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Management of the longwall face advance on the stress-strain state of rock mass

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Abstract

Purpose is to study influence of a longwall face advance on the geomechanical situation in the neighbourhood of a mining site based upon determination of changes in standard and critical subsidence of the immediate roof rocks.

Methods. To study a geomechanical situation in the neighbourhood of a mining site the authors have applied software product GeoDenamics Lite developed at Dnipro University of Technology. The software product relies upon a calculation procedure of stress-strain state of rocks by Professor O.V. Savostianov. Expediency of the software selection is based upon the supported control and adaptation of a coal mining technique to changes in geodynamic stress fields in the anisotropic rock-coal medium impacting temporal and spatial changes in the technological parameters.

Findings. The basic problems have been singled out connected with certain changes in a longwall face advance. For the first time, an analytical scheme of tangential stresses within the immediate roof rocks has been developed for Lisova mine of SE Lvivvuhillia under the conditions of coal seam mining by means of the paired longwalls which makes it possible to determine both physical and geometrical parameters of standard loads within the formation.

Originality. Dependencies of temporal and spatial changes in subsidences and horizontal displacements of rock layers of the immediate roof have been defined being 5.2 m for the upper rock pack and 3.9 m for the lower pack if the longwall longwall face advance is 1.9 up to 4.8 m/day. Both physical and geometrical parameters of the reference pressure have been defined as well as the parameters of lower sandstone pack in the process of the main roof subsidence. Impact of the extra pressure forces on the immediate roof rocks has been analyzed at the moment of critical lowerings of the immediate roof rocks. In this context, standard loading from the overlying formation in addition to tangential stresses in the roof result in rock failure due to vertical cracks above a longwall face.

Practical implications. The engineering methods have been developed making it possible to identify impact parameters of a longwall face advance on the geomechanical situation in the neighbourhood of a mining site. In future, it will help forecast changes in the reference pressure around a longwall face while preventing emergency settlement of the powered support.

Keywords: *mine, longwall face, coal seam, rock mass, stress-strain state*

1. Introduction

The current economic situation in Ukrainian mines prompts the search for internal reserves to improve the efficiency of mining operations. Primarily, such a situation is typical for state-owned mines [1]-[3]. In the context of such enterprises, significant lack of budget funding is the component factor preventing from purchase of new equipment and renovation of fleet of powered systems. Morally obsolete facilities are applied for mining operations. Hence, the necessity arises to re-orient functioning of the mines relying upon the principles of mining intensification and concentration to minimize expenditures connected with performance of both basic and auxiliary operations [4]-[8].

Currently, it is proposed the technological methods of coal mining, which are focused on combining several technologies within a single mining enterprise [9]-[11], mining coal reserves in difficult geological conditions, improving the environmental quality [12] and processing waste on the surface [13]-[15]. Particular attention during conventional mining is paid to the management of stress and pressure in mining to ensure the manufacturability of this process [16]. Reliability of technological innovation systems [17] that lead to safety potential of engineering enterprises [18], resource management [19]-[21] and creation of a green economy in mining [22], must be also taken into account.

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Mostly, coal resource potential is concentrated in Lviv-Volyn and Donetsk coalfields [23], [24]. Unfortunately, due to war, the key Ukrainian coal reserves, being suitable for safe mining, are extracted by such state enterprises as Lvivvuhillia and Volynvuhillia as well as private company DTEK Pavlohradvuhillia. Situation in the private sector, concerning mining capacity, is stable; moreover, certain structural subdivisions demonstrate increase in coal extraction indices. However, despite the available reserves, the state mine fields are stagnant. In addition, no efficient solutions aimed at their activity rescheduling may result in complete termination of their work in the near future [25].

Resource potential of Lviv-Volyn coalfield makes it possible to develop powerful fuel and energy complex with its adaptation to the region needs in energy resources favouring stabilization and growth of economy [26]. At the same time, it is required to consider traditional coal mining techniques as well as geotechnologies inclusive of 'clean coal technologies' using complex physicochemical coal transformations to obtain energy and chemical commodities relying upon the consumer market needs [27]-[31].

There are many factors that, directly or indirectly, impact mining system reliability [32], [33]. Thus, as mining equipment is becoming more complex and sophisticated, its cost is increasing rapidly. This in turn makes it cost ineffective to have standby units. To meet production targets, mining companies are increasingly demanding better equipment reliability [34]-[37].

