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Monitoring of the stress-strain state during preparatory workings

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ABSTRACT
Maintaining and increasing the volume of underground coal mining is possible only if there is a highly efficient technology for conducting and maintaining preparatory workings. The purpose of the research was to assess the parameters of stability control of the contours of the mine workings, anchored with anchorage, to create a technology for intensive and safe excavation of mine workings based on the identified patterns of behavior of adjacent rock massifs. The idea of the approach is to use a man-made stress-strain state to develop an effective technology for fixing a contour rock mass. The mechanism of deformation, displacement, and collapse of rocks in a structurally disturbed inhomogeneous mountain range is investigated to assess the state of the rock mass around the mine workings. The technology of fastening contiguous soil rocks has been developed taking into account the state of the mountain massif around the workings and the parameters of the operation of the anchor supports in mines for fixing rods in workings in order to ensure the safety of mining operations in the mines of the Karaganda coal basin have been determined.

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

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Introduction

Stable growth in the volume of underground coal mining is possible only when using effective and safe technology to conduct and maintain production workings.

Currently, more than 65% of all mine workings in the Karaganda coal basin are anchored, which allows to expand the technological possibilities of underground coal mining [[1, [2]].

An anchoring system of the carbon rock mass limits deformation and allows horizontal stress to hold the roof in place without destroying it. If the height of the stratified rock is lower than the anchoring level, the condition of the excavation will be satisfied, ensuring that the rock stress remains unchanged. If the height of the stratified rock in the roof is higher than the first level of the excavation anchoring, the increase in stress before the face, will cause the collapse of the roof. Longer second level anchors will be required to maintain the excavation. In practice the non-pillar development systems used in direct ventilation schemes, it is reasonable to use workings.

World experience of advanced coal-mining countries (USA, Australia, China, etc.) shows that effective and reliable fastening of capital and preparatory mine workings can be provided by using steel-polymer anchors with a load-bearing strength of at least 100 - 130 kN [3]. Monitoring the use of anchorage in coal mines shows that it is used in accordance with existing regulations as the main and auxiliary in combination with metal frame compressible support. The existing methods for determining the parameters of anchoring are based on the fixing of excavations by creating an anchor bridge or "hanger" of relatively weak layers to the strong zone of hard grounds [[4], [5]].

Improvement of anchoring technology and expansion of the area of anchoring support are a priority in the mining industry, which allows for an increase in the stability of mine workings at a high rate and reduces the cost of their support [6].

To increase the efficiency of rock mass support around the excavation for its strengthening, a purposeful geotechnological impact on the stressed and deformed zones with active manifestations of pressure around mine workings on the basis of the results of production monitoring and modeling of the "wall rock mass - contour support" system is necessary [[7], [8]].

Therefore, one of the important scientific and applied research in the coal mining industry is the application of strengthening technology using anchoring in soft wall rock around the rock artificial cavities supported behind the face on the border with the mined-out space, taking into account the technogenic state of the adjacent rocks of the rock massif.

The use of various types of supports with unsatisfactory load-bearing capacity and constructive suppleness with relatively low rock strength is the main reason for the unsatisfactory condition of underground mine workings [[9], [10]].

Conducting mine workings with active support systems is one of the most common and progressive types of mine support. The use of this type of support can significantly improve conditions for safe work performance. The main advantage of active fastening is that the fastener begins to function as soon as it is installed. This prevents the collapse of the rock mass, reduces the zone of non-elastic deformations around the excavation, and thus increases the stability of the excavation with a minimum amount of supporting material [[11], [12]].

Increasing the level of underground coal mining is possible only if there is a rational technology and reliable support of preparatory workings, providing an increase in the volume of tunneling work. Therefore, the development of advanced technology of mine workings based on the definition of the stress-strain state (SSS) of the massif and its influence on the parameters of support and subsequent maintenance, is an important scientific and technical task of mining production [[13], [14]].

