New technologies of mining stratal minerals and their computation

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Abstract. The paper considers the systems of flat and volumetric modeling of controlling long-wall faces for schemes with rock collapse of the immediate and main roof and smooth lowering of the remaining layers, as well as in forming a vault over the face. Stress distributions are obtained for the reference pressure zone. They are needed for recognizing the active state of the long-wall face in the feedback mode. The project of the system "support - lateral rocks" is represented by a multidimensional network base. Its connections reflect the elements of the system or rocks, workings, supports with nodes and parts. The connections reflect the logic of the operation of machines, assemblies and parts, and the types of their mechanical connections. At the nodes of the base, there are built-in systems of object-oriented programming languages. This allows combining spatial elements of the system into a simple neural network.

1. Introduction

In Germany, the Marco Company develops the program "Geomechanics" for controlling long-wall faces. It allows predicting dynamic phenomena in the face. Sensors mounted on the support sections allows one to control pressure on the support section and its position in the face [1]. In 2017, an experimental long-wall face of 180 m in the Polysaevskaya mine (the Kuznetsk Basin, RF) one shift is worked under the control of one operator instead of 40 people in the brigade.

The automation system will become efficient and intelligent with reducing the face length and the use of technologies with pivoting the face around the transport gangway. This will eliminate the works and costs of mounting the equipment and dismantling it after the coal is cut. The face will also become insensitive to disruptive geological disturbances of the formation. For the new technology, one needs an adequate computing model of the support operation and rock deformation for the short-wall face progress.

2. Computing scheme

The computing scheme for the length of the face of about 20-50 m should be volumetric. In the known systems of computing the roof rocks at the face, there is no generally accepted model of deformation and collapse of the layers. Their models were mainly based on experimental data. Let us consider two deformation schemes:

1. The rocks of the immediate and main roof collapse and the rocks to the earth surface smoothly descend to the collapsed rocks. The immediate roof collapses immediately behind the support and the main roof (usually strong) is in the form of blocks and consoles, Figure 1.
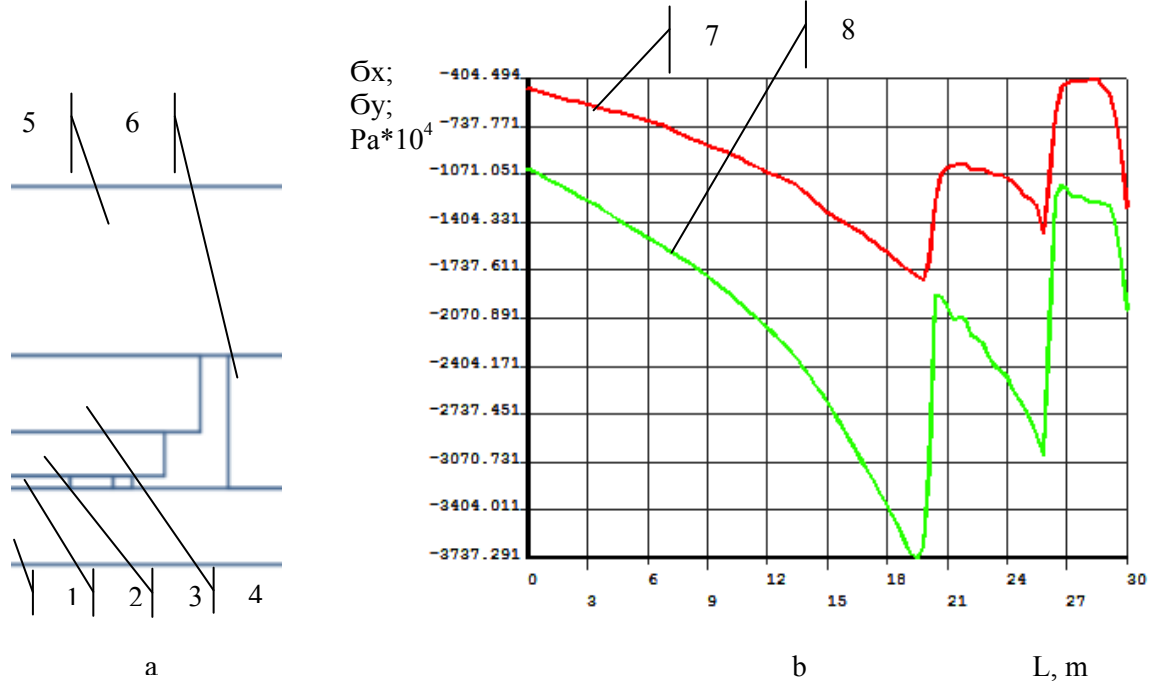

