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EXPERIMENTAL DETERMINATION OF ANGLE VALUES OF THE ROCKS FULL DISPLACEMENT WHEN UNDERMINING THEM BY BREAKAGE HEADINGS

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ЕКСПЕРИМЕНТАЛЬНЕ ВИЗНАЧЕННЯ ЗНАЧЕНЬ КУТІВ ПОВНИХ ЗРУШЕНЬ ПОРІД ПРИ ЇХ ПІДРОБЦІ ОЧИСНИМИ ВИРОБКАМИ

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ABSTRACT

Purpose. Experimental determination of angle changes of full displacement of rocks by removing the breakage face from the face entry in different mining and geological conditions.

Methods. On the basis of experimental data on parameters of the earth's surface subsidence and the breakage headings size the full displacement angles of undermined rocks are determined graphically.

Findings. The angle changes of the earth's surface maximal subsidence are determined from the ratio of breakage heading size and mining operations depth.

Originality. The maximal earth's surface subsidence values correspond to the minimal values of the displacement angles above the face entry.

Practical implications. The obtained results make it possible to estimate the displacement zones possible boundaries of undermined rocks with their discontinuity.

Keywords: *angles, displacement, earth's surface, flat bottom, trough, face entry, breakage face*

1. INTRODUCTION

According to the normative document (Minpalyvenerho Ukrainy, 2004), full displacement angles (ψ_1, ψ_2, ψ_3) are used in the calculation of displacements and deformations of the earth's surface after its complete undermining by breakage headings (the trough flat bottom formation). These angles are internal with respect to worked-out area. They are formed on the vertical cuts along the main sections of trough by the seam sheet and lines connecting the borders of mine working and trough flat bottom. Angle ψ_1 is laid off near the bottom border, angle ψ_2 – near the upper border, angle ψ_3 – near the border of mine working along the strike (Salehnia, Collin, & Charlier, 2016; Suchowerska Iwanec, Carter, & Hambleton, 2016; Filatiev, 2017a; Filatiev, 2017b).

For the conditions of Donbas, Western Donbas and the Lviv-Volyn basin full displacement angle values are taken as constant and equal to 55° (Ivanova & Zaitseva, 2004; Russkikh, Demchenko, Salli, & Shevchenko, 2013; Demydov, Astafiev, & Kaminski, 2015). The conditions of Donbass and Western Donbass are an exception, for which a correction to angle ψ_2 for angle of slope (α) of mined coal seam is applied. In this case, $\varphi_2 = 55° + 0.3$.

When mining coal seams, the angle of maximal subsidence of undermined rocks (θ) is used to determine the location of the most characteristic places of trough displacement of the earth's surface – highs of soil subsidence. According to the normative document, this parameter is determined from the drop of the reservoir in vertical section in the main part of the trough across the stretch of the reservoir by a horizontal line and by a line connecting the middle of the working with the point of maximal subsidence in the incomplete part of the earth's surface. Academician S.G. Aversion assumed that undermined massif line of the maximal displacements is not straightforward and tends to become steeper as it approaches the earth's surface. To simplify the calculations at the present time, the angles θ are accepted, including constant for the whole of undermined rocks strata in compliance with the normative document.

It is believed that the angle of maximal subsidence of rocks in particular geological-mining and mining-technical conditions depends only on the angle of slope of coal seam development (Khomenko, Kononenko, & Petlyovanyy, 2014; Ghabraie, Ren, Barbato, & Smith, 2017; Salmi, Nazem, & Karakus, 2017). For individual coal deposits θ is calculated according to the General equation:

$$\theta = 90^{\circ} - k \cdot \alpha \text{, degrees,} \quad (1)$$

where:

k – is an empirical coefficient taken equal from 0 to 1.

With the exception of recommendation for seams with coal grades T and A:

$$\theta = 95^{\circ} - \alpha \text{, degrees.} \quad (2)$$

Recommended values of edge angles of undermined rocks maximal subsidence for different coal basins are in the wide range from 300 to 950 (Fig. 1).