Study methods: a comprehensive research methodology was used, including the generalization, assessment, and analysis of specialized information contained in the production practice, literature sources; statistical processing of numerical information; experimental mine studies [[15], [16]].

Experimental part

To solve various problems associated with finding the most effective method of supporting preparatory mine workings, in practice a large number of methods of actual measurement are used. According to their physical essence, these studies are reduced to measuring the density of rocks, observation of deformations, and displacements of excavation contours [[17], [18]].

To determine the characteristics of deformation and development of displacement of contour rock mass near the preparatory workings, we conducted field observations of displacements of rocks roof, soil, and sides of preparatory workings (for example, conveyor entry 231k19-s - Table 1) of Abaiskaya mine of the Karaganda coal basin. To assess the complexity, disturbance, and methods of impact on the rock massif, Figure 1 shows the types of complex conditions, the characteristics of the rock massif, the nature of the manifestation of complexity, and the nature of the manifestation of deformations.

Analysis of mining-geological and mining-technical conditions of the conveyor entry 231k_{19}-c of Abaiskaya mine showed that among the factors that have adverse effects noted: the possibility of encountering unpredictable small-amplitude disturbances, opening and departure from the formation, encountering a geological fault with *H*=0,9 m, a geological fault of "up-throw" type with the amplitude of *H*=17 m.

Table 1 - Technical characteristics of belt entry 231k$_{19}$-c

Name of workings	Length, m	Width, m	Height, m	Cross-section, m^2	Support type	Set lagging type
Belt entry 231к$_{19}$-с	1120	4.5	3.0	13.5	Anchor	mesh /ZMP

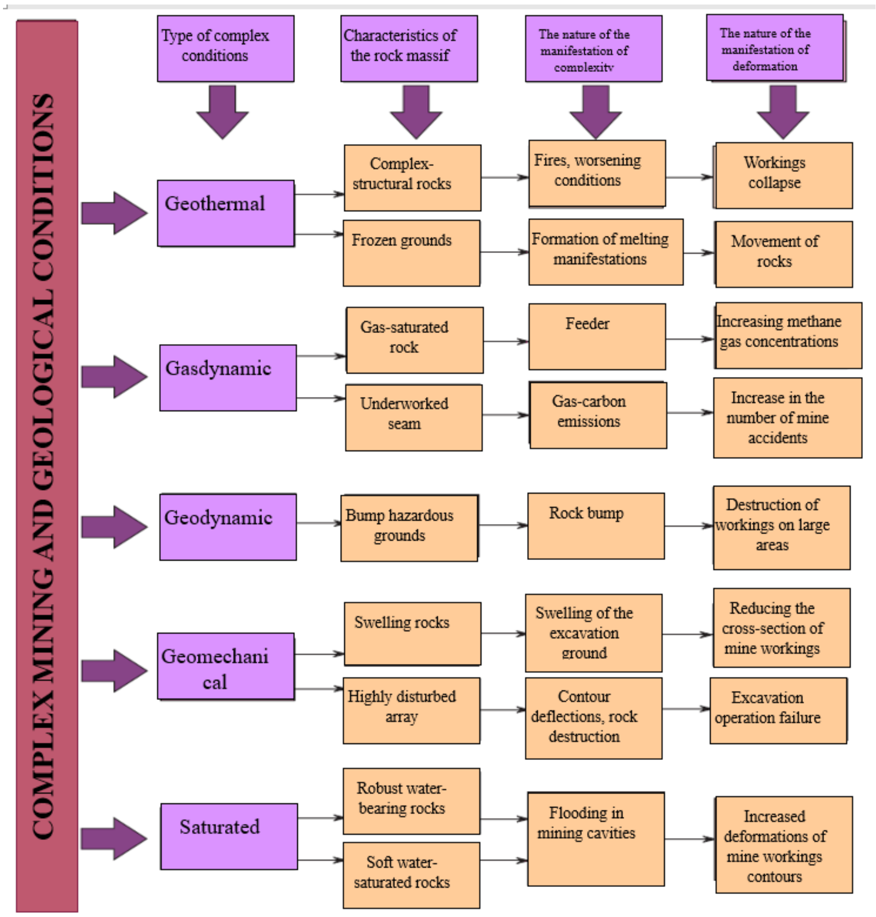


Figure 1 – Assessment of deformation manifestations considering mining and geological conditions of development

