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Assessment of contour deformations of reused mine workings

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Abstract. The paper describes studies to assess the impact of high-intensity mining of flat-lying coal seams in difficult mining and geological conditions on the stability of reused development workings. A scheme for computer modeling of changes in the stress-strain state of a layered carbon rock mass, including development workings, at different positions of the working face is proposed. For the conditions of one of the operating mines of the Pechersk coal basin (Komi Republic, Russia), numerical experiments were carried out using the finite element method in the MIDAS / GTS NX software package. To describe changes in the geomechanical state of the described mining system, the Coulomb–Mohr criterion was used. The results of numerical studies made it possible to estimate the displacement values of the boundary areas of the development mine workings as the working face advances. The obtained estimates are confirmed by data from mine instrumental observations.

1 Introduction

Stable operation of coal mines can be ensured only with timely preparation of the mining front, which is created by carrying out main and preparatory workings [1, 2]. The method of mining, the type of support and the conditions for its maintenance during operation depend on the properties of the host rocks, the thickness of the seam being mined and the depth of work [3]. In conditions where the thickness of the developed formation does not allow the formation of a working of the required cross-section without undercutting the host rocks, as a rule, technological schemes are used with the reuse of development workings. This decision is accompanied by the need to use methods to reduce the magnitude of displacements of the excavation contour [4, 5]. Therefore, assessing the effectiveness of using engineering solutions to maintain reused workings is especially important in increasingly complex mining and geological conditions [6]. This report presents the results of numerical calculations of the displacements of the contour of a reused development working for specific mining and

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geological conditions of the development of a flat-lying coal seam.

An assessment of the deformations of the contour of the reused working is necessary, since after the passage of the longwall it is intended to drain the outgoing jet. Therefore, the supported excavation must have a certain cross-section to remove the calculated amount of air, which will reduce aerological risks during mining of the excavation area.

The studies were carried out for the mining conditions of the Fourth seam of the Komsomolskaya mine of Vorkutaugol JSC. The studied preparatory working is a conveyor bremsberg of longwall face 221. The working is made using a combine method and secured along its entire length with the main arched support of the AP - 3P type, installed every 0.67 m with the roof and sides of the working being tightened. Strengthening the main support is carried out:

- at a distance of at least 40 m to the working face with beams made of a special interchangeable profile (SVP), which are arranged in two continuous threads, AK01 rope anchors 6 m long are installed under each thread, their installation density is 1.5 anchors per meter;
- strengthening of the main support behind the longwall is carried out by installing "bonfires" from timber measuring 1.3 m × 4 m × 3 m. The permissible lag of "bonfires" behind the sections of powered support is no more than 4 m.

Maintaining the interface of the longwall with the excavation under study is ensured by wooden posts installed under a continuous thread of SVP beams closest to the longwall with an installation density of 1 post per meter. To prevent roof rocks from spilling into the longwall, the roof is completely tightened with boards on 3 sections of support at the junction of the longwall with the workings.

The length of the longwall is 152.0 m. The longwall is mined at depths of 538 - 748 m. The coal seam has a simple structure and consists of strong semi-shiny coal. The thickness of the formation ranges from 1.32 m to 1.58 m, the average is 1.5 m.

The objective of the described studies is to obtain a picture of changes in the stress-strain state of the indicated sections of the coal rock mass and to estimate the magnitude of displacements of the contour areas of the development mine workings at different positions of the face.

2 Materials and methods

To solve many problems of applied geomechanics, including performing calculations to assess the impact of mining operations on existing workings for various purposes, numerical modeling approaches are effectively used [7, 8]. One of the generally accepted approaches has long been numerical modeling methods based on the use of nonlinear continuum mechanics models [9-11]. In particular, these approaches are implemented in the MIDAS / GTS NX software package (PC) [12].

The problem under consideration is solved by the finite element method in the MIDAS / GTS NX PC using the Coulomb–Mohr failure criterion [13]. The Coulomb-Mohr criterion is distinguished by its simplicity and can be considered as a first-order approximation to a real description of deformation processes in a rock mass. Nevertheless, this approach allows us to give a fairly realistic idea of the nature of the distribution of the required parameters, including in the case of a complex geological structure of the massif.

The rock massif is considered as heterogeneous, isotropic (within individual rock layers and layers) and nonlinearly deformable. The values of the deformation-strength characteristics of the various components of the geotechnical system under consideration used in the calculations are presented in Table 1.