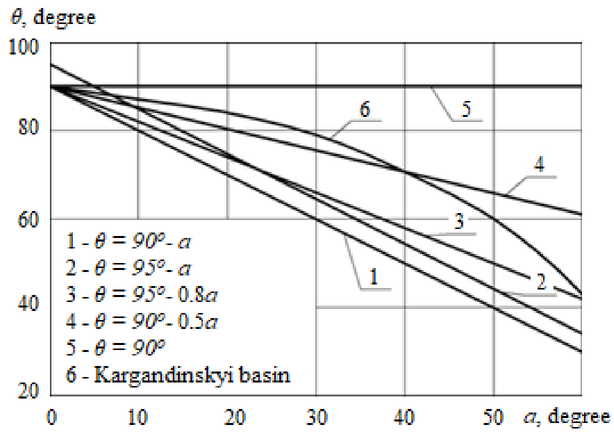

Figure 1. Examples of change of maximal subsidence angles of rocks (θ) and angles of slope of the mined seam (α) for different coal basins

This indicates the possible influence of other factors, besides the angles of slope (Kuz'menko, Petlyovanyy, & Stupnik, 2013; Mohammed, Wan, & Wei, 2015; Petlovanyi, 2016). The reliability of the parameter definition θ influences largely the effectiveness of the developed rational measures for the protection of objects on the earth's surface from the harmful effects of wastewater treatment works. Therefore, it is important to establish additional influencing factors, besides the angle of slope.

In case of incomplete undermining, in addition to full displacement angles (ψ_1, ψ_2, ψ_3) in the computational schemes (Minpalyvenerho Ukrainy, 2004) the angles of maximal subsidence of the earth's surface (θ) are used. For the Lviv-Volyn basin angle θ is assumed constant and equal to 90°. For the rest coal deposits of Ukraine a correction to the angle of slope of the mined seam $\theta = 90° - 0.8\,\alpha$ is applied.

2. MAIN PART

Based on the calculated schemes (Minpalyvenerho Ukrainy, 2004) of the trough displacement size determination with incomplete and complete undermining of the earth's surface, it follows that the angles of full displacement in both cases are taken up the same and constant regardless of the degree of broken working development.

Full displacement angles can be constant only after trough flat bottom formation. As studies have shown (Filat'yev, Antoshchenko, Gasyuk, & Pyzhov, 2015), until full undermining of the earth's surface, the angles of maximal subsidence of the earth's surface (θ) change under the influence of broken working. If to determine the full displacement angles on the basis of the breakage heading size and the maximal subsidence values of the earth's surface corresponding to them, the values of full displacement angles cannot be constant.

The angle changes of full displacement with the position of the earth's surface maximal subsidence by removing the breakage face from the face entry is characterized by diagram (Fig. 2).

For its implementation it is necessary to know the location of the experimental points *1*, *2*, *3* ... *i* and their maximal subsidence η_1, η_2, η_3 … η_i. This calculated scheme and experimental data on the trough's parameters make it possible to determine the angle changes of full displacement above the face entry (ψ_{01}, ψ_{02}, ψ_{03} ... ψ_{0i}), and above the removing breakage face (ψ_1, ψ_2, ψ_3 ... ψ_i). Knowing of these angles is necessary for the development of measures for the rational protection of objects on the earth's surface. Until now, their ratios have not been studied, so research in this direction is relevant. The purpose of work is the experimental determination of the angle changes of full displacement when removing the breakage face from the face entry in different mining and geological conditions.

The methods of angles (ψ_{01}, ψ_{02}, ψ_{03} ... ψ_{0i} and ψ_1, ψ_2, ψ_3 ... ψ_i) determination according to the experimental data are represented in diagram (Fig. 2). Each experimental point of the earth's surface maximal subsidence is connected by one line segment with a face entry fixed wall, and by another line segment each point is connected with a position of this breakage face, corresponding to it. The angle between the first segment and the seam sheet is the full displacement angle above the face entry and the angle between the second segment and the seam sheet is the full displacement angle above the moving breakage face. The total of the experimental points of the earth's surface maximal subsidence corresponds to the trajectory curve *4* of the maximal subsidence.

The trajectory curves of maximal subsidence points of dependence η_m on their projection distances to face entry (L_r) are chosen by least squares method based on the results of observations (Iofis & Shmelev, 1985; Larchenko, 1998; Borzykh & Gorovoy, 1999; Babenko, 2009; Averin, Kir'yazev, & Dotsenko, 2010; Nazarenko & Yoshchenko, 2011) on twelve sites of seven mines in different coal basins. The dependence $m = f(L)$ is described more precisely by way of exponential equation. Taking up in the equation of the curve $m = f(L)$ value of $m = 0$ we have found the position of point *1* (Fig. 1), in which the earth's surface displacement begins for each of the studied object.