Figure 1. Scheme of breakage of type I rocks: a –computing scheme: 1 – soil, 2 - layer, 3 – immediate roof; 4 – main roof, 5 – rocks to the earth surface, 6 – collapsed rocks; b – stress plots (photo from the screen): Бx (7) and Бy (8) in the reference pressure zone.

2. The contour of collapse is a vault. Its shape is assumed to be a trapezoid. Its right lower part coincides with the work beginning area. The left part is above the bench of the rocks of the immediate and main roof. When the face moves to the left, the height of the vault increases in jumps until it reaches the earth surface, Figure 2.

Which of the schemes will be implemented depends on properties and parameters of the rocks. The distribution of pressures in the formation zone at the face (it is called the reference pressure zone) for each scheme is different.

For automatic control, these distributions should be identified. In particular, this can be done using the computation method. This zone is modeled by an abrupt decrease in the modulus of elasticity of the zone sections. The value of the module decreases toward the surface of the face. The length of the reference pressure zone is usually equal to 5 m (m is the height of the formation) and up to 3 sections are formed in it. Depending on the depth of operations and the parameters of the formation and rocks on the basis of bench studies, there is a software program made for modifying the module by jumps. It is used in the model depending on the current pressure on the reservoir, its parameters and the initial state [2].

When the face moves, the state of changes of the reference pressure zone. The authors believe that it has the features of pressure distribution depending on the length and power of the collapse of the main roof layer and depending on which a collapse scheme (with a smooth lowering or formation of the vault) occurs.

Earlier the authors proposed a scheme of the face controlling in the feedback mode (USSR patent No. 1833471, 1993. Bulletin No. 29). In this case, these program models, the values of the computed coefficients for connecting the theory to practical data can be corrected using the results of

measurements. This provides a possibility of selecting progress computing adequate for the current section of the face.

3. Methods and results of the research

At KSTU, there have been computation schemes made to the depths of 200-500 m. For auto-controlling, it is also necessary to identify characteristic features of the breakage of a powerful layer of rocks, for example:

- a special type of the roof line from the face to the worked out space with a greater descent from the worked out space, if a part of the layer that loads the console is not pressed (there is no visible fracture of the formation to the depth of 1, 2 m) [3,4];

- close lowering of this line along the entire length if the part of the layer that loads the console is pressed;

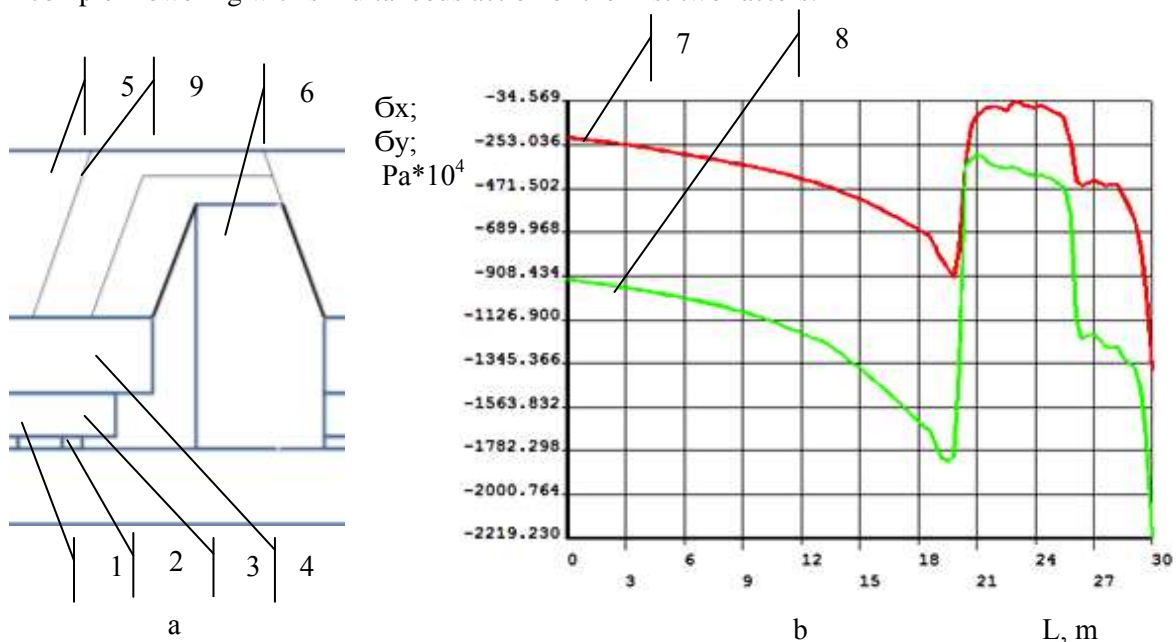- complex lowering with simultaneous action of the first two factors.