Table 1. Rock properties.

Materials	Density ρ, kg/m³	Elastic modulus, E, GPa	Poisson's ratio, ν·10³	Coupling C, kPa	Angle of internal friction φ, °
Weakened mudstones	2200	1	250	1000	25
Sandstone	2600	14	200	6500	50
Coal	1340	2	200	2600	50

Considering the technology of mining the “Chetverty” seam of the Komsomolskaya mine of Vorkutaugol JSC, the stages of modeling the stress-strain state of the rock mass during the process of carrying out and operating the preparatory mine working are considered, shown in Fig. 1:

1) Pristine heterogeneous rock mass

2) Preparatory workings secured with arched support

3–14) The cycle of technological operations from installing support to strengthen the main support to strengthening the main support behind the longwall is carried out by installing “fires”.

3 Results and discussion

Figure 1 shows the spatial distributions of the resulting deformations of the geomechanical system under consideration, corresponding to the above stages of coal seam mining.

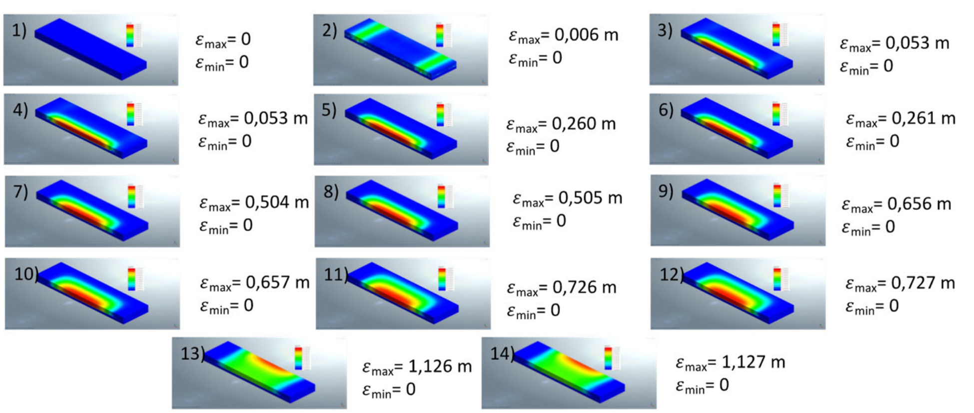

Fig. 1. The resulting deformations of the massif obtained at each stage of modeling: εmax – maximum deformation value, m; εmin – minimum deformation value, m.

To use the results obtained to develop engineering solutions for the trouble-free operation of a reused mine during its entire service life, it is necessary to identify vertical and horizontal deformations. Figure 2 shows the final stage of modeling the geomechanical state of the studied rock mass in the zone of influence of the working face and shows the distribution of the indicated components of deformation of the rock mass containing the reused development working, secured by the main support and reinforcement support. The obtained values of vertical and horizontal deformations make it possible to assess the compliance of the applied methods of fastening and protecting the excavation with the requirements of ensuring the design cross-section of the mine opening with the calculated indicators and can be used to assess the effectiveness of decisions made.

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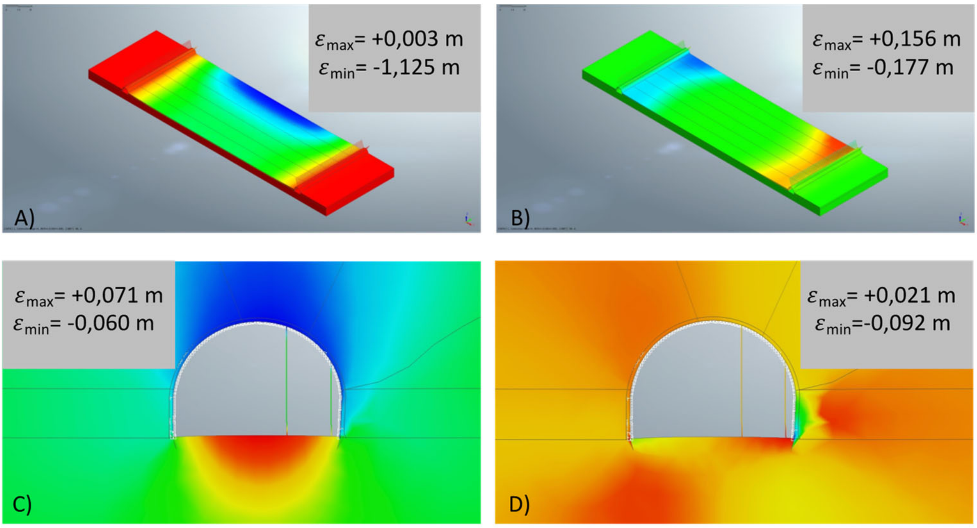

