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Research

QUALITATIVE ASSESSMENT OF STRAIN STRESS DISTRIBUTION OF ROCK MASSIF IN THE VICINITY OF PRE-DRIVEN RECOVERY ROOM

G.N. KARPOV * AND A.V. LEISLE

Saint-Petersburg Mining University, Russian Federation, 199106, Saint-Petersburg, Vasilievsky Island, 21 line, 2, Russia

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ABSTRACT

In underground mining of flat-lying coal seams with the application of longwall mining systems, the downtime period of cleaning equipment during its face-to-face transfer is inevitable and has no relation to the reliability of the process flow chart. The downtime period, in some cases, may last two-three months, while technologically, the period of full dismantling does not exceed 20 days. Thus, the downtime period incurs substantial financial losses.

The main cause of the dismantling work duration increase is roof rocks' caving into the working area of the dismantle camera, as the rectification of its consequences is extremely labor-intensive. The geomechanical state of the roof rocks above the dismantle camera is in significant correlation with the technology of the dismantle chamber forming. The paper briefly reviews the forming technologies which currently exist. Basing on the computer simulation method, a geomechanical model is constructed demonstrating changes of the stressed and strained state of rocks in the adjacencies of the dismantling area, with the technology application of advance forming of the dismantle chamber with subsequent insertion of a longwall set of equipment into it. The findings enable to conduct the qualitative assessment of the changes of the rock massif's geomechanical state when the longwall mining face approaches the place of its dismantling.

INTRODUCTION

In 2015, the Russian coal-mining industry had the volume of coal produced through underground mining of 103.6 million tones which is by 15% exceeds the outcomes of 2000. In 2015, the average number of fully mechanized faces in Russia was 73.2. (Tarazanov, 2015)

Such a substantial increase of the production rate of the mining faces was accomplished mainly by means of the large-scale implementation of reliable high-performance mining equipment at the coal companies' mines. However, the application of expensive equipment enabling stable coal production of up to 10,000 tonnes of per day and above from one face, is inseparably linked with the increase of the downtime cost of this equipment. For this reason, the issue of minimizing the period of remounting longwall sets of equipment when transferring them to new extraction areas, which has always been of importance during their operation, has gained particular significance.

THEORETICAL BACKGROUND-PROBLEM STATEMENT

During remounting heavy longwall sets of equipment, the period of time required by the technology for performing all the remounting operations, is about 16-20 days, depending on the mining parameters (the longwall length, the transportation route, the layout

***Corresponding authors email: prk42@mail.ru**

of mounting and dismantling and others). At the same time, the actual duration of remounting frequently exceeds 30 days, lasting up to 160 days and above in some cases. Studying this matter at the mines of the Kuznetsk Coal Basin for the period 2009-present day resulted in the following conclusions: the duration of remounting the longwall set of equipment directly relates to the success rate in forming the dismantle chamber.

Currently, in underground fully-mechanized coal mining, two methods of forming dismantle chambers are applied, which are fundamentally different. The first and the most frequently applied method is forming the chamber by means of the shortwall combined with simultaneous erection of a protection ceiling above the powered support sections. The second method which was developed as an alternative in the 1980s, is inserting the longwall set of equipment into a previously sunk and reinforced mine working (Fig. 1).

Each of the two abovementioned methods has a number of advantages and disadvantages. Currently, the first method of forming the dismantle chamber is most widely used, in combination with a polymer net which is described in sufficient detail in (Artemiev, 2010). When this method is applied, the average duration of forming a chamber of 200 m to 220 m in length is 12-16 days. The second method of forming a dismantle chamber is applied significantly more seldom. There have been cases in the present day practice when the second method's implementation resulted in the longwall equipment set being put in operation in less than one day, but in some other cases, this period exceeded two months. The main cause of the protracted downtime periods was the destruction of the pillar between the advanced mine working and the mining face, as well as of the roof rocks destruction in its area when the longwall approaches the dismantling area (Wichlacz, 2009; Oyler, 1998; Tadolini, 2003; Karpov, 2013).

