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Justification of the stress-strain state's parameters of the mine workings contours depending on the influencing factors

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ABSTRACT
The complication of mining and geological conditions is associated with the involvement in the development of areas and entire deposits with complex tectonics, an increase in the depth of development, the manifestation of dangerous dynamic effects of rock pressure, which necessitates the improvement of methods, systems, methods and means of supporting mine workings, as well as improving the quality of materials used for support. Mining and geological factors affecting the use of mining support include: the depth of occurrence, which determines the magnitude of the vertical and horizontal components of the rock pressure; layer thickness, developed deposit; bed angle; properties of the host rocks, structure and physical and mechanical properties of rocks and minerals. The paper presents the conduction of the analytical modelling of the rock mass stress-strain state around the active mine workings using the ANSYS software with the assessment of the influence of its cross-section shape and the angle of the coal seam fall on the value of the maximum stresses arising in the rock mass when the workings are supported with the anchoring support depending on the thickness of the easily collapsible rock layer at different lengths of anchoring.

Keywords: massif, mine development, stress-strain state, stress, anchoring.

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Introduction

Due to the high rate of drifting faces' advance and the strategy of mining operations' development, two mining areas require accelerated and timely development of mine workings with intensive technology of preparation workings.

The increase in the volume of underground coal mining is possible only with the highly efficient technology of carrying out and maintaining preparatory mine workings.

As the level of mining depth increases, one of the problems is to ensure the stability of mine workings. Metal compliant support of arch type and anchoring is used to maintain mine workings in the mines of the Karaganda basin. The cost of money is more than one thousand dollars at the expense of metal-roll to conduct and fix 1 meter of mine workings using arch support. The maintenance cost is at least 10-15 % of the cost of mine workings. The development of 5.0-5.5 km of mine workings is required for 1 million tons of coal accepted in practice systems, which defines essential expenses for preparing mine workings.

More than 10 % of underground workers are engaged in the repair of mine workings [[1], [2], [3], [4], [5]]. Loss of the cross-sectional area of reservoir workings reaches 60-70%. This leads to 20% of mine workings being repaired and refastened annually. The share of expenses on carrying out, fastening and maintenance of mine workings reaches 15-20 % of the cost price of coal mining.

The use of more significant profiles and increased density of frame support considerably increases the metal intensity of workings and labor intensity of erection. Its operation has several serious drawbacks, which lead to significant deformations of excavations: flattening of tops, extrusion into the section cavity of lateral legs, and failure of locking joints.

Improving the efficiency of maintaining the mine workings' stability can be achieved using progressive anchoring technology.

The behavior of rocks of the coal seams' roof in the Karaganda basin is determined by their composition, physical and chemical properties, stratification and fracturing. The immediate roof of the coal seams is most often represented by mudstones, more rarely siltstones and by sandstones in isolated cases; the main roof is usually composed of sandstones. Argillites predominate in the soil of coal seams [[6], [7], [8], [9], [10]].

The value of using the technology of anchoring mine workings in 2021 in the mines of the Karaganda basin reached 25%, and with the combined (metal-anchored underlay and anchoring) - 48%. To increase the volumes of using the anchoring technology, it is necessary to estimate its application depending on operating conditions and develop typical effective driving and supporting workings technologies [[11], [12], [13], [14]].

An urgent task of mining production is the study of rock mass deformation peculiarities around preparatory workings with anchoring at different dip angles and anchoring depths, justification of anchoring parameters and determination of the rational area of its use [[15], [16], [17], [18]].

The experimental part

The research aims to develop effective technology for supporting the contour rock mass based on studying the technogenic stress-strain state (TSSS). To implement it, a technology of intensive and safe conduct of mine workings based on the identified patterns of behavior of host rock massifs adjacent to them, optimization of parameters of technological schemes of preparatory works was created.

One of the main directions of technical progress in anchoring and maintenance of mine workings is the use of resource-saving technology of preparatory workings with the use of anchoring, including in combination with metal arch support.

Thus, the urgent task of mining production is the study of the deformation features of the rock mass around preparatory mine workings with anchoring at different angles of bed dip and anchoring depths, justification of the anchoring parameters and determination of the rational area of its use.

The excavation disturbs the equilibrium state of rocks. It leads to the redistribution of stresses in the surrounding massif, and the intensity of stresses on the excavation contour is much higher than in the disturbed massif. Increased stresses on the mine workings lead to a zone of inelastic deformations around them. The structure of the zone and the nature of rock deformation depend on the excavation depth, physical, mechanical and technological properties of rocks, the size of the excavation, the type and characteristics of the mount, and the angle of the enclosing rocks.