In the zones of interception rocks are fractured, kaolized, stable, prone to collapse, and falling out [[19], [20]]. Figure 2 shows the section of the excavation during its implementation.

Discussion of results

Field studies of the condition of the belt entry 231k$_{19}$-c for 3 months showed that, in general, the deformation processes proceed evenly throughout the contour of the excavation. In some places, the most intense displacements of the sides and roof of the workings are observed. Also, ground swelling in the excavation was detected. Figure 3 shows the dynamics of displacement of the left (a) and right (b) sides of the excavation.

According to field observations, in the first month after the installation of the measuring device displacement and deformation of the left side of the excavation was 6 mm. In the second month, the deformation of the left side was 7 mm. The third month of field observations of the mine working condition showed that the displacements were 5 mm. The total deformation and displacement of the left side of the excavation over 3 months was 17 mm.

Full-scale observations of the condition of the sides of the workings showed that the displacement and deformation in the first month amounted to 6 mm, in the second month the deformation was - 5 mm. In the third month the displacement was 7 mm. The total deformation and displacement of the sides of the excavation for 3 months was 18 mm. In general, the values obtained are within the range of permissible displacements of the mine workings. The displacements of the excavation sides are the result of elastic deformations of the massif. The total deformation and displacement of the excavation roof was 10 mm - figure 4.

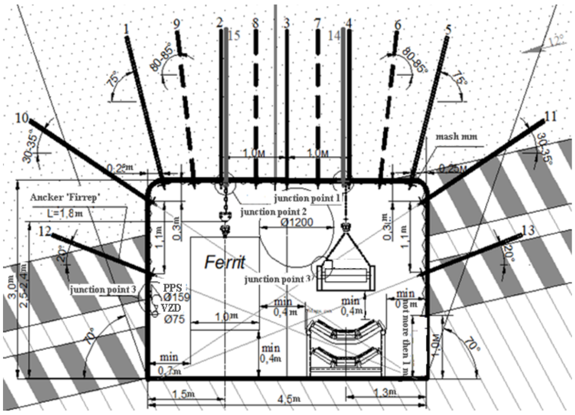
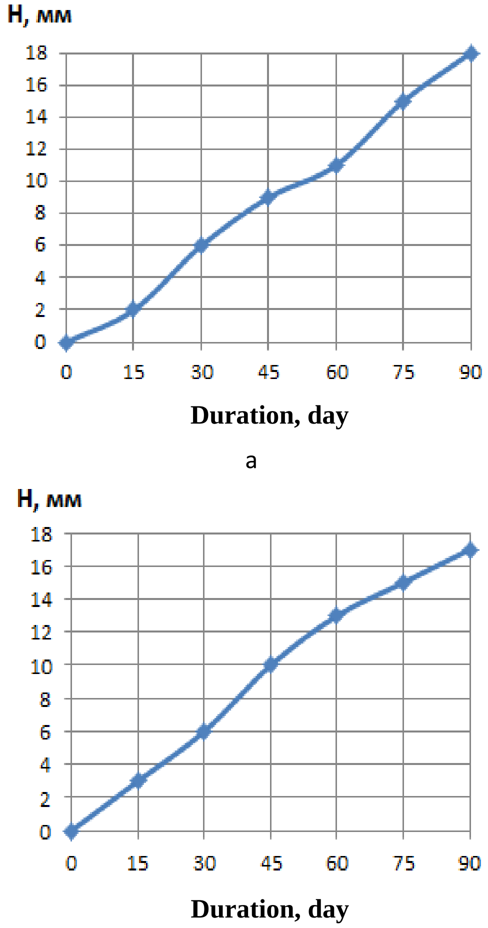