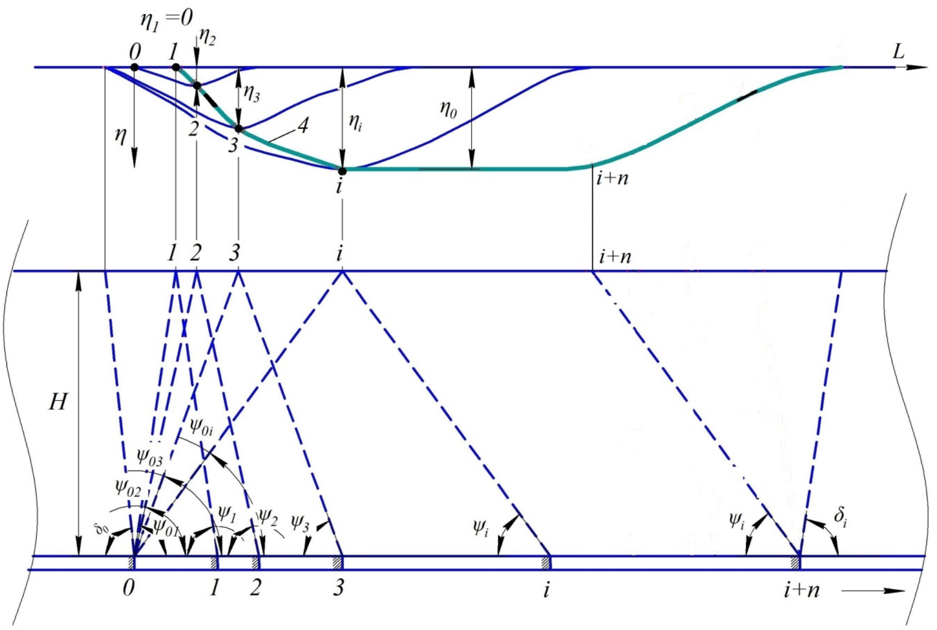

Figure 2. Diagram of the angle changes of displacement of rocks, undermined by removing the breakage face from the face entry: 1, 2, 3 ... i – positions of the breakage face and the points corresponding to them of the trajectory curve of the earth's surface maximal subsidence; 4 – trajectory curve of the earth's surface maximal subsidence points; i + n – random position of breakage face after complete undermining of the earth's surface; η_1, η_2, η_3, η_i – maximal subsidence of the earth's surface, respectively, for the positions of the breakage face 1, 2, 3 ... i; η_o – depth of the displacement through flat bottom; δ_o, δ_i – adjoining angles of the impact on the earth's surface, respectively, from side of the face entry and moving breakage face; ψ_{01}, ψ_{02}, ψ_{03} ... ψ_{0i} – angles from side of the face entry, which characterize earth's surface maximal subsidence at positions of the breakage face 1, 2, 3 ... i, corresponding to them; ψ_1, ψ_2, ψ_3 ... ψ_i – angles from side of the breakage face, respectively, at its positions 1, 2, 3 ... i

The position of the breakage face *1*, which corresponds to the beginning of the earth's surface displacement at the point *1* has been determined in the same way, using the dependence η_m on the distance between the face entry and breakage face *L*.

This analysis of experimental observations made it possible to supplement the initial data (Iofis & Shmelev, 1985; Larchenko, 1998; Borzykh & Gorovoy, 1999; Babenko, 2009; Averin, Kir'yazev, & Dotsenko, 2010; Nazarenko & Yoshchenko, 2011) with values of ψ_{01} and ψ_1 angles on twelve objects for $\eta_m = 0$ at the moment when displacement processes reach the undermined rocks of the earth's surface (Table 1).