Figure 2. Scheme of collapse of type II rocks: a – computing scheme: 1 - soil, 2 - layer, 3 - immediate roof; 4 - main roof, 5 - rocks to the earth surface, б - collapsed rocks, 9 - contours of the vault, 10 - zone of the work beginning; b - stress plots (photo from the screen): бx (7) and бy (8) in the reference pressure zone.

Similar models have been made for different deformation schemes of the roof rocks of type 1 and 2 [2]. Typical pictures are selected by models and compared with the picture of stresses when the breakage does not occur.

The same pictures can be obtained when carrying out studies of equivalent materials (a physical reduced model of long-wall faces is made on the bench); however, this takes a long time and has technical difficulties. But it is possible to execute a bench model from fragments of the general scheme. Then computing and loading of natural fragments should be used alternately. The breakdown in the long-wall face itself is fixed in the database by bursts of load on the hydraulic legs (pressure sensors and seismic radiation). Thus, let us have a three-factor analysis method to determine the state of the massif. However, in a lot of cases it is sufficient to use the first two, especially if identification is carried out from the beginning of the work of the long-wall face and its conditions are well known (properties and parameters of rocks, features of rock pressure). Here let us consider the deformation features [4, 5] of the reference pressure zone for schemes I and II for a planar and three-dimensional

