформациялар аймағының шекаралары анықталды. Тау-кен қазбасының бүйір жыныстарының қабаттың құлау бұрышынан және анкерлеудің тереңдігінен деформациялану параметрлері қарастырылады.

Түйінді сөздер: тау-кен қазбалары, бекіту параметрлері, геомеханикалық процестер, анкер бекіткіші, тау қысымының көріністері, технологиялық схемалар.

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Технологические условия обеспечения устойчивости массива вмещающих пород при креплении горных выработок

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АННОТАЦИЯ
Обеспечение устойчивости массива вмещающих пород при креплении горных выработок возможно лишь при наличии высокоэффективной технологии проведения и поддержания выработок. Для крепления горной выработки с учетом технологического расслоения угле-породных массивов рекомендуется способ с использованием технологии анкерного крепления. Эффект от предлагаемого способа крепления выработок состоит в том, что обеспечивается высокая надежность крепления, и снижается объем трудоемких процессов по борьбе с обрушением и расслоением горных пород. Исследована устойчивость контуров подготовительных выработок с учетом их напряженно-деформированного состояния в зависимости от горно – геологических и технологических факторов с использованием метода конечных элементов. Определены границы области неупругих деформаций методом последовательных нагружений. Рассмотрены параметры деформирования боковых пород горной выработки от угла падения пласта и глубины анкерования.

Ключевые слова: горные выработки, параметры крепления, геомеханические процессы, анкерная крепь, проявления горного давления, технологические схемы.

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