Table 1. The results of ψ_1 and ψ_{01} angles determination for $\eta_m = 0$ and reaching by the displacement processes of the earth's surface rocks

No.	Mine, longwall face, seam, literary source	The distance between the breakage face and face entry for $\eta_m = 0$, *L*, m	The distance from point *1* projection to the face entry for $\eta_m = 0$, L_r, m	Number of analyzed experimental data to determine the dependency curves $\eta_m = \varphi(L)$ and $\eta_m = f(L_p)$	The angles corresponding to the beginning of the earth's surface displacement at the point *1* (Fig. 2), degree	
					ψ_{01}	ψ_1
1	"Stepova"*	24	–1	16	87	81
2	"Stepova", No. 604, C_6**	26	7	9	83	85
3	"Stepova", No. 606, C_6**	35	14	11	79	84
4	"Yuvileina", No. 530, C_6**	33	13	10	85	83
5	"Yuvileina", 2nd east, C_1**	16	21	5	86	88
6	"Yuvileina", No. 715, 713, C_6**	37	20	14	80	89
7	"Pershotravneva", No. 302, 304, C_4**	20	5	4	88	84
8	"Yuvileina", No. 605, 607, C_6**	58	15	15	87	81
9	"P.L. Voikova", K_5***	173	55	6	89	80
10	"M.V. Frunze", h_8****	186	70	5	85	84
11	"H.H. Kapustina", m_3^H*****	30	15	5	88	87
12	"Appalach Basin" ******	141	70	15	82	82

* (Larchenko, 1998)
** (Nazarenko & Yoshchenko, 2011)
*** (Borzykh & Gorovoy, 1999)
**** (Averin, Kir'yazev, & Dotsenko, 2010)
***** (Iofis & Shmelev, 1985)
***** (Babenko, 2009)

The following values of full displacement angles above the face entry (ψ_{fe}) and breakage face (ψ_{bf}) were determined graphically from the experimental data of the earth's surface maximal subsidence (η_m) and from corresponding to them breakage face removals from face entry (L).

The results of such ψ_{fe} and ψ_{bf} determinations are exemplified for "Stepova Mine", "P.L. Voikov Mine", "M.V. Frunze Mine" and "Appalach Basin Mine" (Fig. 3). Mining and geological conditions of these mines differ significantly. The differences are in the different depth of mining operations, the strength of the host rocks, the metamorphic grade of coals and other indicators. For example, in "Stepova Mine" the seam C_6 was mined at a depth of 107 m with G grade of coal. The host rocks for these grades are less strong within the range of coal metamorphism. On the contrary, the anthracite seams, which were mined at a depth of about 700 m in such mines as "P.L. Voikov" and "M.V. Frunze", differ by the most strong host rocks. Mining and geological conditions of the objects have determined the different location of curves, which describe the angle changes of full displacement when removing the breakage face from the face entry. In all cases, the full displacement angles above the moving breakage face exceed their values above the face entry. It indicates that angle changes, despite the difference in mining and geological conditions happened approximately in the same direction. Such changes could cause the main factors influencing the earth's surface displacement. According to (Yagunov, 2007), it is the ratio of breakage heading sizes (L) and the depth of mining operations (H) that determine the parameters of undermined rocks displacement by 80%.

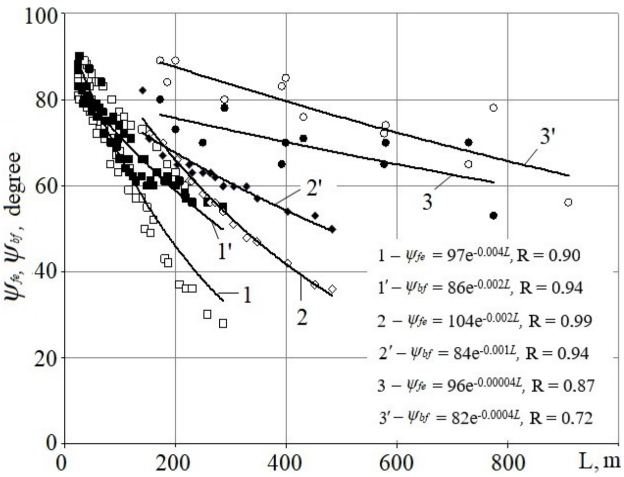

Figure 3. The angles (ψ_{fe}, ψ_{bf}) change, which correspond to the earth's surface maximal subsidence when removing the breakage face from the face entry (L): 1 – curves of angle changes, respectively, from side of the face entry (ψ_{fe}) and removing breakage face (ψ_{bf}) according to experimental data (Larchenko, 1998) 2, 3 – the same is as for Appalachian Basin mines, respectively (Babenko, 2009) and for mines, exploiting the anthracite seams (Borzykh & Gorovoy, 1999; Averin, Kir'yazev, & Dotsenko, 2010); □, ■, ◇, ◆, ○, ● – experimental data; R – correlation ratio