The diversity of mining and geological and mining conditions and the related mechanism of interaction between rocks and supports have led to various geomechanical mathematical models of the rock mass state around mine workings.

Modelling is executed using the numerical method of finite elements, the stress-strain state of the massif around the active mine working. The solution is carried out in the elastic statement due to a comparatively short time of rock deformation in the vicinity of the preparatory face during its movement. In contrast to the known approaches, the dimensions of the deformation propagation zones are specified with the analysis of their parameters [[19], [20], [21]].

Using the ANSYS software package, the influence of the shape of the mine cross-section and the dip angle of the coal seam on the value of the arising maximum stresses in the rock massif when securing the mine with the anchor support is evaluated.

Figure 2 (for reservoir conditions of 4.0 m) shows calculations of stress components: σ_y is normal, σ_x is the longitudinal component of supports. Vertical (Figure 1a), longitudinal (Figure 1 b), and tangential (Figure 1c) components increase with formation dip angle, within its component change from 100 to 400. For all cross-sectional forms, the values of σ_x and σ_{xy} are an order of magnitude higher than σu for the same x, with high σ_x, σ_y characteristic of the arch form, the same for σ_{xy} (the tangential stress component).

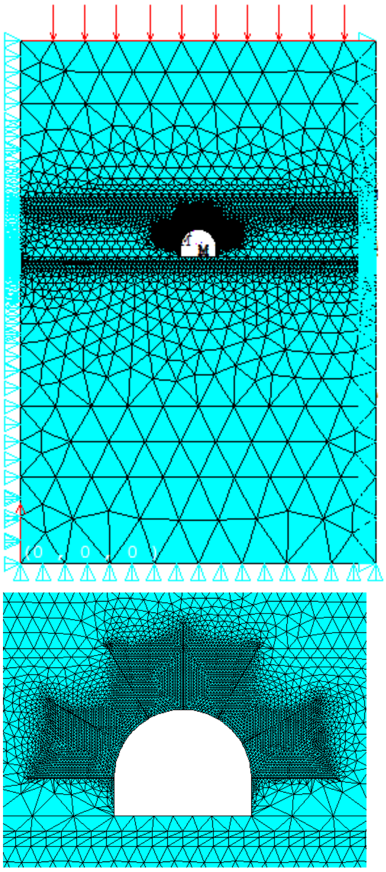


Figure 1 - Calculation scheme of the problem

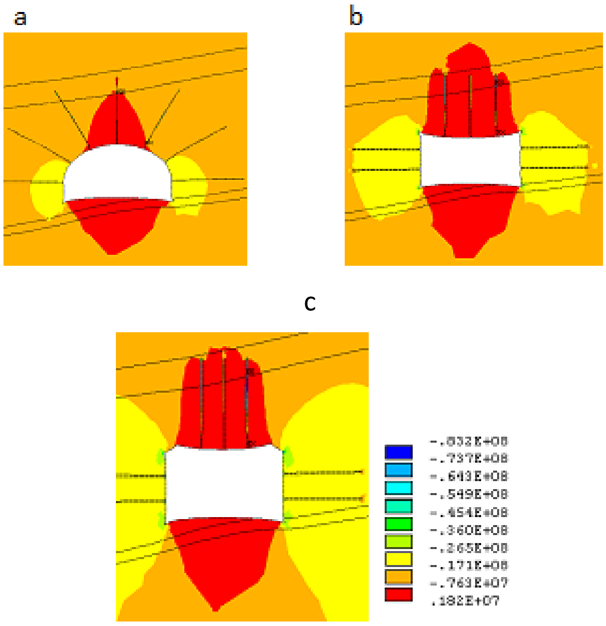


Figure 2 - Diagrams (at α = 100) of the maximum normal stresses in the areas surrounding the mine workings of the arch (a), rectangular (b) and polygonal (c) cross-sectional forms

Figure 3 shows plots of maximum normal (a), longitudinal (b), and shear (c) stresses in rock mass at anchoring of arch (1), rectangular (2) and polygonal mine workings with formation dip angle.

