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Analysis of Possible Origination of Domes in Longwalls

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Abstract: The research is aimed at solving problems of assessing underground working stability in complicated mining and geological conditions to increase reliability and safety of mining operations. Analysis of geomechanical processes occurring in a rock mass during extraction of coal seams to determine the stability of mining block roof is the most important task. The performed digital modeling of the rock mass based on the structural logs for K1 seam and the nearest borehole log enabled highly detailed identifying the types of rocks occurred in the seam roof and their strength characteristics, compressive stresses. To determine the stability of a mining block roof, the factor of safety of the rocks was used, which was determined by modeling method using Phase 28.0 and Rockscince software. The carbonaceous argillite parting 0.09–0.12 m thick was taken as the contact of the longwall with the seam roof, and, for completeness of the analysis, the upper high-ash coal member in the seam roof up to 0.7 m thick was used. The modeling findings, presented in the graph of dependence between the safety factor and the distance between the belt heading and air drift, showed that the probability of dome formation in the longwall is high, as the factor of safety of the rocks is less than unity, that indicates the roof instability in the course of the coal seam block extraction. The modeling methods allowed assessing the mine working stability, based on which the measures to improve the reliability and safety of mining operations can be timely developed, and due technical and technological solutions shall be reached.

Keywords: longwall, seam, rock mechanical and gas-dynamic process, stress, strain, stability, modeling, factor of safety.

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Анализ возможного возникновения куполов в лаве

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Аннотация: Исследования направлены на решение задач по оценке устойчивости горных выработок при подземной разработке в сложных горно-геологических условиях, повышающих надежность и безопасность проведения горных работ. Исследование геомеханических процессов, происходящих в горном массиве при отработке угольных пластов, с целью определения устойчивости кровли выемочного блока является важнейшей задачей. Выполнено цифровое моделирование массива горных пород по структурным колонкам пласта К1 и ближайшей скважине, которое позволило с высокой детальностью определить типы пород, залегающих в кровле пласта, и их прочностные характеристики, напряжения на сжатие. Для определения устойчивости кровли выемочного блока был использован показатель коэффициента запаса прочности пород, который определялся методом моделирования с использованием программного обеспечения Phase 28.0 и Rockscince. Контактом комплекса лавы с кровлей пласта был принят прослой углистого аргиллита мощностью 0,09–0,12 м, и для полноты анализа использовалась верхняя высокозольная пачка угля в кровле пласта мощностью до 0,7 м. Результаты моделирования, отраженные на графике изменения коэффициента запаса прочности в зависимости от расстояния между конвейерным и вентиляционными штреками, показывают, что вероятность образования куполов в лаве велика, так как коэффициент запаса прочности пород менее единицы, что указывает на неустойчивость кровли при отработке выемочного участка угольного пласта. Методами моделирования показана возможность произвести оценку устойчивости горных выработок, на основании которой своевременно разработать мероприятия, повышающие надежность и безопасность проведения горных работ, и принять правильные технические и технологические решения.

Ключевые слова: лава, пласт, геомеханический и газодинамический процесс, напряжение, деформация, устойчивость, моделирование, коэффициент запаса прочности.

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Introduction

Underground coal mining is almost always accompanied by difficult mining, geological, and geotechnical conditions, therefore, an urgent issue is studying rock mechanical and gas-dynamic processes occurring in underground workings. Determining the level of maximum effective stresses around mine workings is one of the most important tasks of rock mechanics [3, 4]. Analysis of the simulation results, taking into account the safety factor of the rocks, allows selecting the optimal parameters for the deposit mining, the opening scheme and horizon development work.

The study of the effect of rock pressure on the rock mass and powered support during extraction of a mining block of the longwall allows to determine the change in the condition of the seam roof rocks from compression to tension, which may lead to gradual caving the rock from the roof up to a sudden bulk collapse and the formation of domes.

The research tasks and objectives

The idea of the research is to study a combination of various factors: the structure and properties of a coal-rock mass, a combination of geological and mining conditions, the level of existing stresses in the rock mass, and the technological parameters of the mining block extraction [5].

In this regard, the development of methods for the integrated management of rock mechanical and gas-dynamic processes in coal mines is an urgent scientific and practical task.