solution [6,7]. Let us consider a planar solution as a simplified volumetric solution for thin volumes, Figure 3.
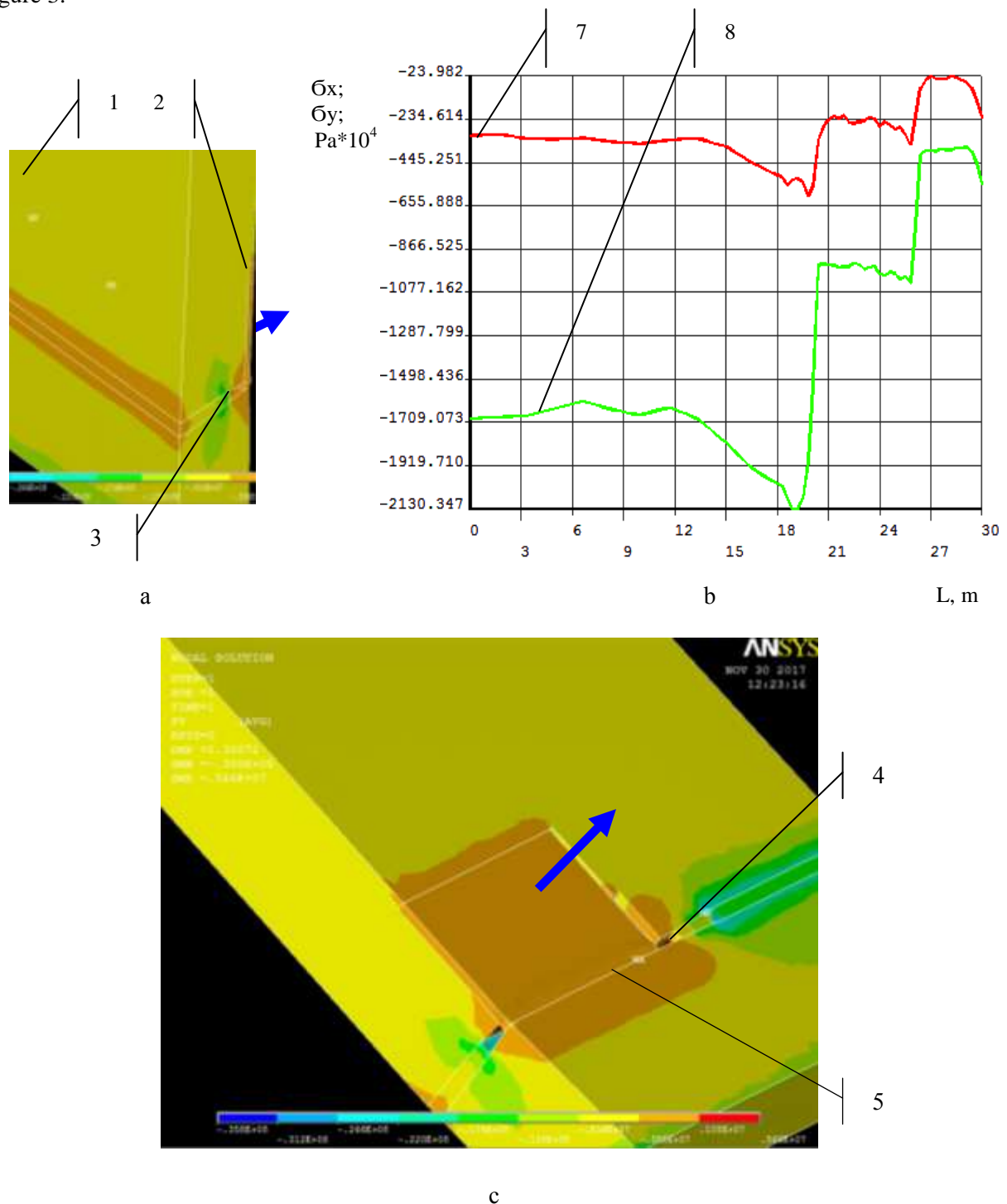

Figure 3. Transition to the volumetric model (photo from the screen): a - block of rocks with a transport drift: 1 - block, 2 - section of the face with surrounding rocks, 3 - drift, the arrow means the direction of copying in the program of the face sections to form its full model; b - stress distribution бx (7) and бy (8) in the reference pressure zone for the type I scheme; c - model (conditionally inclined) with the pattern of distribution of color stress bars: 4 - zone of the face, 5 - section of the drift.

Simulation methods on the ANSYS-type package are well known in mechanics and there are methods of refining computation of the stress state [8]. In stress concentration zones, the grid cell size is sharply reduced. For mining environments, these methods are adapted taking into account the structure of the rocks obtained as a result of the action of limiting stresses [2] and taking into account characteristics of its destruction.

Figures 1 and 2 show the distribution of the reference pressure for the presented schemes. They differ quantitatively and in the features of distribution. So the maximum vertical stresses for scheme II are almost 2 times greater than for scheme I. In the faces for studying the distribution in the zones of reference pressure, there are drilled bore holes and placed sensors. It is well known that in this case the pressure varies by jumps, and the largest jump reaches 3-5γH (γ is the density of the rocks, H is the height of the column of rocks above the reservoir). For scheme I, this ratio is about 6, and for scheme II - about 3, and it increases with the long-wall face progress. Thus, when forming a vault, the pressure on the long-wall face is quite different. It is also easy to predict the features of the seismic pulses in the collapse of the vault for scheme II and the main roofing layer for scheme I. When designing a three-dimensional model in Figure 3 for the previously obtained section of Scheme I or II, there are added blocks without cavities from the face and collapse of rocks and stuck with previously constructed ones, then there is a repeatedly copied area to achieve the necessary length of the face. To complete the model on the right, one more solid unit is added. One can also model the gap inside the face. On its plane, the sections do not stick together, but it is possible to slip due to the contact elements. It is also possible to model disturbances in the form of weakened sections of rocks, which is achieved by selecting pseudo-elastic characteristics, Poisson's ratio that are also distributed in the zone of violation of systemic cracks. In Figure 3, stresses in the reference pressure zone for the face section adjacent to the block with the working are 1.7 times lower than those for scheme I. This is explained by the fact that a relatively complete block unloads the face and takes pressure for itself. Thus, the model is adapted to the possibilities of working with correcting the model on the basis of the obtained data from the rock massif and allows obtaining the most adequate design scheme for the current operating conditions of short-wall faces.