Despite the fact that today's specialists everywhere demonstrated their preference for the first method, in the authors' opinion, the second method should not

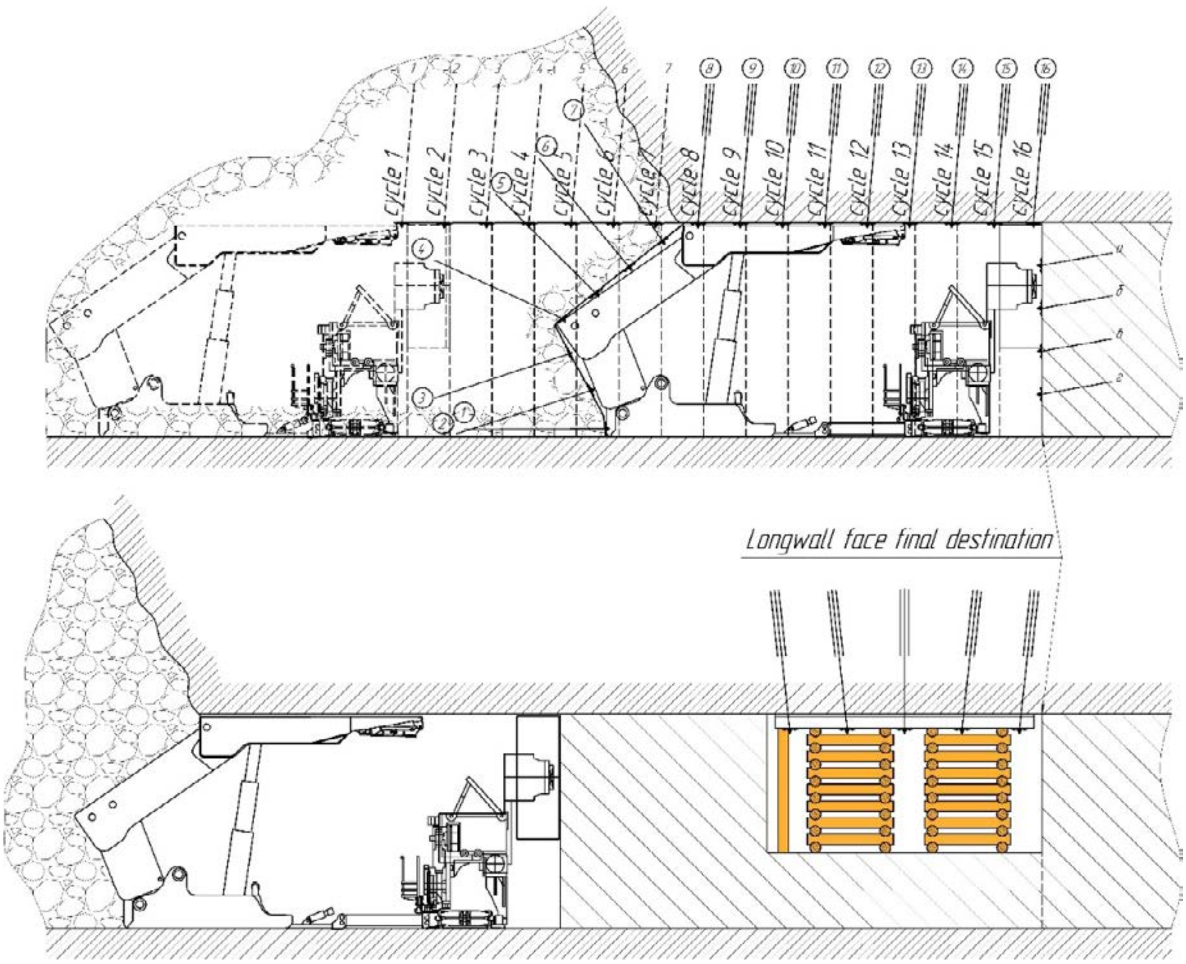

Fig. 1 Diagram of dismantle chamber forming via inserting the longwall set of equipment into a previously sunk mine working.

be considered as unviable even under the conditions of a fractured roof. Thus, in order to have more comprehensive understanding about the stressed and strained state of the rock massif in the area of the advanced mine working, when the mining face approaches it, the authors decided to create a numerical geomechanical model.