The obtained scientific and practical results of the studies performed by the authors can be used as the basis for the integrated management of rock mechanical and gas-dynamic processes in mines [6–10].

Most studies are based on solving the elastic rock mechanical problem, and the resulting stresses and strains are compared with the maximum allowable for the near-outline rock mass. When solving rock mechanical problems, one of the main issues is the determination of reliable calculated values of the strength properties of a rock mass.

The research methods

By the level of stresses existing in a rock mass, it is possible to assess the stability of mine workings and determine the rock safety factor.

Cross section of permanent mine workings in the course of their drifting may change due to the influence of the stresses occurring in the surrounding rocks [11–13]. Instability of the workings is caused by high vertical stress. However, in practice, there are cases when horizontal stresses significantly exceed vertical ones that may lead to deformation of the roof and bottom rocks. The bottom deformation is manifested by bulging only, which may go practically unnoticed.

The existence of tensile stresses does not always cause failure of the rock mass in the area. The rocks themselves can to some extent resist tension, and even in case of some displacements, the rock mass retain some stability (the so-called residual rock strength) [3, 17].

Deformation of the roof rock (Fig. 1) may be accompanied by intensive rock failure, initially in the form of flaws, and then with the transition to collapses. The transition to collapses is connected with decreasing the bearing area when approaching the crest part of the roof.

It should be noted that with the dynamic manifestation of instability in the form of gradual phased roof rock collapse, a sudden bulk collapse may happen.

In the areas where vertical and lateral stresses σ_v and σ_l can simultaneously affect the formation of the cross-sectional shape of a working, the physics of the deformation process is fully determined by the physico-mechanical properties of the rocks.

Therefore, both the level of effective stresses and the properties of rocks, in each case, are individual in nature.

The research subject is K1 coal seam being extracted by 46 K1 longwall. Extraction of a mining block leads to changing rock pressure on rock mass and powered support. This in turn causes periodic changing the rock condition from compression to tension, inducing changing the size and number of hanging rock members in the seam roof, participating in producing abutment pressure [1, 4, 18, 19].

To determine the longwall roof stability (Fig. 1), digital simulation of the rock mass [20] was performed based on the structural logs for K1 seam (Fig. 2) and Borehole No. 11355.