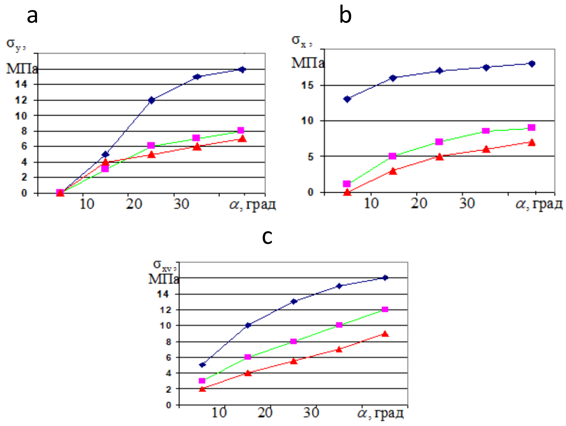


Figure 3 - Plots of maximum normal (a), longitudinal (b) and tangential (c) stresses in rock mass at anchoring of arch-shaped (1), rectangular (2) and polygonal (3) workings on the dip angle

The stress-strain state of the host rock layers depending on the thickness of the easy-rock layer is studied at different anchoring lengths. We investigated the character of changes and distribution of stresses in the roof, the ground and the sides of the mine workings by the example of a trapezoidal excavation of a cross-sectional form with the following parameters of the claim scheme: the dip angle of the formation is 15°; its thickness is 4,0 m; the depth of development is 500 m; the working cross-section is 15.5 m^2; the anchor diameter is 0.022 m.

The conducted research allowed us to establish the following character of the behavior of lateral rocks by zones of their location (Fig. 4, a and b).

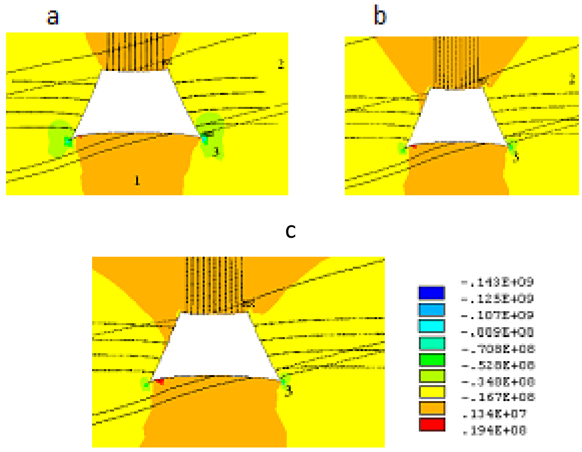


Figure 4 - Distribution diagram (a) and dependences of changes in normal stresses (b) in the host rock with a thickness of argillite layer 1 - 1 m; 2 - 3,5 m; 3 - 5 m, on the depth of their anchoring at the anchor length of 3,5 m.

The influence of the roof rocks (with increasing the layer of easily collapsing argillite) at the trapezoidal form of the excavation cross-section is studied. Parameters of the rated scheme: dip angle 15°, its thickness 3.8 m; excavation depth 400 m; working cross-section 15.5 m^2; anchor length 3.0 m, its diameter 0.05 m.

Figure 5 shows the distribution of longitudinal stresses around the trapezoidal excavation with a claystone layer of 1 m along the length of the boreholes. Significant stresses are subjected only to the area of rocks at the extremities in the roof of the boreholes, which requires increasing their density in this area [4].

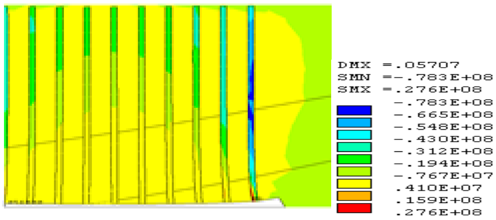
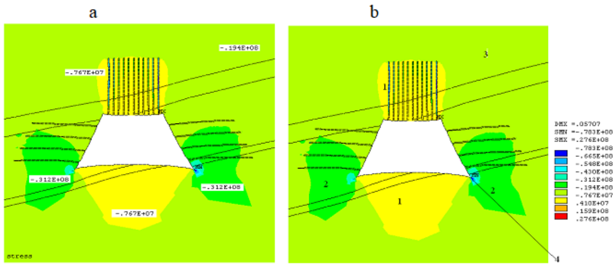


Figure 5 - Distribution of longitudinal stresses around the trapezoidal excavation with a layer of argillite 1 m on the length of the boreholes

Figure 6 shows the distribution of normal and longitudinal stresses at the argillite layer of 7.5 m along the contour of the mine workings.

Analysis of the stress distribution shows that zones of unstable rock formations occur around the excavation. The analysis of the stress distribution shows that there are zones of unstable rock around the excavation. The maximum value of normal stresses is in the anchor, located on the top of the excavation, in the rightmost anchor of the securing point. The maximum value of longitudinal stress occurs in the anchor on the right side surface of the excavation (first from the bottom).