SUBSTANTIATION OF THE RESEARCH METHOD

The study of the impact of mining on the changes in the stressed and strained state of a coal massif is a complex problem of mining and geomechanics. As a rule, such problems have no precise analytical solutions. According to the literature (Kuna, 1989; Barry, 2013; Lanovsky, 1999; Fadeev, 1987), in studies of the stressed and strained state of a rock massif, application of physical or mathematical modeling is of maximum efficiency.

Application of numerical methods in rock mechanics has a number of advantages over the other methods of simulation: universality; capacity to take into account the bigger number of influence factors; relatively low time and labor intensity required for developing the models (compared with physical experiments); no need for materials, special equipment, etc.

The numerical simulation methods are in the category of net methods applied for the approximate solutions of the boundary-value problems. From the viewpoint of theoretical estimates, the existing numerical simulation methods-the finite elements method and the finite difference method-have approximately the same precision which depends mainly on the shape of the simulated area, boundary conditions and other factors.

The main difference between these methods is that in the problem solving via the finite elements method, the solution itself is approximated, and in problem solving via the finite difference method, the derivatives of the sought-for functions are approximated.

The finite difference method is more frequently applied in solving the problems having functions with straight-line boundaries, as the peculiarities of the geometry of the regions in constructing regular nets are considered only in near-boundary nodes.

When problems are solved by the finite elements method, the geometrical peculiarities of the model regions are considered in the process of the model fragmentation into elements. The net constructing process is implemented in the direction from the boundary for ensuring better approximation of its geometry. The net constructing algorithm includes the capacities on increasing the net compactness in the areas of the model elements interface, as well as enables to preserve the proportions between the side lengths of each of the triangular cells which practically eliminates errors in the calculations related to breaking down the region. These special features enable to use the finite elements method in calculating the strength of parts, structural components of different types, as well as of the parameters of stressed and strained state of various media, including geological media.

The stressed and strained state of the rock massif in the mine working area is mainly studied in the elastic approach when the Hooke's law in bulk approach acts as the medium equation. This is caused by relative simplicity of the mathematical tool used in analytical calculations.

However, it is worth mentioning that many rocks have high plasticity causing the formation of limiting state zones (non-linear deformation zones) around them. For this reason, the application of the rock massif elastic model in calculations brings the results which frequently differ from in situ observations.

The finite elements method chosen as the key research method, enables to consider the non-linearity of rocks behavior in its mathematical tool. Consequently, in order to specify the stressed and strained state of the rock massif in the studied area with consideration of the geometrical parameters of the process flowchart and the medium properties, the finite elements method should be applied in elastic and plasticity setting of the researched problem. The effectiveness of solving geomechanical problems via the finite elements method proves the expediency and sufficiency of applying this method for studying the rock massif stressed and strained state for this research.

Application of the numerical simulation methods for solving the problems of rock geomechanics, in particular for coal mines, has becoming more widespread with the sophistication of hardware and software. For example, LaModel, Plaxis 2D, FLAC, FLAC3D and other software (Esterhuizen, *et al*., 2010) are successfully applied for the simulation of the stressed and strained state of various elements of a coal massif. As a rule, the choice of software is based on the software applicability to the specific problems to be solved. Despite the relative simplicity in use and proved efficiency, such methods of the stressed and strained state assessment have a number of flaws.

Currently, the most perfect numerical models enable to simultaneously consider both the spatial structure and state of the rock massif, as well as the change of any elements in a course of time, while studying the most complex mine engineering situations (Larson and Whyatt, 2009; Sarathchandran, 2014). In order to obtain representative results in such cases, the work of a team of highly qualified engineers is required, along with the high precision of the source data and, if possible, the model should be calibrated by the data of the massif state monitoring in situ. However, if the rock massif has sufficiently well pronounced spatial homogeneity of the mechanical properties within the sites under consideration (mine workings, pillars, supports and so on), as well as if only summary, average data on the rock massif properties are available, the stress and strained state is possible and expedient to be assessed via the planar deformation approach.