Growth of a mining sector, involving coal industry, is based upon rational technological schemes of reserve preparation and availability of hi-tech mining facilities which depends directly on the intensification of coal extraction processes [38]-[40]. Consequently, a problem to substantiate influence of a longwall face advance on the stress-strain state of rock mass becomes quite important [41], [42]. Analysis of the data concerning the rock pressure manifestations while mining has demonstrated negative impact by rock shifts, deformations, and falls over the mined-out areas on the extraction facilities [43], [44]. Shift of rock formation, containing a longwall face, takes place in the form of successive bending of rock layers. Beyond area of complete shifts, the layered roof formation hangs over a coal seam. Hence, loads increase and develop the reference pressure areas. Loads over the mined-out area decrease and develop a low pressure zone [45]-[47]. Abnormal pressure zones initiate in the neighbourhood of mining area with the increased loads above the rock mass and the decreased loads over the mined-out area along with the longwall face advance which results in the deceleration of mining operations [48]-[50].

In such a way, the study purpose is to analyze the influence of a longwall face advance on the geomechanical situation in the neighbourhood of a mining site based upon the changes in standard and critical subsidence of the immediate roof rocks.

In this context, the increased rock pressure makes it problematic to provide technical velocity of the powered support advance. In turn, the abovementioned impacts the stress-strain state of the rock mass. Moreover, calculation procedures for stress-strain state take into consideration neither structural features of formation nor technological parameters of coal mining [51]. The situation prevents from comprehensive and quantitative assessment of geomechanical processes taking place in the rock formation. The majority of calculation techniques make it possible to solve certain applied problems, for instance, determine wall rock convergence; load on the powered support; interval of roof subsidence etc. Hence, the authors have proposed to analyze geomechanical situation in the neighbourhood of a longwall face relying on determination of regulations of changes in physical and geometrical parameters of the reference pressure zone depending upon the velocities of longwall face advance.

2. Methods of the research

2.1. Software product selection for the research

Studies of geomechanical parameters in the neighbourhood of a longwall face is closely connected with the layered rock mass behaviour, namely with sedimentary rocks. To analyze stress-strain state of rock mass, the authors have applied software product GeoDenamics Lite developed at Dnipro University of Technology. The software product relies upon a calculation procedure of stress-strain state of rocks by Professor O.V. Savostianov [52]. Expediency of the software selection is based upon the supported control and adaptation of a coal mining technique to changes in geodynamic stress fields in the anisotropic rock-coal medium impacting temporal and spatial changes in the technological parameters [53], [54]. The involved method, studying stress-strain state of rock mass, helps identify both geometrical and physical parameters of stress fields in the neighbourhood of a longwall face varying dynamics of the geomechanical situation in the neighbourhood of a mining site. At the same time, the variety of geodynamic stress fields in an anisotropic, technogenic rock mass influences heavily a direction of a resulting stress vector with a variable value depending upon orientation in the rock mass.

Changes in the stress vector while extracting impacts directly the stability of mine workings of a mining site [51]-[58]. The situation dynamics needs both timely forecast and correction of technological parameters according to the changes in technogenic media where the mine workings are placed [59]. Determination of technological parameters of longwall face depends upon the well-timed analysis of mining and geological conditions, geomechanical parameters, and mining factor making it possible to solve a problem of simulation modelling of production processes while mining taking into consideration temporal and spatial changes in mining and geological conditions as well as geomechanical and technological parameters.

2.2. Analytical mechanism to study SSS of rock mass

Subsidences, horizontal shifts, and rock deformations of the main roof were determined according to [60]:

– subsidence of the main roof rock packs:

$$Y = \frac{1}{f_{(k)}}\left[A\left(\cos\frac{\pi}{L}x-1\right)+C\left(\cos\frac{2\pi}{L}x-1\right)\right]; \quad (1)$$

– horizontal shifts of the main roof rocks:

$$\varepsilon = \frac{1}{f_{(k)}}\left[D\left(\cos\frac{\pi}{L}x-1\right)+N\left(\cos\frac{2\pi}{L}x-1\right)\right]; \quad (2)$$

– horizontal deformations within the main roof rocks:

$$\varepsilon_d = \frac{\varepsilon_2-\varepsilon_1}{x_2-x_1}, \quad (3)$$

where:

A, C, D, and N – parameters which depend upon the structure of roof rocks and parameters of a reference pressure diagram taking into consideration space and time as well as confidents of Fourier series (B_{k1}, B_{k2}):

$$A = 0.39\frac{L^3}{h^3}\cdot B_{k_1};\quad C = 0.5\frac{L^3}{h^3}\cdot B_{k_2};$$
$$D = 1.2\frac{L^2}{h^2}\cdot B_{k_1};\quad N = 0.3\frac{L^2}{h^2}\cdot B_{k_2},\qquad (4)$$

where:

