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Influence of tectonic disturbances on the parameters of excavation support with rock anchor

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Abstract. The mechanism of deformation, movement and rockfalls in structurally disturbed nonuniform rock mass using analytical modeling operation for assessment of the strain-stress state (SSS) of the rock mass around mining has been investigated. The SSS research of the rock masses by means of the ANSYS program of the excavation in the "Saransk" mine of coal mining JSC "ArselorMittal Temirtau" in the Karaganda coal basin has been conducted. The parameters of the exploitation of the anchor support on the mines for fixing the rock bolts in the workings to ensure the safety of mining operations in the areas of geological disturbances have been determined.

1. Introduction

Management of the rock masses in the areas of explosive tectonic disturbances represents the very complex technical problem. Processes of deformations, movements and destructions of rocks near the workings which are carried out in the areas of fissures are investigated not completely. So far in the theory of elasticity, plasticity and flowing medium a number of continuum mechanics methods is developed. However, they are inapplicable for problem solving of carrying out and maintaining of workings in the states of the composite and nonuniform formations of rocks in the areas of faults. On the mechanism of manifestations of rock pressure in the areas of tectonic disturbances the crucial importance in the phenomena of a collapse of rock masses and pressure bumps is allocated to a spatial relationship of working limit and system of the surfaces slackening creating by the fault [1]. In the areas of faults under the influence of rock pressure forces and sole weight around the workings, there is a division of the rock massif according to the natural surfaces slackening.

The probability of emergence of rockfalls and coal, pressure bumps and other harmful manifestations of rock pressure depends on type and parameters of disturbances and working, their relative orientation in the massif, the purpose of working (lava, coal road, cross-drift, etc.), the way of its carrying out, the width, resisting power and the geometry of rock sheets and rows. Combinations of the specified factors and their parameters in the massif define the nature of manifestation of rock pressure and, as a result, various degree of danger of possible rockfalls, blows and other harmful phenomena. The rock massif has the following natural surfaces (contacts) of slackening, differentially oriented in the massif, reducing its stability. It is the surface of the fault planes actually representing an area of the ground and shattered masses width beginning from millimeters to several decimeters near fissures with amplitudes up to 10 m. This area near the high amplitude faults fluctuates within wide range – up to tens of meters. Coupling of rocks in the areas of fault planes is practically absent in the presence of slickensides. The surface of the fault plane is the border dividing the massif into separate structural blocks. The surfaces of tectonic fractures of breakage and shearing, accompanying the explosive disturbances are auxiliary slackening contacts dividing masses into the shallow blocks into small blocks of various shapes having reduced cohesion. The width of an area of disturbance influence that is normal to fissure surface on the massif includes an area of subdivision of rock masses and fissured, unstable rocks adjoining it in wings of blocks.

Coal of banks in these areas is also fractured, often wrinkled, resistant, consistent to rashes and rock falls in workings. Areas of rock masses weakened by tectonic processes in lying and hanging wings of rock blocks are approximately parallel to the fissure plane though their widths can be different. The angle of slope of the fault plane (β) depends on resisting power of rock masses, the direction of action of tectonic forces and is almost equal to 90° or 0^o can be only in isolated points. The most often the falling of fault planes changes in the massif, sometimes up to the inverse values. Generally, the fault plane has sloping bedding. The extension of fault planes changes in the massif too, and generally, the line of crossing in the plane of layer is diagonal to its extension. In the massif of rocks, the explosive disturbances with a diagonal arrangement of sloping or steep fault planes on an extension of rocks are most obvious. The layer of coal of a prime structure near the explosive disturbances is often wrinkled and unstable, especially in areas of bearing pressure of breakage faces. In the layers of the complex structure, there are often the packs of weak or the tectonic broken coal, sometimes with slickensides, which sharply reduce the stability of steep and sloping layers. On layers with slope angles (α) more than 30°, conditions for rashes and rock falls into working of tectonic broken, often wrinkled coal from areas of faults with passing reinforced gas emission are created. Following the coal falls, rocks can fall into the workings.

In a roof of working with the increase in the slope angle of the layers, the volumes of rock masses separated by contacts of slackening from the massif rise, increasing in several times the support load of workings and danger of rockfall. In the sides of working the increase in volumes of the unstable masses limited by the weakened contacts and faults, happens with the decrease of angles of their falling. Under the influence of rock pressure, these volumes of masses in the form of wedges, prisms move towards the working, putting intensive side pressure.