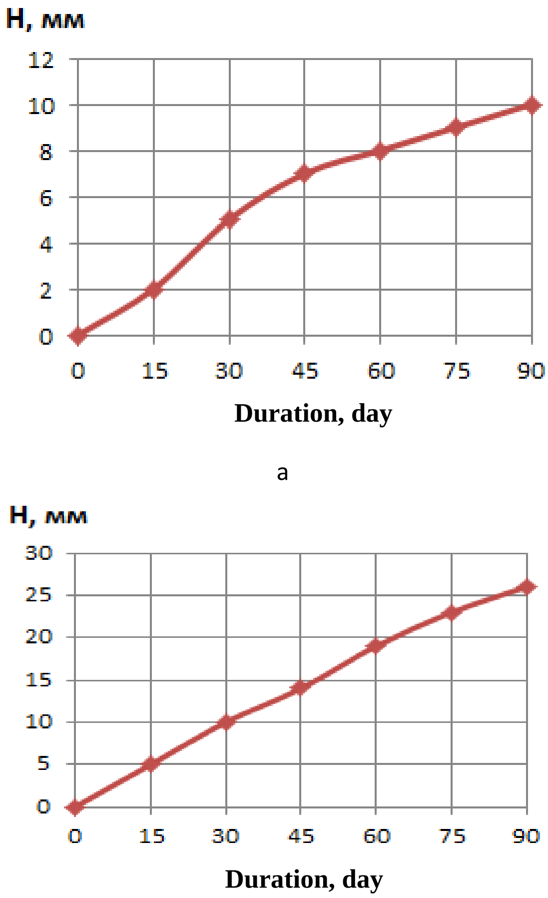
Figure 2 – Excavation cross-section during its conduct of the belt entry 231k19-s



a

b

Figure 3 – Dynamics of development of displacements of the right (a) and left (b) sides of the belt entry 231k19-c



a

b

Figure 4 – Dynamics of displacement of roof rocks (a) and ground (b) of belt entry 231k19-c

On average, the total values of ground swelling were 26 mm. The most intense ground swelling was recorded on the right side of the excavation and reached 40 mm - figure 5.

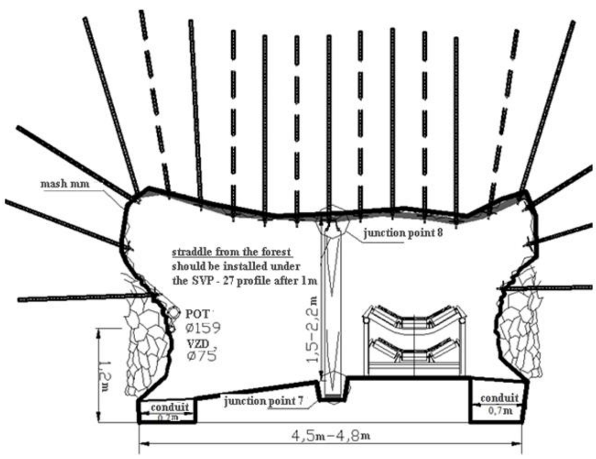


Figure 5 – Operational cross-section of belt entry 231k19-c and during field production observations

Figure 5 clearly shows that the negative condition of the mine is influenced by the unloaded rock mass, which was formed as a result of previous mining operations at face $231k_{18}$-c.

Figure 6 shows the deformation of the contours of the belt entry $231k_{19}$-c during field observation of the condition of the contours of the excavation.