L – complete semi-bend of the studied rock layer;

$f_{(k)}$ – deformational modulus varying along with the rock layer length and calculated as follows:

$$f_{(k)} = E_0 \text{ at } 0 < x < a;$$
$$f_{(k)} = \left(E_0 - E_n\right)\frac{f_2 - x}{b_2} + E_n \text{ at } 0 < x \le f_2;\qquad (5)$$
$$f_{(k)} = E_n \text{ at } f_2 < x \le L.$$

Under critical subsidences, a moment within the cross-section point above a longwall face (involving load on the immediate roof from the overlaying sandstone) was defined using the Expression:

$$M_r = \frac{2L}{\pi}\left[B_{k_1}\left(\cos\frac{\pi}{L} - x - 1\right) + B_{k_2}\left(\cos\frac{\pi}{L} - x - 1\right)\right]\cdot\alpha,\qquad (6)$$

where:

a – coefficient characterizing standard ($Y_н$)-critical (Y_k) ratio of a rock layer subsidence.

Tangential stresses within the roof rocks of the mined coal layer are calculated according to the analytical scheme shown in Figure 1.

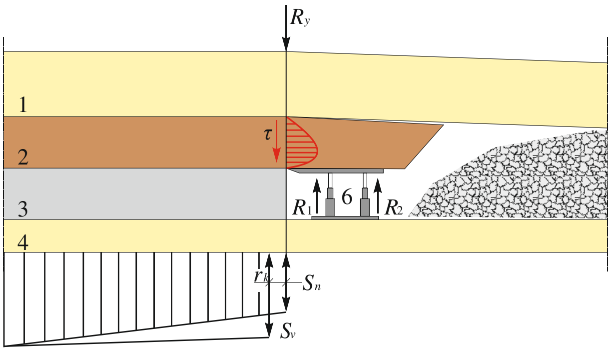

Figure 1. Analytical scheme for tangential stresses within a rock layer (shale) of the immediate roof in the process of the coal seam extraction: 1 – lower coal pack of the main roof; 2 – immediate roof; 3 – coal seam; 4 – seam foot; 5 – mined-out longwall area; 6 – supported working area of the longwall

According to the analytical scheme, S_y reaction shifts towards a longwall face with its increase in the face area. The value depends upon a shearer velocity. It is defined in accordance with the Expression:

$$S_{\max} = \frac{S_2 r_k + S_n f_2}{f_2 + r_k};\qquad (7)$$

$$S_x = 0.2V_k\left(S_{\max} - S_n\right) + S_n \text{ at } 0 < V_k \le 3;\qquad (8)$$

$$S_x = \left(0.057V_k - 0.44\right) + \left(S_{\max} - S_n\right) + S_n \text{ at } 3 < V_k \le 10,\qquad (9)$$

where:

r_k – cutting width of a shearer, m;

V_k – the shearer velocity, m/min.

In this regard, critical load (S_c) from the roof rocks in the longwall face plane is relieved with the help of the mechanized support resistance. It is identified using the Expression:

$$S_c = \frac{\left(R_1 + R_2\right)B}{f_2},\qquad (10)$$

where:

R_1 and R_2 – support resistance within a face area and within the mined-out area of a longwall face, MPa/m^2;

B – face area width, m;

f_2 – width of a reference pressure zone for the immediate roof layer, m.

2.3. Output data for the research

Analysis of the full-scale studies of mining operations within longwall 166 of n_7 seam has helped state that unsubstantiated changes in a longwall face advance influence heavily variations in geometrical and physical parameters of the reference pressure zones being formed in front of longwalls within a face formation as well as in the neighbourhood of a preparatory mine working. Fluctuations of a reference pressure parameters result in origination of geodynamic phenomena within mine workings.

Coal seam (n_7) with $m = 1.3$ m thickness in Lisova mine (SE Lvivvuhillia) was mined using longwall 166 equipped with the powered support 2M-87UMN, coal shearer RKU-10, and a face conveyor SP-250.11. Overcoal rock mass is the formation of sedimentary rocks being shale, sand shale, sandstone layers. Throughout the formation, thickness of the layers varies from 3.8 up to 27 m; immediate roof is $h_1 = 3.5$-4.9 m sand shale; and the main roof is $h_2 = 6.4$ up to 9.1 m sandstone.