Such an approach simplifies both the process of constructing the model and its editing at reusing in similar mining-and-geological conditions.

METHOD MODEL DESCRIPTION-DISCUSSION OF RESULTS

For the purposes of physical interpretation of the process described, a finite element mining-and-geomechanical model was developed (Fig. 2), which includes the geometry of the worked out space, the extracted layer and advanced mine working. The source data for the model are taken in accordance with the conditions of the development of extraction pillar 5208 of Kotinskaya mine of SUEK-Kuzbass Public Corporation.

The raised problem was solved via elastic plasticity planar deformation approach. Simulation was constructed for the worked out space which represents the cavity of finite dimensions with the roof consoles protruding above the layer edge part. The interrelation of the consoles was simulated via setting the interface conditions on their boundaries.

Fig. 3 demonstrates the displacement vectors of the bearing rocks. It is visible that the rocks of the main and immediate roof create the torsion torque with the arm leaning against the layer edge part. The pillar between the wall face and the advanced mine working is located in this zone.

This causes the increase of the rock pressure in the edge part of the rock massif, in the roof rocks above it and, respectively, in the pillar.

When stresses exceed the layer strength, layer destruction occurs which is demonstrated in Fig. 4 in the form of developing plastic deformation zones.

A pillar of certain dimensions is completely destroyed. In this case, the pattern for the pillar having the width of 5 m (a) and 10 m (b), is demonstrated. It is well seen that in the first case, the layer in the vicinity of the advanced mine working has completely transferred in the limiting state. In reality, this means that these rocks are destroyed, and their carrying capacity is significantly reduced. As the pillar lost its stability, the protruding console loses the support. The console length increases, the support point switches to point C (Fig. 4a).