To verify this conclusion a joint statistical analysis of all data obtained on the basis of experimental observations (Iofis & Shmelev, 1985; Larchenko, 1998; Borzykh & Gorovoy, 1999; Babenko, 2009; Averin, Kir'yazev, & Dotsenko, 2010; Nazarenko & Yoshchenko, 2011) has been held. The results of this analysis (Fig. 4) have proved a close correlation dependence of the angle changes of the earth's surface maximal subsidence as from the side of face entry (ψ_{fe}), so above the breakage face (ψ_{bf}) with the complex parameter L/H. Correlation ratios for these dependences amounted respectively to 0.88 and 0.97. Almost functional dependences of ψ_{fe} and ψ_{bf} on L/H for different coal deposits confirmed the conclusion concerning the main effect of this parameter.

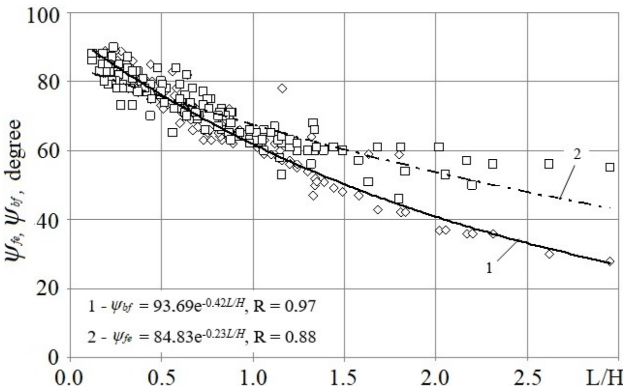

Figure 4. The angle changes of the earth's surface maximal subsidence with a complex parameter (L/H): 1, 2 – curves of angle changes respectively from side of the face entry (ψ_{fe}) and removing breakage face (ψ_{bf}) according to the original experimental data (Iofis & Shmelev, 1985; Larchenko, 1998; Borzykh & Gorovoy, 1999; Babenko, 2009; Averin, Kir'yazev, & Dotsenko, 2010; Nazarenko & Yoshchenko, 2011); ◇, □ – experimental data; R – correlation ratio

The parameter L/H determines the degree of the earth's surface undermining. If its value is less than 1, there is approximately the same change of angles ψ_{fe} and ψ_{bf}. When $L/H > 1$, the angles ψ_{bf} exceed ψ_{fe}, ψ_{bf} substantially. Angle values with sufficient breakage heading development ($L/H > 1$) are stabilized in the range of 50 – 60°. Such their values are close to their value (55°) recommended by the normative document (Minpalyvenerho Ukrainy, 2004).

The ψ_{fe} angles above the face entry reduced to 30° (Fig. 4), with a significant broken working development ($L/H \approx 3.0$). This situation is explained by dislocation of points of the earth's surface maximum subsidence in the direction of removing breakage face.

It should be noted that the earth's surface maximal subsidence values correspond to the minimal values of ψ_{fe} angles. Obviously, using the ratio of the ψ_{fe} and ψ_{bf} angles and calculated scheme (Fig. 2) it is possible to estimate the displacement zones possible boundaries of undermined rocks with their discontinuity.

3. CONCLUSIONS

Full displacement angles of undermined rocks, determined by the earth's surface maximal subsidence and degree of the broken working development do not remain constant.

The main factor, which influences the displacement angle changes above the face entry and breakage face, is the ratio of a linear size of the breakage heading and the depth of mining operations.

Full displacement angles above the face entry and breakage face depend almost functionally on a complex parameter – a ratio of the breakage face removal from the face entry (L) and the broken working depth (H).

When the degree of broken working development $L/H \leq 1$, there are approximately the same displacement angle changes above the face entry and removing breakage face.

When $L/H > 1$, the displacement angles above the breakage face substantially exceed their value above the face entry.

With sufficient broken working development ($L/H > 1$), the displacement angles above the breakage face are stabilized and equal approximately to 55°.