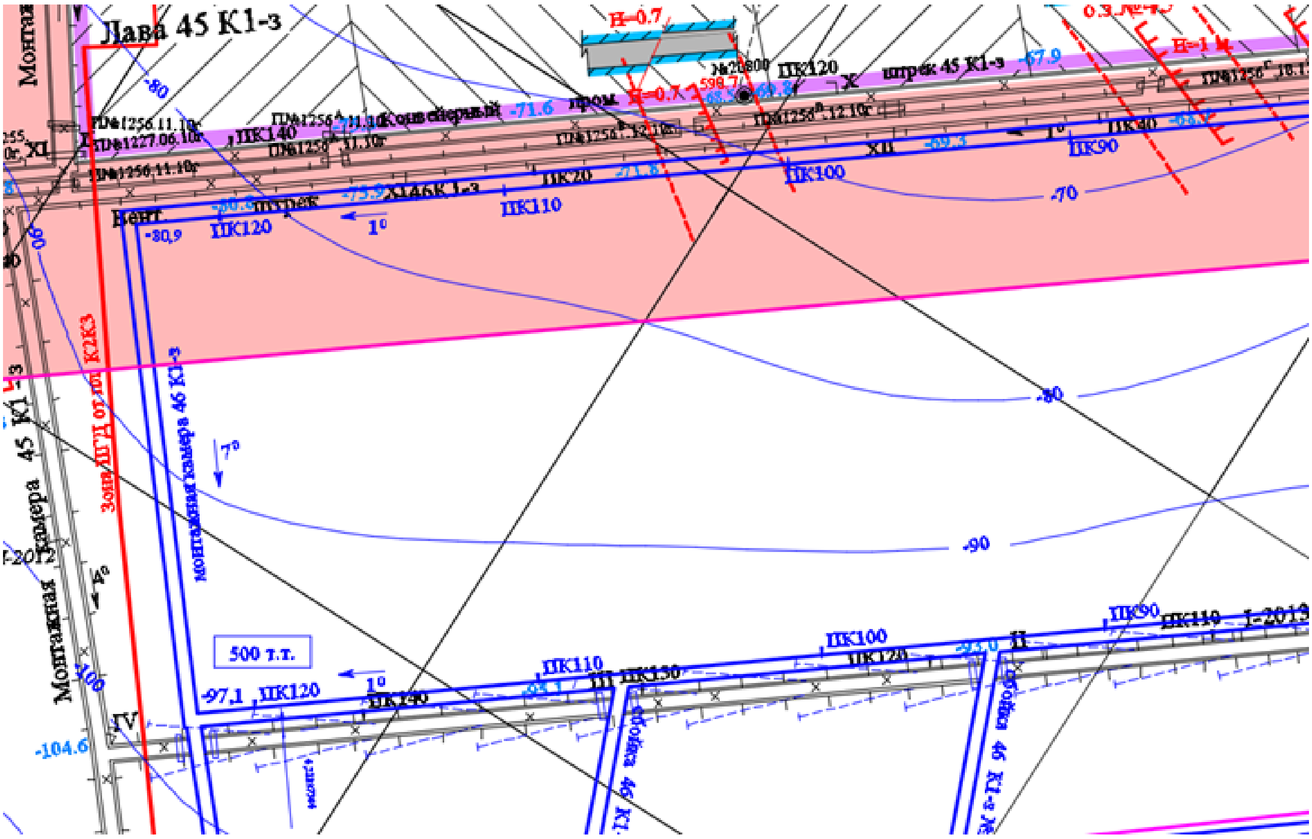

Fig. 1. Longwall 46 K1 mining plan

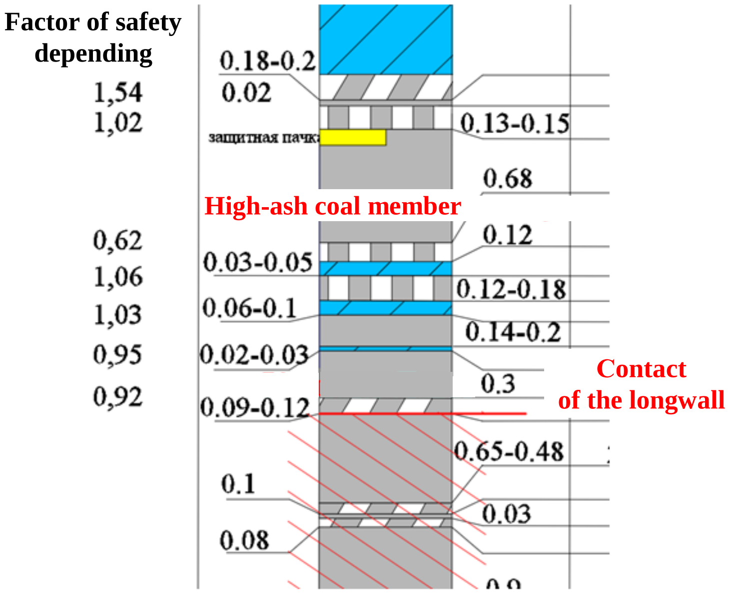

Fig. 2. K1 seam structural log

K1 seam consists of 6–7 standard and two high-ash coal members in the seam top (compressive stress σ_{comp} of 11–12 MPa). The seam top is represented by medium-grained mudstone up to 20.5 m thick (compressive stress σ_{comp} of 22–25 MPa). In the immediate top of the seam, in depth interval 1.2–1.8 m, K1´ stratum up to 0.2 m thick occurs. Sandstone and siltstone with compressive stress σ_{comp} of 35–59 MPa lie in the seam bottom.

To determine the stability of the roof of the extraction pillar, the rock safety factor values were used. The carbonaceous argillite parting 0.09–0.12 m thick was taken as the contact of the longwall with the seam roof (Fig. 2), and, for completeness of the analysis, the upper high-ash coal member in the seam roof up to 0.7 m thick was used.