1 - zone of very unstable; 2 - zone of unstable; 3 - zone of unstable; 4 - zone of medium stability; at the minimum point - zone of stable

Figure 6 - Distribution of normal (a) and longitudinal (b) stresses at argillite layer equal to 7.5 m

Conclusions

The revealed patterns of change in the stress-strain state of coal massifs (displacements, stresses, fracture zones) depending on the main mining-geological and mining-technical factors make it possible to set the optimal parameters anchorage to increase the stability of preparatory mine workings under particular operating conditions. This will allow the development of new and improved technologies for effective and safe anchoring of near-surface rocks when conducting mine workings on flat and inclined coal seams, adaptive to changing mining-geological and mining-technical conditions of operation.

Conflicts of interest

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

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Әсер етуші факторларға байланысты тау-кен қазбалары контурларының кернеулі-деформацияланған жай-күйінің параметрлерін негіздеу

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ТҮЙІНДЕМЕ

Тау-кен-геологиялық жағдайлардың күрделенуі кен қазбаларын бекіту әдістерін, жүйелерін, тәсілдері мен құралдарын жетілдіруді, сондай-ақ бекіту кезінде пайдаланылатын материалдардың сапасын жақсартуды қажет ететін күрделі тектоникасы бар учаскелер мен тұтас кен орындарын игеруге тартумен, игеру тереңдігінің ұлғаюымен, тау-кен қысымының қауіпті динамикалық әсерінің көрінуімен байланысты.Тау бекітпесін пайдалануға әсер ететін тау-геологиялық факторларға мыналар жатады: тау қысымының тік және көлденең құраушыларының шамасын анықтайтын тереңдік; кен шоғырының игерілетін қабатының қуаты; қабаттың жату бұрышы; негізгі тау жыныстарының қасиеттері, жыныстар мен пайдалы қазбалардың құрылымы мен физикалық-механикалық қасиеттері. ANSYS бағдарламалық кешенін қолдана отырып, жұмыс істеп тұрған қазба айналасындағы массивтің кернеулі-деформацияланған күйін аналитикалық модельдеу, оның көлденең қимасының пішіні мен көмір қабатының құлау бұрышының әр түрлі анкер ұзындығы бар оңай бұзылатын жыныстар қабатының қуатына байланысты қазбаларды анкермен бекіту кезінде тау жыныстарының массивінде пайда болатын максималды кернеулерге әсерін бағалай отырып жүргізілді.

Мақала келді: *17 наурыз 2022*
Сараптамадан өтті: *24 сәуір 2022*
Қабылданды: *11 шілде 2022*

Түйін сөздер: массив, қазба, кернеулі-деформацияланған күй, кернеу, анкерлік қолдау.

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Обоснование параметров напряженно-деформированного состояния контуров горной выработки в зависимости от влияющих факторов

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АННОТАЦИЯ

Усложнение горно-геологических условий связано с вовлечение в отработку участков и целых месторождений со сложной тектоникой, увеличением глубины разработки, проявления опасных динамических воздействий горного давления, что обуславливает необходимость совершенствования методов, систем, способов и средств крепления горных выработок, а также улучшать качество материалов, используемых при креплении**.** К горно-геологическим факторам, влияющим на использование горной крепи, относятся: глубина залегания, что определяет величину вертикальной и горизонтальной составляющих горного давления; мощность пласта, разрабатываемой залежи; угол залегания пласта; свойства вмещающих пород, структура и физико-механические свойства пород и полезного ископаемого. Выполнено аналитическое моделирование напряженно-деформированное состояние массива вокруг действующей выемочной выработки с использованием программного комплекса ANSYS с оценкой влияния формы ее сечения и угла падения угольного пласта на величину возникающих максимальных напряжений в массиве горных пород при креплении выработки анкерной крепью в зависимости от мощности слоя легкообрушающихся пород при разной длине ее анкерования.

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References

[1] Rozenbaum MA, Demekhin DN. Opredeleniye deformatsionnykh kriteriyev ustoychivosti porod krovli i ankernoy krepi [Determination of the deformation criteria for the stability of roof rocks and anchor support]. Fiziko-tekhnicheskiye problemy razrabotki poleznykh iskopayemykh = Physicotechnical problems of minerals development. 2014;2:82-87. (in Russ.).

[2] Otraslevaya instruktsiya po primeneniyu ramnykh i ankernykh krepey v podgotovitelnykh vyrabotkakh ugolnykh i slantsevykh shakht [Branch instruction on the use of frame and anchor bolts in the preparatory workings of coal and shale mines]. IGD them. A.A. Scochinsky, Moscow, 1985. (in Russ.).

[3] Ruppel U, Opoloni K. Features of the use of anchor support on high-performance production in the aspect of international comparison. Glukauf. September, 2000;2(3):31-37.