Figure 2 shows a scheme to prepare data on the cross section of n_7 seam for calculation of both physical and geometrical parameters of standard loads within rock formation of longwall 166.

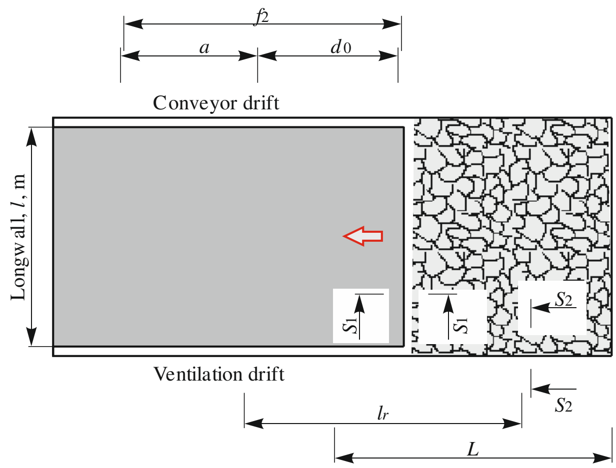

Figure 2. Scheme to prepare data on the cross section of n_7 seam (well #285933) for calculation of standard loads within the rock formation of longwall 166: d_0, a, f_2, l_p, and L – geometrical parameters of the support zone, and analytical bend and semi-bend of rock layers; and S_1, and S_2 are cross sections of the longwall under consideration

For analytical studies of standard loads in rock layers of overcoal formation where n_7 seam is mined using paired longwalls, the rock mass is divided into 9 layers depending upon their lithological difference. The layers are numbered from a roof of coal seam being mined. Geometrical and qualitative indices of the rock mass as well as technological parameters are tabulated to be calculated using a computer. According to the full-scale studies, monitoring of velocities of longwall face advance, the velocity alternatives have been assumed: 1.9; 3.2; and 4.8 m/day. The considered cross sections are identified according to $T = 0$ time. They are located along the normal to a longwall face. Such a temporal cross section as $T = 100$ days is located in parallel with a longwall face.

3. Results and discussion

Resulting from the analytical studies, performed in terms of coal reserve mining from n_7 seam of longwall 165 in Lisova mine, geometrical and physical parameters have been defined as for the diagrams of load on hard layers of overcoal formation (Table 1). The longwall length was 185 m; and velocity of the longwall face advance was 1.9 m/day.

Data from Table 1 have helped understand that if thickness of 4th hard layer is 20 m then standard loads within the layer are propagated uniformly taking loads of overlaying rock seams.

Table 1. Geometrical and physical parameters of diagrams of load on hard layers of the overcoal formation

Layer number	Geometrical parameters, m				Subsidence, m	Physical parameters, MPa		
	a	d_0	B_2	f_2	Y	S_1	S_{max}	T_2
8	24.4	16.5	54.1	87.6	0.35	0.6	0.82	0.53
4	21.9	16.2	39.8	75.3	0.44	3.1	4.3	2.2
2*	29.1	11.8	16	37.2	0.56	6.8	12.1	3.3
2	25.4	9.6	15.5	36.8	0.62	8.5	20.5	3.7
1	20.7	7.2	4.3	25.9	0.74	5.5	9.8	3.9

where 2* is at the roof level of a hard rock layer

The phenomenon results from the bridge rock formation using the rock layer having direct influence on the formation of a support zone within the underlying rock layers. Propagation of standard loads within the underlying rock layers differs in sharp variation of geometrical and physical values. At the level of 2nd sandstone layer, maximum loads are $S_{max} = 20.5$ MPa. The loads are 2.7 times more than the loads in the undisturbed rock mass. Within the mined-out area, the loads achieve 3.9 MPa which is almost twice less to compare with the undisturbed rock mass loads being 7.6 MPa.

Analytical studies of standard loads at the level of 2nd level have been carried out taking into consideration different velocities of longwall face advance from 1.9 m/day until the moment mining operations terminate (100 days) within S_2 cross (Fig. 2). Table 2 represents the calculation results.

1.9 up to 4.8 m acceleration of a longwall face advance results in the increase of geometrical parameters of a reference pressure zone. In this regard, physical parameters grow and a layer subsidence decreases. In terms of 100-day parameters of a longwall face advance, subsidence of 2nd layer of the roof rocks achieved their maximum being 1.18 m.