Findings

Based on the study findings, we can conclude that the seam roof at contact with the carbonaceous argillite parting in the longwall is unstable and easily collapsed. The safety factor value at the contact of the longwall and the carbonaceous mudstone (Fig. 3) is 0.92 on average in the longwall.

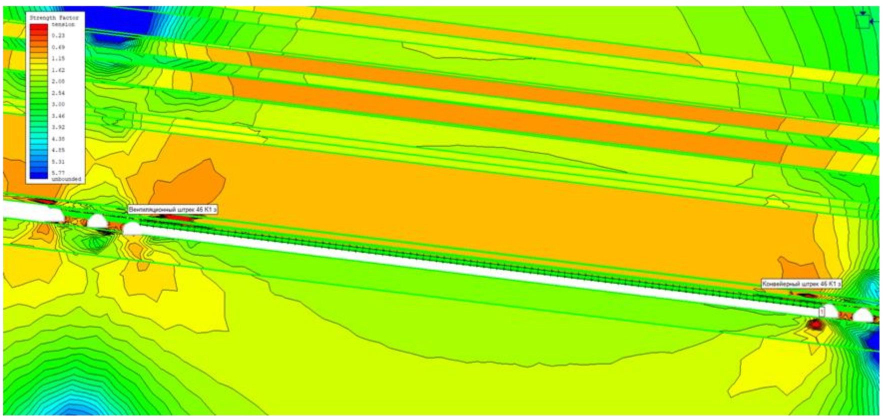

Fig. 3. Factor of safety of the modeled rock mass

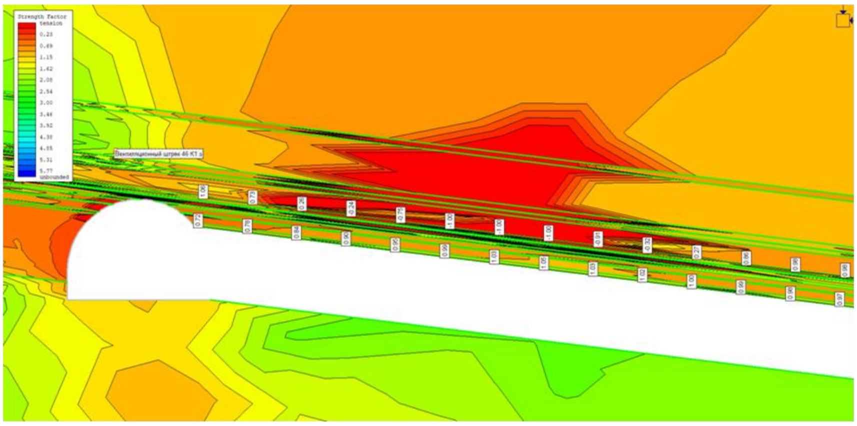

Fig. 4. Factor of safety of the air heading

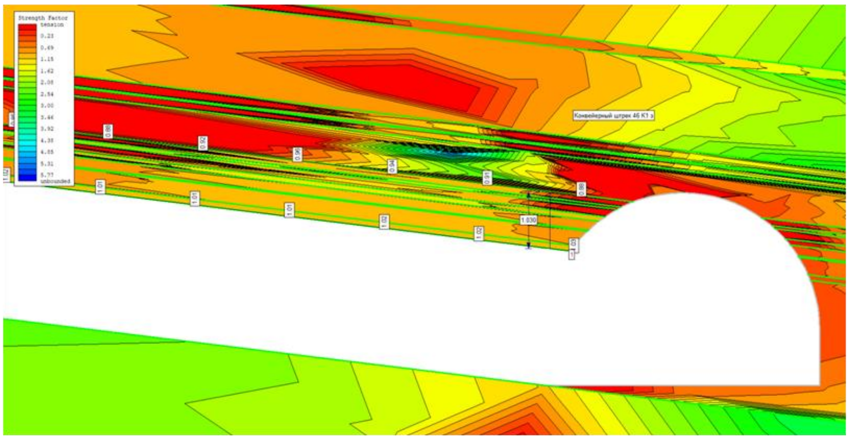

Fig. 5. Factor of safety of the belt heading

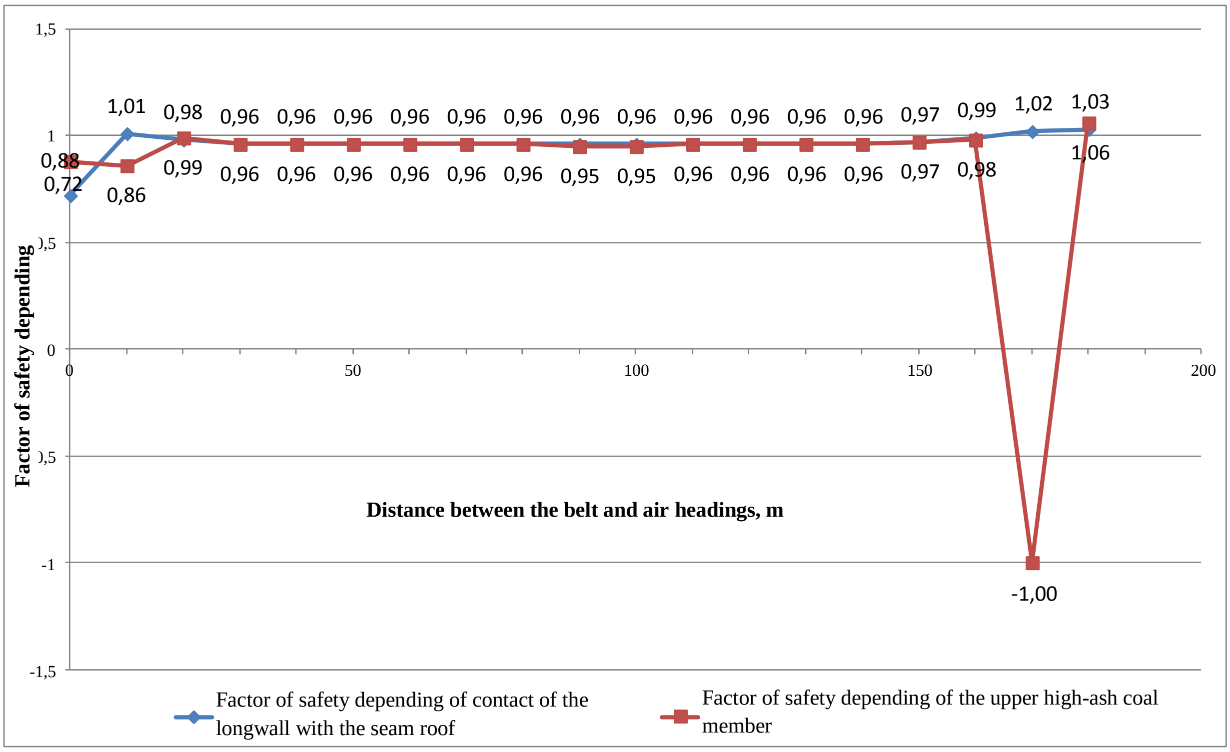

Fig.6. The change in factor of safety depending on the distance between the belt and air headings

The safety factor of the upper high-ash coal member is less than unity and in some places becomes negative in a section 25 m long from the air heading towards the extraction block (Fig. 4). Such value of the safety factor is an indicator that the roof rocks during mining of the extraction block in this place will collapse [21–23]. A possible reason for this is that this block is located in the OGD zone of the overlying extraction block mining.

Conclusion

The modeling findings, presented in the graph of dependence between the safety factor and the distance between the belt heading and air heading, obviously demonstrate that the probability of dome formation in the extraction block roof is high, as the factor of safety of the rocks is less than unity, that indicates the longwall roof instability in the course of the coal seam extraction (Fig. 6).

Based on the findings of the performed studies of rock mechanical processes occurring in the rock mass during extraction block mining, the right decisions can be made on further coal seam mining [24]. Knowing the forecasting data for a coal seam section mining will allow predetermining the most dangerous places, namely the roof collapse points, at the design stage.

The implemented studies with the determination of the safety factor allow predicting the likelihood of domes formation in the extraction block roof and developing measures to ensure safe coal seam mining conditions, as well as preventing potential future emergencies [24, 25].

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