The condition of the breaking and over-extreme limit condition of masses of a side of working can be written in the form of inequality [2]:

$$\frac{t \cdot P \cdot \cos\beta' \cdot tg\varsigma + KL}{t \cdot P \cdot \sin\beta'} \le 1 \,, \tag{1}$$

where K - coupling of masses on the fault plane of fault; - angle of internal friction of rocks on the contact of the fault plane; P - vertical component of tension vector in the massif; t- stress concentration coefficient in rocks of the side of working; L - length of a side of a wedge of rocks along the fault plane.

At extreme values ς (about 10^0), angles of slopes of the fault planes over 600 the sides of coal headings in the areas of oversteps at the angles of attack γ < 800 - are in the limiting condition. With decrease of angles, the stability of rocks in the working side decreases sharply. The movement of rock masses towards the working will lead to the development of unidirectional enforced side pressure on support. The phenomena in mines when the workings in areas of fissures are exposed to the reinforced pressure with decrease of angle of their entrance to the faults areas are confirmed by experience of mining operations and researches.

2. Results

The development and change of deformations and tensions in time in a preparatory excavation (the 7th of western conveyor cross-drift k10 (the 2nd area) in a zone of opening and removal from layer k12) of a rectangular cross-section, fixed anchor support, in the area of unpredictable small-amplitude geological disturbances of the coal layer in the mine "Saranskaya" of the coal mining JSC “ArselorMittal Temirtau” - figure 1.

Movement along the axis «y» Tension along the axis «y»

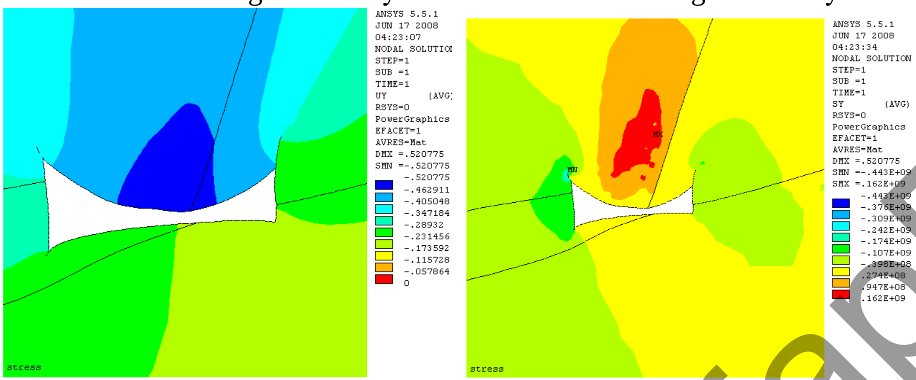
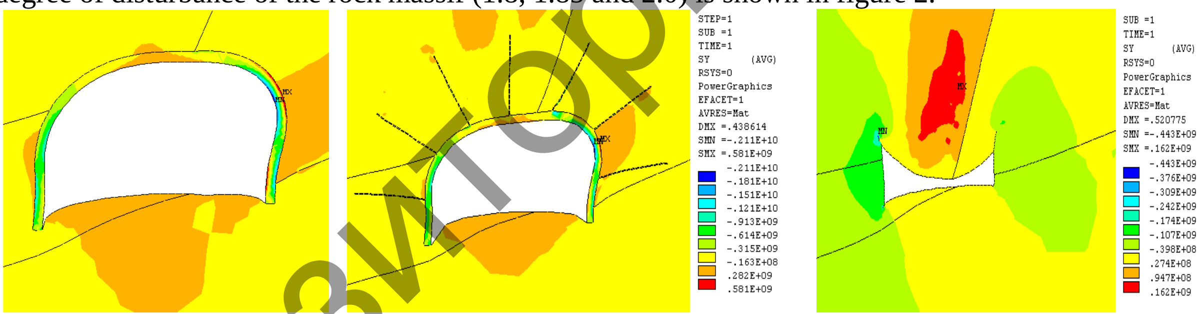


Figure 1. Development of deformations in the period of the preparatory excavation, fixed by the anchor support in the area of nip-out of the coal layer in the mine "Saranskaya" of the coal mining JSC “ArselorMittal Temirtau”

The analysis of results of researches of analytical modeling shows that vertical movements and tensions lead to 2.5 – 3.0 times loss of a cross-sectional area of the working and growth of tension up to destructive with loss of stability of the working limit.