Table 2. Geometrical and physical parameters of diagrams of loads on the lower pack (2nd layer) of the main roof rocks if a longwall face advance varies

A longwall face advance, m/day	Geometrical parameters, m				Subsidence, m	Physical parameters, MPa				
	a	d_0	B_2	f_2	Y	S_1	S_{max}	T_2	B_{k1}	B_{k2}
1.9	20.4	9.6	15.5	27.8	0.62	8.5	11.6	3.7	18.5	23.8
3.2	15.8	9.0	15.2	23.6	0.57	9.2	14.7	2.8	15.5	20.6
4.8	12.5	8.1	15.4	22.9	0.54	9.0	15.3	1.6	14.2	20.1
100 days	49.6	13.2	16.6	41.4	1.18	7.4	9.2	5.0	9.8	6.7

If a longwall face advance is $V_{nв} = 3.2$ m/day then geometry of a reference pressure zone achieves 23.6 m. 9 m distancing from a longwall face is its maximum. 14.7 MPa will be maximum pressure of a support zone. Velocity increase up to $V_{nв} = 4$ m/day will result in the down to 22.9 m decrease in the support zone as well as maximum pressure approaching by 8.1 m, and its growth up to 15.3 MPa. Relative to loads initiating in the mined-out area in terms of $V_{nв} = 1.9$ m/day and $V_{nв} = 3.2$ m/day a longwall face advance, maximum loads above the mined-out area will be 1.6 MPa in terms of $V_{nв} = 4.8$ m/day to be 2.3-1.8 times less to compare with the listed velocities of a longwall face advance.

Over time, geometrical parameters of a support zone also experience increase in S_2 cross section (Fig. 2) placed behind the longwall face at a 100-day distance. They are 41.4 m. Loads within the mined-out area grow up to 5 MPa achieving loads in the undisturbed rock mass. The fact is explained by the availability of thick 3rd sandstone layer. Subsidence of a roof rock layer (cross section S_2 in Figure 2) becomes more intensive in the mined-out area of the longwall. The loads start their growth through redistribution and reduction of the undermined hanging rocks.

Mining operations influence directly roof rock shift as well as origination of such geodynamic phenomena as technogenic fracturing; inrush and failure of roof rocks; and emergency settlement of longwall supports. Formation of the overcoal rocks is of uneven nature. Periodicity of dynamics of rock layer shifts results in the sharp increase of subsidences. A thick main roof being sandstone with $f = 7$-8 hardness and 9.1 m thickness and divided by the calculations into two packs (i.e. upper $h_{вп} = 5.2$ m pack and lower $h_{нп} = 3.9$ m one) stipulates behaviour of the roof rocks.

The research has made it possible to understand that in the process of a longwall face advance, the main roof formation is layered into two packs – upper pack and lower one. In this regard, the subsidences were calculated individually for each roof pack. Figure 3 explains findings of timely and spatial subsidences and horizontal shifts of rock layers of the main roof. Analysis of the findings concerning the main roof rock subsidence should involve such a notion that subsidence of the rock packs starts in the support zone 5. At the same time, there is no any substantial difference in the subsidence of upper and lower packs of layers.