4. Conclusion

The project of the support system - lateral rocks - is represented by a multidimensional base. At first, it is a hierarchical structure and then it is rebuilt into a network. Its connections reflect the interaction of the system elements from the rock units with the face and drift, supports and other equipment. The connections reflect the logic of the operation of machines, assemblies and parts, as well as the types of their mechanical connection. In the nodes-tables, there are processing programs (macros and modules). The nodes use built-in programs based on object-oriented languages such as VB, C ++. Hyperlinks use CAD / CAM / CAE packages: ANSYS (work bench), Adams, SolidWorks, as well as systems developed at KSTU [2] and [9].

The database provides interaction with neighboring mates and nodes located outside the simulated object. These connections through the nodes-tables with powerful processors of software packages make the network base of a similar simple neural network [10]. Thus, the possibilities of expert analysis and self-learning are provided on the basis of [11]. Their algorithms are simple and are set out in the Basic language. The base permits to combine the nodes with other bases: a combine, a conveyor, manipulators with logic modules. This forms the "awareness" (forecasting) of the upcoming situation in the face in the next cycle of work. Figure 5 presents an information management scheme for self-propelled supports with separated hydromounts for new technological schemes of mining. Forecasting shows that robotics and new technological schemes of their use can give a new impetus to the development of underground mining of minerals, and once again bring it to the leading position. Now the task is to develop mining control programs which can be divided into stages of developing models for controlling simplified prototypes and using modern equipment for automated control of mechanized supports based on, for example, electrohydraulic valves and sensors of the German company Marco.
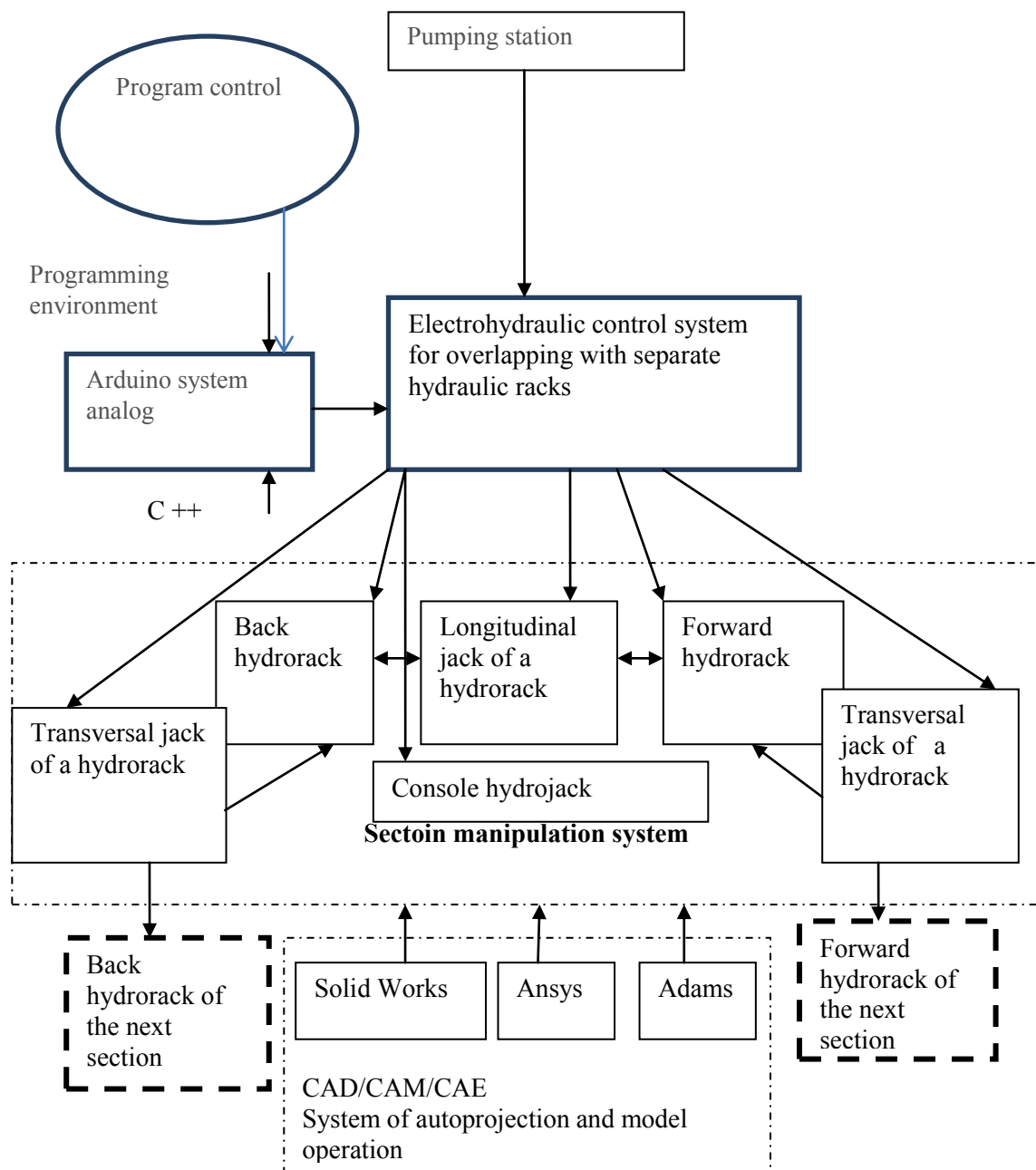
Figure 4. Model of controlling support system with separate hydroracks