Deformational picture on varying degrees of disturbance of rock massif. Dynamics of the growth of movements along the Y-axis with metal frame lining and anchorage of the working on a different degree of disturbance of the rock massif (1.8, 1.85 and 2.0) is shown in figure 2.



1 2 3

Figure 2. Dynamics of change of vertical movements at metal-frame pliable (1), combined (2) and anchor (3) support of the working for various degrees of disturbance of the rock massif

3. Discussion

The analysis of dynamics of change of vertical movements at the metal-frame pliable, combined and anchor support of the working at various degree of disturbance of the massif shows that in the areas of tectonic disturbances, the more expedient is applications of the combined support of the workings limits. The results of experimental studies to determine loads on workings supports, the estimation of unstable roof distances located in the areas of influence of faults are given below [3-11].

Technology of control of manifestations of rock pressure in the areas of faults when carrying out excavations. Crossing by the working of the coal layer is the considerable change of an intense strained state of coal - rock massif around the working therefore the technology of crossing of layer k_{12} by a face the 7th of the western conveyor cross-drift on k_{10} (of the second areas) the mine “Saransk” of the Karaganda coal basin is considered below.

In a dangerous zone the face is provided with not reduced reserve of materials: for construction of a front line support (an anchor AMV-22, 2.4 m long in the amount of 30 pieces); for hardening of rocks of a roof and a wall face (wooden anchor -21 pieces, PUR cartridges -70 pieces).

When leaving a wall face up to 0.5 m due to cleavage of rock mass, the strengthening of wall face on the basis of reinforcing with application of wooden anchors is made.

In an unstable roof (formation of domes over the support more than 0.5 m), additional anchors (at least 4 pieces) are drilled in a bottom-hole area - in advance, with a driving advancing by 1 m under a profile with application of a front line support.

Barring at an approximation, opening and removals from layer k_{12} is made by the combined support with application of two frames of KMP A3-17.2 of sq. m and 17 steel-polymer anchors on 1 running meter with the continuous advancing installation of anchors.

In dangerous areas of the unpredictable fine-grained geological disturbances, additionally for prevention of inrush of roofing rocks in a face, lag of the support from a face in all technological cycles should not exceed 1.0 m, if necessary (at increase in a technological withdrawal up to 1.0 m due to layer cleavage of wall face) chemical hardening on the basis of reinforcing is carried out. The role of fittings is carried out by the blast-holes filled with the hardening structures with placement in them of wooden anchors 3.0 m long through each 2.0 m of a sinking for strengthening of wall face.

Technological measures for the safe performance of mining operations when carrying out the 7th western conveyor cross-drift k_{10} (the second area) in the hazardous area of the geological disturbance H = 1.5 m (PK53 +7) provide: in a dangerous area of geological disturbance - to drill the advancing relief holes; when crossing the fault plane of geological disturbance and removal from a fault plane by 3,0 m normally - to make sinking of working with strengthening of a roof of working by chemical composition Bevedol-Bevedan, reinforcement of the roofing rocks is carried out every 3 m of sinking into the blast-holes length not less than 3.0 m, injection is carried out after installing the anchor support through the injection anchor IRMA by pumping station DP-40, to produce each injection cycle at least in three injection anchors located at a distance of 1.5 -2.0 m apart from each other. In a dangerous area of geological disturbance, to make fastening of the working by the combined support KMP-A3-17.2m^2 with installation of 2 frames and 17 anchors AMV-22 2.4 m with the length of 2.4 m per 1 running meter, to install all anchors with a deviation on face 20-25^o; when forming the domes to drill them off by the anchors AMV-22 of 2.4 m length, then to install the frames of the arch support, then to spread cages between cups of frames and rock massif, lag of cages from a face is no more than 2.0 m.

In case of unstable roof, to drill additional anchors (not less than 5 pieces) in a bottom-hole area in advance of sinking under interbed with application of a front line support;

If necessary (at the increase in a technological withdrawal up to 0.5 m due to cleavage of wall face), the chemical hardening on the basis of reinforcing is carried out, the role of fittings is carried out by the blast-holes filled with the hardening structures with the placement wooden anchors in them of 3.0 m long via each 2.0 m of sinking with strengthening of wall face by wooden anchors.

The technological passport of fastening of working in areas of disturbances is developed as shown in figure 3.