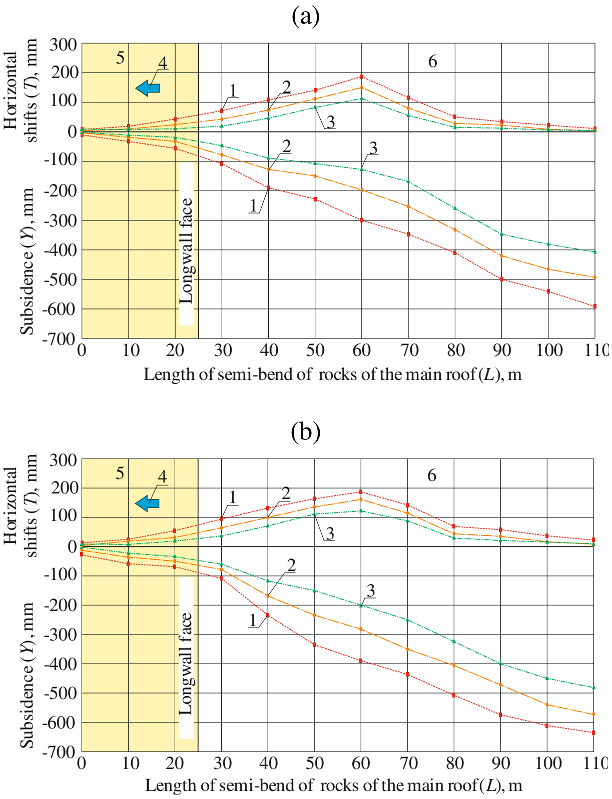

Figure 3. Dependencies of timely and spatial changes in subsidences and horizontal shifts of rock layers of the main roof: (a) upper rock pack (h_{up} = 5.2 m); (b) lower pack (h_{lp} = 3.9 m); 1 – V = 1.9 m/day being a velocity of the longwall face advance; 2 – V = 3.2 m/day; 3 – V = 4.8 m/day; 4 – advance direction of the longwall face; 5 – support zone of abnormal pressure; 6 – the mined-out area of the longwall

The difference in shifts of rock packs of the main roof in terms of various velocities of a longwall face advance depends upon the layering between them. Along with distancing from the support zone, a point of layer bend (i.e. the point within which the bending changes its sign) shifts to the worked-out area of the longwall. Increase of the longwall face velocity advance results in dynamic changes in load parameters from the overlying rock formation on the roof rock layers. If longwall face advance accelerates up to 4.8 m/day a support zone maximum moves to a geometrical bend point distancing 30.5 m from the origin (γH) (Fig. 3, diagram 2). Lower rock pack of the main roof experiences intensive shift when it is loading the immediate roof rocks and increasing the layering within the upper pack of the main roof rocks. Simultaneously with the phenomena, both physical and geometrical parameters of a support zone vary. The loads propagate up to a physical bending point (Fig. 3). Support load increases from 11.6 to 15.3 MPa.

Figure 4 demonstrates physical and geometrical pars of the reference pressure zone in terms of subsidence of lower sandstone pack of the main roof.

It should be mentioned that changes in the support zone parameters happen periodically depending upon a longwall face advance; it is followed by periodicity in rock layer shifts as well as reference pressure propagation. Under critical conditions, a longwall face advance is 2 m/day and lesser subsidence of lower sandstone pack within a face plane is 138 mm while being 187 mm at the boundaries of the face area (5 m from a longwall face) (Figs. 3, 5 and 6).

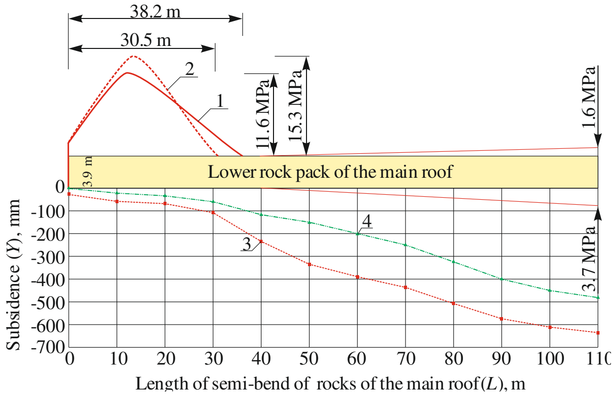

Figure 4. Diagrams of load on the lower sandstone pack of the main roof in the context of standard and critical subsidences: 1 – load diagram when a longwall face advance is 1.9 m/day; 2 – load diagram when a longwall face advance is 4.8 m/day; 3 – subsidence of lower layer of the main roof when a longwall face advance is 1.9 m/day (i.e. critical); 4 – subsidence of lower layer of the main roof when a longwall face advance is 4.8 m/day (i.e. standard); 5 – rock layer subsidence within a longwall face plane; 6 – subsidence of rock layer within the face area (5 m from the longwall face)

In the context of a lower pack, the situation will be repeated every 7-8 meters (9-10 cycles if cutting width of a shearer is 0.8 m), and every 10-11 meters for an upper pack (13-14 cycles).

The subsidence periodicity is also typical for the immediate roof rocks (1st layer being sand shale, h_1 = 3.7 m, Figure 1). Such critical subsidences of a roof rock layer result from the load by overlying rocks within a support zone while its propagating to a geometrical bending point. Frequency of the periodicity is observed every 2.56 m or every 3 cycles.

Figure 5 shows both standard and critical subsidences of the immediate roof rocks within the characteristic points above a longwall face plane.