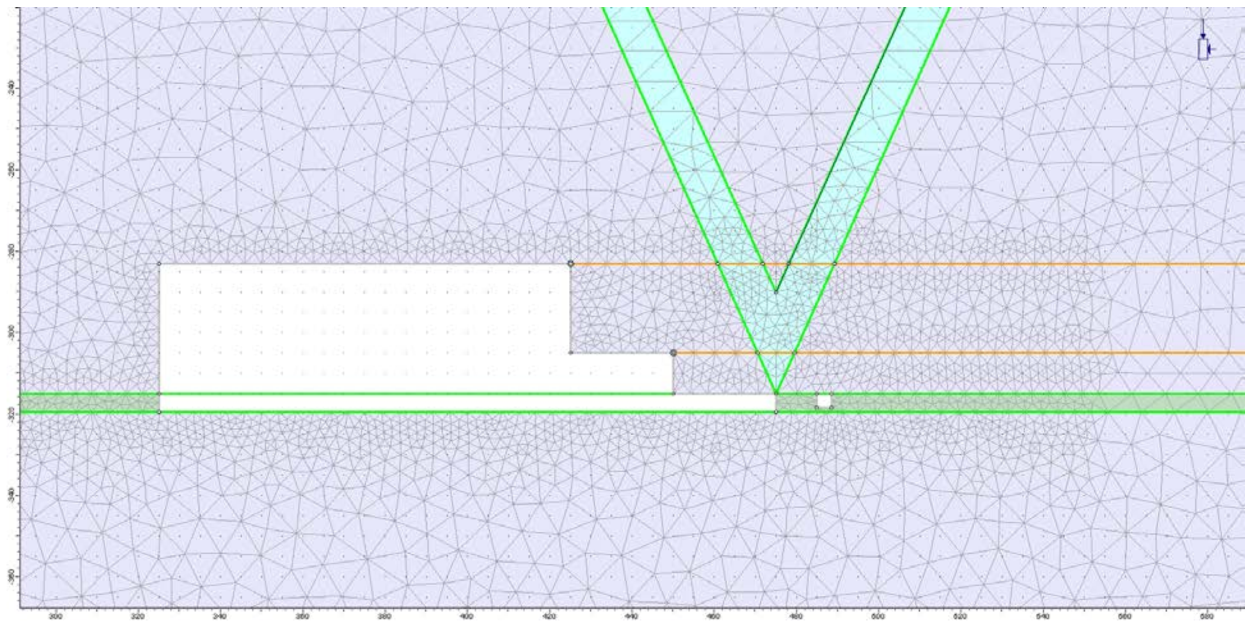

Fig. 2 Mining and mechanical model of rock massif in mining face approaching the dismantling area.

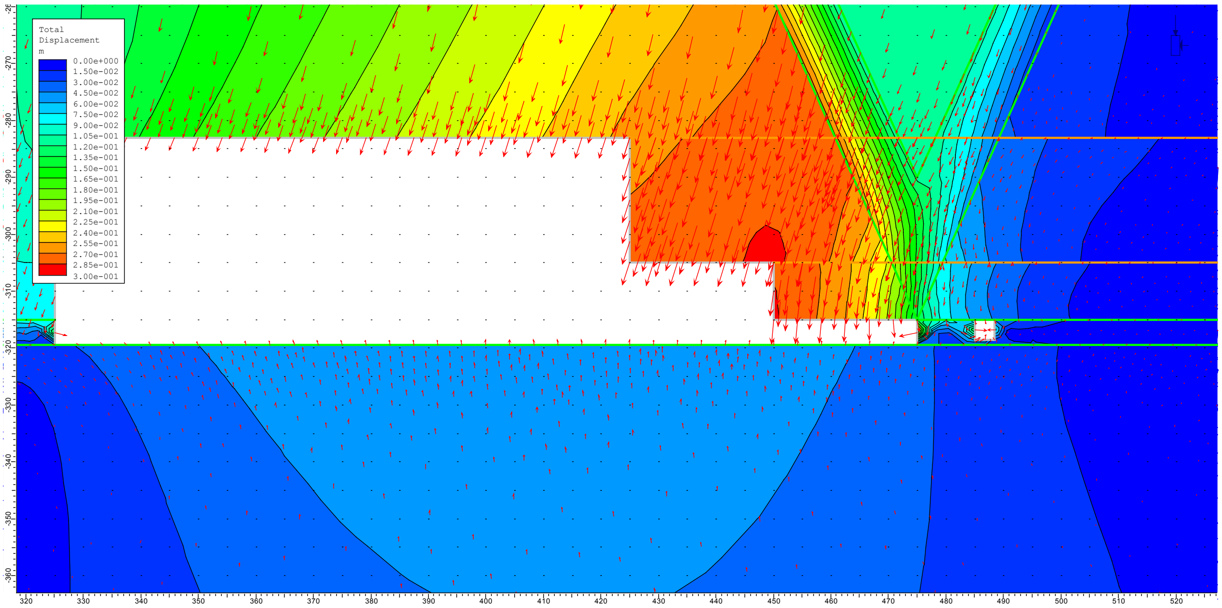

Fig. 3 Field of summary displacements distribution in the vicinity of the dismantling area.