Figure 6 – Deformations of contours of belt entry $231k_{19}$-s of Abaiskaya mine, Karaganda coal basin

Functional dependences of the deformations of excavation contours in time were established (regression coefficient 0.99):

- swelling of the ground: $y_{см}^{к}$=0,095 *ln*(*x*)+0,2;

- roof displacements: $y_{см}^{к}$=0,045 *ln*(*x*)+0,1;

- side displacements: $y_{см}^{к}$=0,035 *ln*(*x*)+0,1.

Conclusions

Studies of the state of mine workings (by the example of the belt entry $231k_{19}$-s) of Abaiskaya mine allowed to determine the degree of influence of mining-geological and mining-technical factors on the displacement in the near-contour rocks using different methods of mine workings support. The identified patterns in the deformations of mine workings contours can be used to select and calculate the most optimal method of supporting preparatory mine workings in various mining and geological conditions. Functional dependences of the deformations of excavation contours in time were established (regression coefficient 0.99): swelling of the ground: *уп*=0,095 *ln*(*x*)+0,2; roof: *ук*=0,045 *ln*(*x*)+0,1 and sides displacements: *уб*=0,035 *ln*(*x*)+0,1, that can be used to determine the parameters of support of mine workings.

Assessment of geomechanical processes taking place in the rock massif with the establishment of optimal parameters of support, taking into account the current economic indicators for the conduct of preparatory excavations, taking into account the technogenic state of the massive rocks.

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

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Дайындық қазбаларын жүргізу кезіндегі кернеулі-деформацияланған жай-күйдің мониторингі

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ТҮЙІНДЕМЕ

Көмір өндірудің жерасты көлемін қалыпты ұстап тұру және ұлғайту дайындық қазбаларын жүргізу мен қолдаудың жоғары тиімді технологиясы болған жағдайда ғана мүмкін болады. Зерттеудің мақсаты іргелес тау жыныстары массивтерінің анықталған әрекет ету заңдылықтары негізінде қазба тау-кен қазбаларын қарқынды және қауіпсіз жүргізу технологиясын құру үшін якорь бекіткішімен бекітілген тау-кен қазбалары контурларының тұрақтылығын басқару параметрлерін бағалау болды. Тәсілдің идеясы контурлық тау жотасын бекітудің тиімді технологиясын әзірлеу үшін техногендік кернеулі-деформацияланған күйді пайдалану болып табылады. Тау-кен қазбаларының айналасындағы тау жыныстарының жай-күйін бағалау үшін құрылымдық бұзылған гетерогенді тау жыныстарындағы жыныстардың деформациясы, жылжуы және құлау механизмі зерттелді. Қарағанды көмір бассейнінің шахталарында тау-кен жұмыстарын жүргізу қауіпсіздігін қамтамасыз ету мақсатында қазбаларда штангаларды бекіту үшін шахталарда якорь бекіткіштерін пайдалану параметрлері айқындалды.

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Мониторинг напряженно-деформированного состояния при проведении подготовительных выработок

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АННОТАЦИЯ

Поддержание и увеличение объема подземной добычи угля возможно лишь при наличии высокоэффективной технологии проведения и поддержания подготовительных выработок. Целью исследований явилась оценка параметров управления устойчивостью контуров горных выработок, закрепленных анкерной крепью, для создания технологии интенсивного и безопасного проведения выемочных горных выработок на основе выявленных закономерностей поведения примыкающих к ним массивов горных пород. Идея подхода заключается в использовании техногенного напряженно-деформированного состояния для разработки эффективной технологии крепления приконтурного горного массива. Исследован механизм деформирования, сдвижения и обрушения пород в структурно нарушенном неоднородном горном массиве для оценки состояния породного массива вокруг горных выработок. Разработана технология крепления приконтурных пород почвы с учетом состояния горного массива вокруг выработки и определены параметры эксплуатации анкерной крепи на шахтах для закрепления штанг в выработках в целях обеспечения безопасности ведения горных работ на шахтах Карагандинского угольного бассейна.

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

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