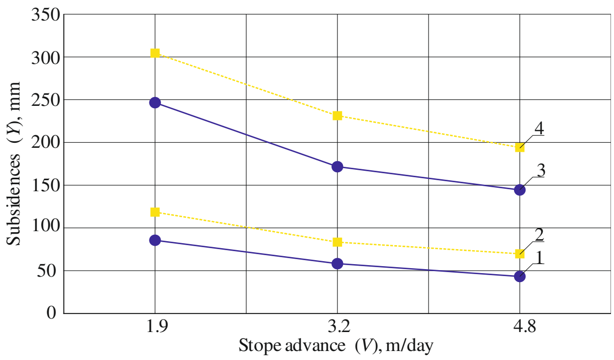

Figure 5. Dependencies of changes in standard as well as critical subsidences of the immediate roof rocks depending upon the longwall face advance velocities: 1, 2 – both standard and critical subsidences within a longwall face plane; 3, 4 – both standard and critical subsidences near the face area boundary

Analysis of data in Figure 4 has helped identify that critical subsidences above a longwall face are 26-33% larger than the standard ones. Taking into consideration T = 100 days, subsidence of the immediate roof rocks within S_2 cross section (Fig. 2) will be $Y_{u.p.}$ = 152 mm and $Y_{l.p.}$ = 407 mm near the face area boundary (i.e. at a 5 m distance from the face).

Extra pressure on the roof rocks, acting at the moment of critical subsidences of rock layers, stipulates formation of vertical cracks as well as rock cut within a longwall face plane. Figure 6 explains studies of extra pressure action on the immediate roof rocks at the moment of critical subsidences of the immediate roof rock layers.

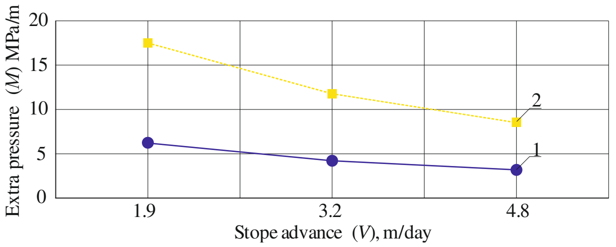

Figure 6. Results of studies of extra pressure action on the immediate roof rocks at the moment of critical subsidences of the immediate roof rock layers: 1 – extra pressure on roof rocks; 2 – reactive moment of critical subsidences

Normal load by the overlying rock formation as well as tangential stresses within a roof layer results from rock destruction by vertical cracks above a longwall face. The potential of the vertical crack initiation and rock layer cut above a longwall face increases along with feed velocity and cutting width of a shearer.

Depending upon a longwall face advance as well as technological parameters of a coal seam mining, studies of tangential stresses in the roof rock layer helps develop measures liquidating geodynamic phenomena in the plane of a longwall area.

Table 3 demonstrates data corresponding to the analytical scheme identifying tangential stresses influencing 1st rock layer (i.e. immediate roof) which initiate rock density disturbance by means of vertical cracks depending upon a longwall face advance (4.8 m/day) and support resistance.

Table 3. Tangential stresses acting on 1st layer of the immediate roof rocks depending upon a longwall face advance (4.8 m/day) and support resistance

Resistance by a support section, MPa	Tangential stresses, MPa			
	Feed velocity of a shearer, m/min			
	1.5	2.5	4	5
0.4	0.58*/0.47*	0.56/0.45	0.53/0.41	0.5/0.39
0.65	0.52/0.45	0.5/0.42	0.48/0.38	0.46/0.36
0.9	0.48/0.42	0.46/0.39	0.43/0.35	0.41/0.34
1.15	0.44/0.4	0.43/0.38	0.42/0.33	0.39/0.31

* tangential stresses under normal subsidences of roof rocks;
** tangential stresses under critical subsidences of roof rocks.

The obtained research results (Table 3) help determine hardness of the immediate roof rocks represented by sand shale splitting. For the purpose, it is required to calculate uniaxial compressive strength of sand shale depending upon a longwall face advance:

$$R^V_{comp} = R_{comp}\left(0.4 + 0.12V\right), \text{ MPa}, \quad (11)$$

where:

$R_{comp.}$ – uniaxial rock compressive strength, 4 MPa;

V – longwall face advance, 4.8 m/day.

According to the abovementioned formula, rock compressive strength depending upon a longwall face advance will be R^V_{comp} = 3.9 MPa. Rock splitting strength should be identified using the Formula:

$$R^V_{adh} = 0.15 R^V_{comp}, \text{ MPa}. \quad (12)$$

It is 0.59 MPa. Comparison between the calculation results, shown in Table 3, and splitting rock strength helps conclude that 4.8 m/day longwall face advance will not demonstrate the development of vertical cracks within a face area. The velocity deceleration down 2 m/day and less will result in vertical crack initiation which will stipulate rock layer density disturbance above a longwall face as well as rock failure in the working longwall space. To prevent negative geodynamic phenomena in roof rocks along a plane of a longwall face area due to the longwall face advance deceleration down to 2 m/day, feed velocity of a shearer should not be more than 1.1 m/min.