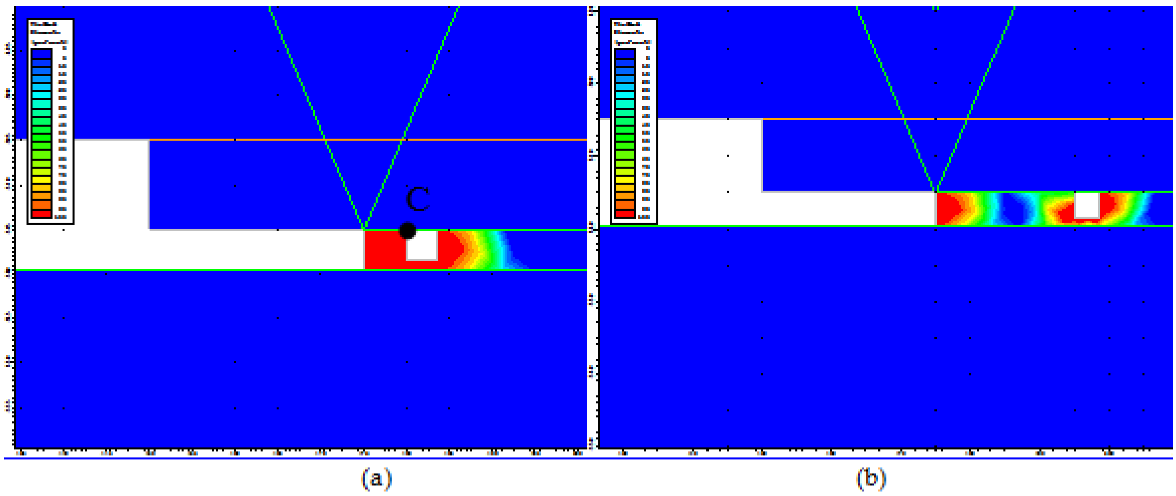

Fig. 4 Field of deformation distribution in the vicinity of the dismantling area for the pillar between the longwall and preliminary sunk mine working having the width of 5 m (a), 10 m (b).

Fig. 5 has stress distribution curves ahead of the mining face with different pillar widths.

In the maximum sized pillar (10 m) considered, the pillar maintains its stability, and the maximal bearing pressure develops in it. In the pillar having the width of 5 meters, the maximum of the bearing pressure moves beyond the mine working. As a result of the pillar destruction, the load on the support of the longwall set of equipment significantly increases, and the process may cause tight caving of the longwall set of equipment.

CONCLUSION

Three The outcomes of the study are as follows:

1. Methodological approach has been developed for the assessment of the qualitative indicators of a rock massif when the mining face approaches the advanced mine working.
2. Mining and mechanical model (design scheme) has been developed, which describes non-stationary processes of changing parameters of rock massif's stressed and strained state in the area of the advanced mine working when a longwall set of equipment is inserted into it.
3. Significant increase of the load on the powered support sections is explained by the reduction