[4] Daipal VSh, Brandari S, Prasat CD. The choice of technology and economically optimal roof anchoring system for the implementation of developments in the coal mines of scientific approaches. Cole International. 2002;12:10-17.

[5] Walker S. The system of fixing the mine workings. World Coal. August, 2003:17-22.

[6] Shaikhova GS. Explanation of the Cluster Structures Melting Mechanism and Their Influence on the Molten State's Physical and Chemical Nature. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources. 2021;1(316): 62-68. https://doi.org/10.31643/2021/6445.08

[7] Firhouse R, Arentz A. A passage of a rectangular section drift with an anchor support in zones of increased rock pressure. Glukauf. 2001;11:4-12.

[8] Karr F. Recent innovations in the anchoring of rocks at mines of the state coal management of Great Britain. Reports at the symposium on anchorage. London. 1984:268-281.

[9] Ulrich L. Design basis of mining pressure control with combined support in reservoir drifts. Glukauf, March, 2002:16-20.

[10] Lushnikov VN, Eremenko VA, Sandy MP, Kosyreva MA. Vybor ankernoy krepi dlya vyrabotok. proydennykh v shakhtakh. podverzhennykh gornym udaram [The choice of anchor support for workings, traversed in mines prone to mountain impacts]. Fiziko-tekhnicheskiye problemy razrabotki poleznykh iskopayemykh = Physicotechnical problems of minerals development. 2017;3:86-95. (in Russ.).

[11] Trushko VL, Protosenya AG, Matveev PF. and others Geomekhanika massivov i dinamika vyrabotok glubokikh gorizontov [Geomechanics of arrays and dynamics of developments of deep horizons]. St. Petersburg Mining Institute, St. Petersburg, 2000 (in Russ.).

[12] Zhurov V.V. Sovershenstvovaniye metodiki rascheta parametrov krepleniya vyrabotok s uchetom gornotekhnologicheskikh faktorov [Perfection of a technique of calculation of parametres of fastening of developments with the account of mining technological factors]. The dissertation on competition of a scientific degree of the candidate of engineering science. KSTU, Karaganda, 2010 (in Russ.).

[13] Demin VV. The choice of the construction of the support for fixing the rocks of the mine workings. In: RUDN university, organizer. Proceedings of the sixth international conference "Resource-reproducing, low-waste and environmental protection technologies of subsoil development". Moscow - Karaganda. 2007;121-123.

[14] Tutanov SK, Tutanova MS. Accounting for creep of the rock mass around the sides of the quarry. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources. 2022;322(3):74-78. https://doi.org/10.31643/2022/6445.31

[15] Demin WF, Demina T I, Kaynazarov A S, Kaynazarova A S. Evaluation of the workings technological schemes effectiveness to increase the stability of their contours. Sustainable Development of Mountain Territories. 2018;10(4):606-616.

[16] Gorbunov MS, Gorbunov IS, Demin VV. Geomechanical processes in host rocks during excavation workings. Proc. scientific-practical conference "Actual problems of the mining and metallurgical complex of Kazakhstan", Karaganda. 2007;110-113.

[17] Demin VV. Investigation of technological parameters of the use of steel-polymer anchors in the mines of the Karaganda basin. Scientific and technical support of mining. Proceedings of the DGP "Mining Institute.D. Kunaev". Almaty, Kazakhstan. 2007;74:179-185.

[18] Tutanov S K, Tutanov M S, Tutanova M S. A mathematical model for determining the influence of factors on the stability of pillars and cameras. Kompleksnoe Ispolzovanie Mineralnogo Syra=Complex Use of Mineral Resources.2020;3(314):15-21. https://doi.org/10.31643/2020/6445.22

[19] Diomin VF, Khalikova ER, Diomina TV, Zhurov VV. Studying coal seam bedding tectonic breach impact on supporting parameters of mine workings with roof bolting. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu. 2019;5:16-21. https://doi.org/10.29202/nvngu/2019-5/5

[20] Q Ye W jun Wang, G Wang, and Z zhen Jia. Numerical simulation on tendency mining fracture evolution characteristics of overlying strata and coal seams above working face with large inclination angle and mining depth. Arabian Journal of Geosciences. 2017;10(4). https://doi.org/10.1007/s12517-017-2856-9.

[21] Barton N. Some new Q-value correlations to assist in site characterisation and tunnel design. International Journal of Rock Mechanics and Mining Sciences. 2002; 39(2):185-216. https://doi.org/10.1016/S1365-1609(02)00011-4