A longwall face advance impacts directly rock layer subsidence as well as density disturbance. Roof rock state and a longwall face advance are directly dependent. Advance acceleration decreases the possibility of geodynamic phenomenon initiation in the roof rocks.

4. Conclusions

The involved method, studying stress-strain state of rock mass, helps identify both geometrical and physical parameters of stress fields in the neighbourhood of a longwall face varying dynamics of the geomechanical situation in the neighbourhood of a mining site.

For safe operations, a longwall face advance should be within 2.2-4.8 m/day. In the context of the recommended minimum velocity being 2.2 m/day, miners have to provide no less than 6-cycle day advance. The potential of vertical crack initiation as well as rock layer cut above a longwall face grows depending upon the increase in a feed width and operation width when coal is mined by means of a shearer.

Under standard loading conditions after immediate roof caving and in terms of 2.2 m/day velocity of longwall face advance as well as 6 cycles, a shearer speed should not be more than 2 m/min. As for the critical loading conditions in the roof rocks during a mining cycle seven and further till following roof caving, a shearer speed should not exceed 1.1 m/min.

Value of 2.7-4.4 m/min shearer feed has to be kept while coal mining. Under 2 m/min and less velocity of a longwall face advance, critical subsidences of roof rocks are 0.7-1.1 MPa the abovementioned provides the decreased probability in roof rock failure in the working longwall area. While coal mining, critical loads are of cyclic nature. Consequently, specific support resistance in a longwall should not be less than 0.8 MPa.

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Обґрунтування впливу швидкості посування очисного вибою на напружено-деформований стан гірського масиву

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Мета. Дослідження впливу швидкості посування очисного вибою на геомеханічну ситуацію навколо видобувної дільниці на основі встановлення зміни нормальних та критичних опускань порід безпосередньої покрівлі.

Методика. Для дослідження геомеханічної ситуації навколо видобувної дільниці авторами роботи застосовано програмний продукт “GeoDenamics Lite”, розроблений у НТУ “Дніпровська політехніка”. В основу даного програмного продукту покладено метод розрахунку напружено-деформованого стану порід професора О.В. Савостьянова. Доцільність вибору програмного продукту ґрунтується на забезпеченні керованістю та адаптацією технологічного процесу видобутку вугілля до змін геодинамічних полів напружень у анізотропному породо-вугільному середовищі, що впливає на зміну технологічних параметрів у просторі та часі.

Результати. Виділено основні проблеми пов’язані зі зміною швидкості посування очисного вибою. Вперше для гірничо-геологічних умов шахти “Лісова” ДП “Львіввугілля” побудована розрахункова схема дотичних напружень у шарі порід безпосередньої покрівлі в умовах виїмки вугільного пласта спареними лавами, що дозволяє встановити фізичні та геометричні параметри нормальних навантажень у товщі порід.

Наукова новизна. Встановлено залежності зміни опускань та горизонтальних переміщень у просторі й часі породних шарів основної покрівлі (верхньої породної пачки $h_{вп}$ = 5.2 м, нижньої пачки $h_{нп}$ = 3.9 м при змінній швидкості посування вибою лави від 1.9 до 4.8 м/добу. Визначено фізичні та геометричні параметри опорної зони тиску та при опусканні нижньої пачки пісковику основної покрівлі. Досліджено вплив додаткових сил тиску на породи безпосередньої покрівлі у момент критичних опускань шару порід безпосередньої покрівлі. При цьому нормальне привантаження з боку вищележачої породної товщі та дотичні напруження у шарі покрівлі є причиною руйнування порід вертикальними тріщинами над очисним вибоєм.

Практична значимість. Розроблена інженерна методика, що дозволяє визначити параметри впливу швидкості посування очисного вибою на геомеханічну ситуацію навколо видобувної дільниці. Це дозволяє в подальшому прогнозувати зміну параметрів зони опорного тиску навколо очисного вибою та уникнути критичних ситуацій щодо посадки механізованого кріплення на “жорстко”.

Ключові слова: *шахта, очисний вибій, вугільний пласта, гірський масив, напружено-деформований стан*