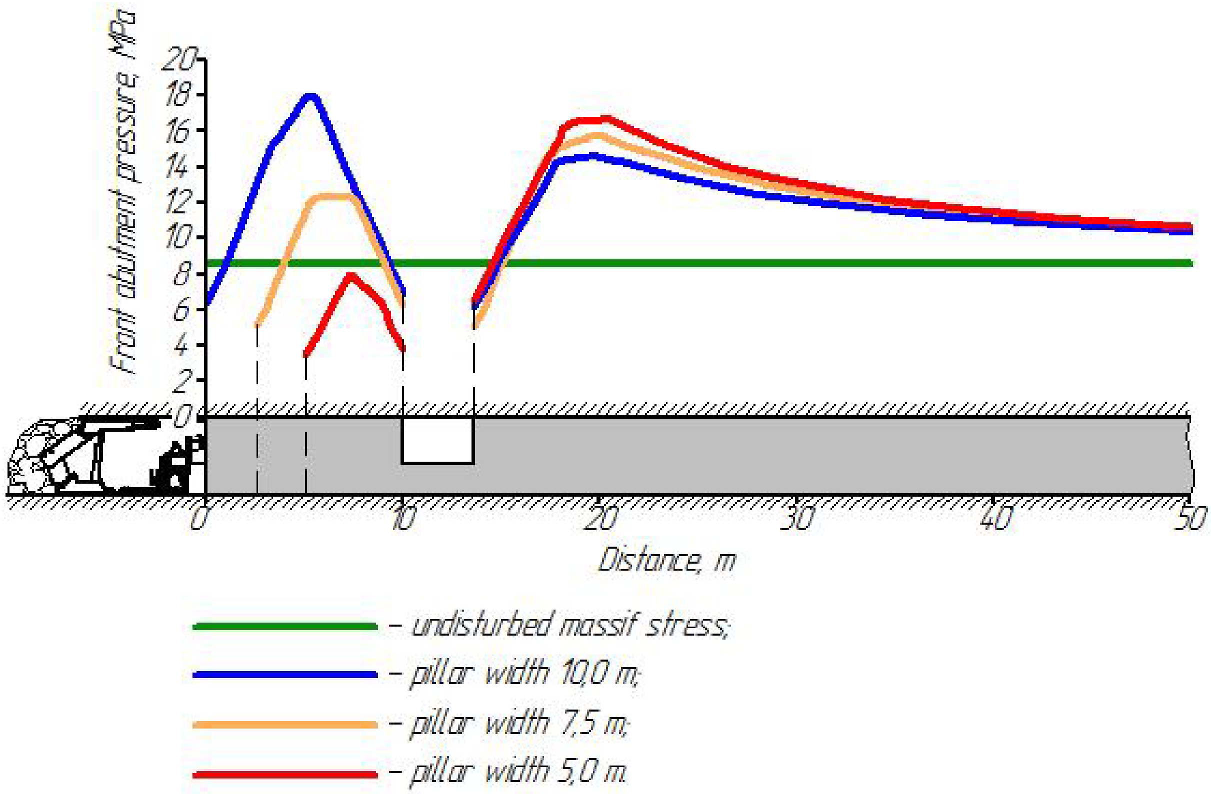

Fig. 5 Distribution of bearing pressure ahead of the mining face at the different stages of the mining face approaching the advanced mine working.

of the pillar carrying capacity resulting in rock pressure redistribution.

4. Currently applied methods of attaching advanced dismantle chambers are not always effective, and further research should be focused on improving the current chamber attachment methods and developing new methods.

REFERENCES

Artemiev, V.B. 2010. Alternative technologies of forming dismantle chambers under conditions of SUEK-Kuzbass public corporation. *Coal*. 3 : 20-23.

Barry, H.G. 2013. Rock mechanics: For underground mining. *Brown-Springer Science & Business Media*. 447.

Esterhuizen, E., Mark, C. and Murphy, M.M. 2010. Numerical model calibration for simulating coal pillars, gob and overburden response. 29th International Conference on Ground Control in Mining. Morgantown. WV.

Fadeev, A.B. 1987. Finite elements method in geomechanics. Moscow: Nedra. 221.

Karpov, G.N. 2013. Substantiating technology of dismantling longwall sets of equipment with high concentration of mine workings. Dissertation for pursuing the degree of candidate of technical science. National mineral resources university (The University of Mines). Saint Petersburg.

Kuna, M. 1989. Finite elements in fracture mechanics. Theory-numerics-applications: Mechanics of underground structures in examples and problems: Schoolbook. Moscow: Nedra. 270.

Lanovsky, Yu. M. 1999. Finite elements method (Basics of Theory, Problems). Novosibirsk: Publishing House of Novosibirsk State University.

Larson, M.K. and Whyatt, J.K. 2009. Mining Publication: Deep coal longwall panel design for strong strata: The influence of software choice on results. Proceedings of the International Workshop on Numerical Modeling for Underground Mine Excavation Design. Pittsburgh, PA: National Institute for Occupational Safety and Health; IC 9512, 2009 Jun. 75-87.

Oyler, D. 1998. International experience with longwall mining into pre-driven rooms. Proceedings 17th International Conference on Ground in Mining. Morgantown, Aug 4-6. 44-53.

Sarathchandran, A. 2014. Three-dimensional numerical modelling of coal mine roadways under high horizontal stress fields, M. of Sc. Dissertation. Exeter: University of Exeter.

Tadolini, S. C. 2003. Ground control support considerations for pre-driven longwall recovery rooms: Ph. D. dissertation submitted to college of engineering and minerals resources. West Virginia University, Morgantown, pp. 163.

Tarazanov, I.G. 2015. Operation results of coal-mining industry of Russia in January-December 2014. Ugol. 3 : 56-71.

Wichlacz, D. 2009. Development of a pre-driven recovery evaluation program for longwall operations. coal operators’ conference. Woollong, Feb. 12-13. pp. 23-36.