5. Acknowledgments

References

[1]   Roiter M, Krakh M, Kisler B and Veksler Yu 2016 Zonal disintegration around breakage faces
       FTPRPI **2** 46 - 52

[2]   Beisembayev K M, Veksler Yu, Zhetesov S S, Kappasov N and Mendikenov K K 2013 Studying rock massif state when moving long-wall face *Izvestiya vysshikh ucebnykh zavedenii. gornyi zhurnal* **3** 69 -76

[3]   Stavrogin A N, Tarasov B G, Shirkes O A 1990 Statistical model of inhomogeneous solids (rocks) deformation under conditions of high pressures and large deformations *FTPRP* **1** 10 - 17

[4]   Boulenouar A, Benseddiq N, Mazari M, Benamara N 2014 FE model for linear-elastic mixed mode loading: estimation of SIFs and crack propagation *Journal of Theoretical and Applied Mechanics* **52(2)** 373-383

[5]   Alshoaibi M A 2015 Finite element modeling of mixed mode crack propagation *International Journal of Soft Computing and Engineering (TM)* **5** 61-66

[6]   Bhardwaj G, and Singh I 2015 Fatigue crack growth analysis of a homogeneous plate in the presence of multiple defects using extended isogeometric *Mechanical Sciences and Engineering* **37** 1065-1082

[7]   Dodagoudar G R, Rao B N and Sunitha N V 2015 A mesh free method for beams on elastic foundation *International Journal of Geotechnical Engineering* **9** 298-306

[8]   Rafał G 2014 FE-modeling of a contact layer between elements joined in preloaded bolted connections for the operational conditions *Science and Technology Resevault Journal* **8(24)** 19–23

[9]   Xiangjun J and Baotong L   Finite element analysis of a superelastic shape memory alloy considering the effect of plasticity 2017 *Journal of Theoretical and Applied Mechanics* **55** 1355-1368

[10]   Marcman H 2006 The blue brain project *NatRevNeurosci* **7** 153-160

[11]   Naylor K 1991 *How to build your* expert *system (*Moscow: Energoatomizdat)