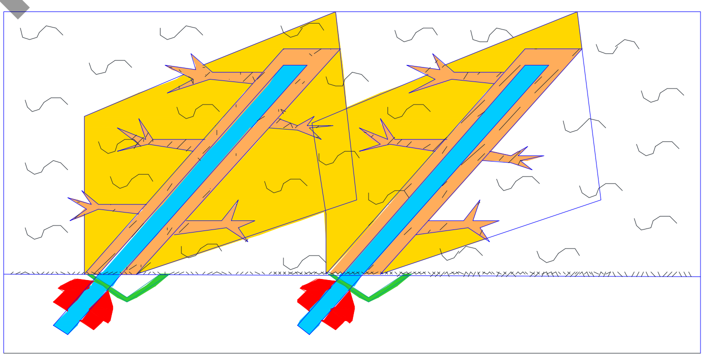


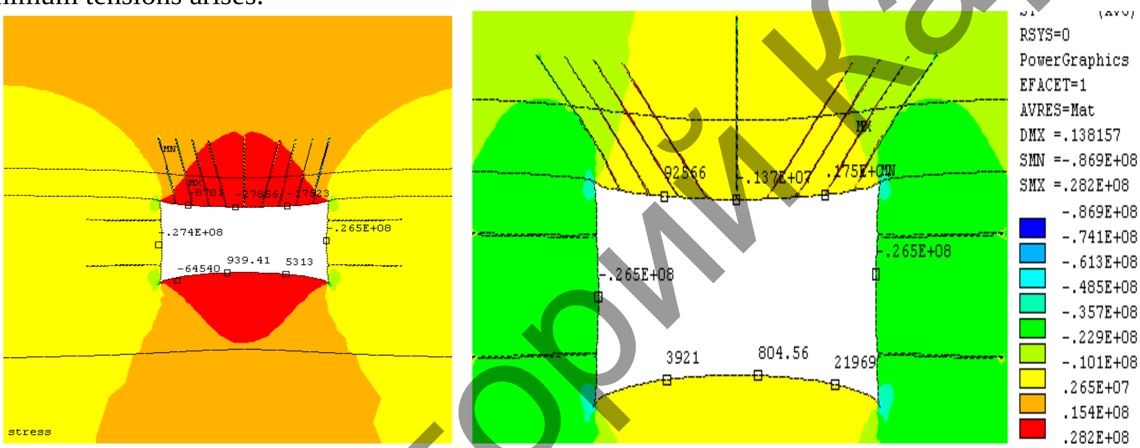
Figure 3. The technological passport of fastening of working in areas of disturbances, the scheme of installation of the next anchors with an overlap

Table 1 shows the values of the maximum normal and tangential tensions with change of the angle of hade of anchors relative to the roof of the mine.

Table 1. The values of the maximum normal and tangential tensions

β ,degree	σ_x ,MPa	σ_y ,MPa	τ_{xy} ,MPa
25	93.7	18.7	53.1
40	93.6	27.2	45.5
55	93.5	25.1	32.6
70	93.4	9.1	30.1
90	93.3	6.7	29.3

The figure 4 shows the tension distributions in the massif of corresponding rocks, when minimum tensions arises.



τ_{xy} σ_y

Figure 4. The distribution of the maximum normal (σ_y) and tangential (τ_{xy}) tensions

The dependence of the maximum normal tensions along the "y" axis as a function of the angle of hade of the anchor has the form:

$$\sigma^y_{\max}(\beta) = 2.7\cdot 10^{-5}\cdot\beta^4 - 5.9\cdot 10^{-3}\cdot\beta^3 + 0.4\cdot\beta^2 - 13.1\cdot\beta + 153.5 \quad (2)$$

The dependence of the maximum tangential tensions as a function of the angle of hade of the anchor has the form:

$$\tau_{\max}(\beta) = 9.4\cdot 10^{-3}\cdot\beta^2 - 1.6\cdot\beta + 94{,}4 \quad (3)$$

4. Conclusion

The mechanism of deformation, movement and rockfalls in the structurally broken nonuniform massif with application of analytical modeling for assessment of the stress-strain state (SSS) of the rock massif around excavations has been investigated.

The SSS research of the rock masses by means of the ANSYS program of the excavation in the “Saransk” mine of coal mining JSC “ArselorMittal Temirtau” in the Karaganda coal basin has been conducted. The parameters of the exploitation of the anchor support on the mines for fixing the rock bolts in the workings to ensure the safety of mining operations in the areas of geological disturbances have been determined.

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