Fig. 2. Distribution of deformations: A) Vertical deformations within the working face; B) Horizontal deformations within the working face; C) Vertical deformations around the excavation secured by arch support; D) Horizontal deformations around the excavation supported by arch support.

To assess the reliability of the modeling results, instrumental measurements of changes in the geometric parameters of the section were carried out along the length of the working at N=11 measuring stations (pickets): (H-height, L-width) of the reused conveyor bremsberg of longwall face 221. Figures 3A and 3B show the values the specified data as of 01/13/2023 and 04/20/2023, respectively. For comparison with the modeling results, data from field measurements in zones of rock disturbance are excluded.

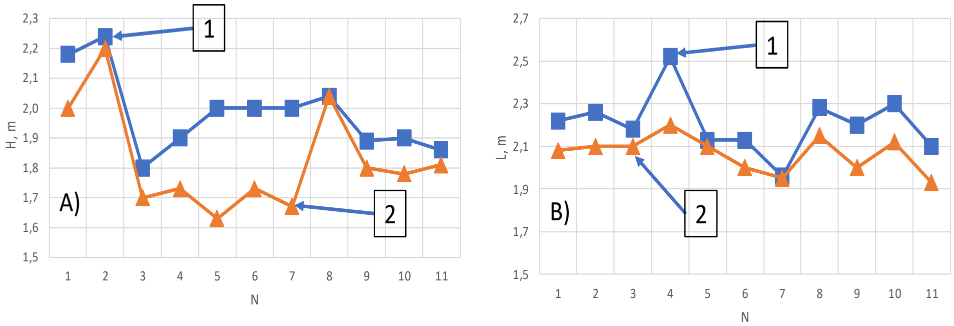

Fig. 3. Results of instrumental measurements of the geometric parameters of the mine workings: A) Change in the height (H) of the workings; B) Change in the width (L) of the excavation. (1 - as of 01/13/2023; 2 – 04/20/2023).

A comparison of the results of field studies and modeling on 01/13/2023 and 04/20/2023, respectively, is shown in Table 2. The values of deformations obtained instrumentally were determined as the difference in the values of the geometric parameter (width (L) or height (H)) of the excavation for the time interval under consideration. Table 2 presents the values of deformations of the excavation section corresponding to picket N=11. On the other hand, for comparison with instrumental measurement data, the strain values obtained at the final stage of modeling at the boundary of the computational area, which corresponds to picket N=11, were used.

Table 2. Comparison of deformations.

Geometric parameter	Deformation values based on instrumental measurements, m	Deformation values based on simulation, m
Width (L)	0.13	0.11
Height (H)	0.16	0.14

Table 2 clearly shows that the vertical deviation of the deformation values does not exceed 13%, and the horizontal deviation - 15%. Thus, the results obtained show satisfactory convergence of the modeling results with field studies.

4 Conclusion

When mining seams whose thickness does not allow the formation of development workings without undercutting side rocks, technological schemes for mining the reserves of the excavation area with the reuse of mine workings are used.

The use of modeling to assess the deformations of a reused mine allows, at the design stage, to analyze the change in the geomechanical state of the mine throughout the entire cycle of its operation, which allows reducing the costs of material and labor resources.

The problem under consideration is solved by the finite element method in the MIDAS / GTS NX PC using the Coulomb–Mohr fracture criterion. This approach allows us to give a fairly realistic idea of the nature of the distribution of deformation processes in a rock mass.

To assess the reliability of the modeling results, instrumental measurements of the deformations of a reused mine with similar conditions were carried out; the results obtained showed satisfactory convergence of the results.

The results of the study demonstrate that the proposed geomechanical model of the rock mass fully reflects the main features of its structure and changes in the contour of the development mine during its operation and can be used to assess the efficiency of reuse of the mine with various methods of its maintenance.

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