Displacement angles above the face entry can reach up to 30° when the parameter $L/H \approx 3.0$, and this is caused by dislocation of points of the earth's surface maximum subsidence in the direction of removing breakage face.

The earth's surface maximal subsidence values correspond to the minimal displacement angles values of face entry.

Comparing the values of the displacement angles above the face entry and the breakage face, and using the trough's parameters of the earth's surface it is possible to estimate the displacement zones possible boundaries of undermined rocks with their discontinuity.

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REFERENCES

Averin, G.A., Kir'yazev, P.N., & Dotsenko, O.G. (2010). Vliyanie sloistosti na osedanie zemnoy poverkhnosti. *Ugol' Ukrainy*, (10), 34-35.

Babenko, E.V. (2009). Nastroyka modeli dlya modelirovaniya seysmicheskikh sobytiy tekhnologicheskoy prirody. *Problemy Hirs'koho Tysku*, (17), 67-93.

Borzykh, A.F., & Gorovoy, E.P. (1999). Vliyanie shiriny vyrabotannogo prostranstva na aktivizatsiyu sdvizheniya uglenosnogo massiva. *Ugol' Ukrainy*, (9), 26-30.

Demydov, M., Astafiev, D., & Kaminski, P. (2015). Specialties of Coal Seams Mining Under Conditions of Western Donbas. *Mining of Mineral Deposits*, *9*(1), 113-116. https://doi.org/10.15407/mining09.01.113

Filat'yev, M.V., Antoshchenko, N.I., Gasyuk, R.L., & Pyzhov, S.V. (2015). Eksperimental'noe opredelenie uglov maksimal'nogo osedaniya podrabotannykh ochistnymi vyrabotkami porod. *Ugol' Ukrainy*, (11), 3-6.

Filatiev, M.V. (2017a). Analytical Determination of Coordinates of Distinguished Points of the Earth Surface Depression Over Broken Workings. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (1), 27-33.

Filatiev, M.V. (2017 b). Determination of Cross-Correlation Dependences Between the Parameters of Swallies of the Earth Surface and the Movement of Underworked Rocks. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (3), 43-48.

Ghabraie, B., Ren, G., Barbato, J., & Smith, J.V. (2017). A Predictive Methodology for Multi-Seam Mining Induced Subsidence. *International Journal of Rock Mechanics and Mining Sciences*, (93), 280-294. https://doi.org/10.1016/j.ijrmms.2017.02.003

Iofis, M.A., & Shmelev, A.I. (1985). *Inzhenernaya geomekhanika pri podzemnykh razrabotkakh*. Moskva: Nedra.

Ivanova, A., & Zaitseva, L. (2004). Studies of the Coal Facies in Western Ukraine (the Lvov-Volyn Basin). *International Journal of Coal Geology*, *58*(1-2), 67-73. https://doi.org/10.1016/j.coal.2003.08.007

Khomenko, O., Kononenko, M., & Petlyovanyy, M. (2014). Investigation of Stress-Strain State of Rock Massif Around the Secondary Chambers. *Progressive Technologies of Coal, Coalbed Methane, and Ores Mining*, 241-245. https://doi.org/10.1201/b17547-43

Kuz'menko, O., Petlyovanyy, M., & Stupnik, M. (2013). The Influence of Fine Particles of Binding Materials on the Strength Properties of Hardening Backfill. *Mining of Mineral Deposits*, 45-48. https://doi.org/10.1201/b16354-10

Larchenko, V.G. (1998). Vliyanie podzemnoy razrabotki ugol'nykh plastov na sostoyanie zemnoy poverkhnosti. *Vestnik Mezhdunarodnoy Akademii Nauk Ekologii i Bezopasnosti*, *4*(12), 39-41.

Minpalyvenerho Ukrainy. (2004). *Pravyla pidrobky budivel, sporud i pryrodnykh ob'iektiv pry vydobuvanni vuhillia pidzemnymy sposobamy*. Kyiv: Haluzevyi standart Ukrainy.

Mohammed, M., Wan, L., & Wei, Z. (2015). Slope Stability Analysis of Southern Slope of Chengmenshan Copper Mine, China. *International Journal of Mining Science and Technology*, *25*(2), 171-175. https://doi.org/10.1016/j.ijmst.2015.02.002

Nazarenko, V.A., & Yoshchenko, N.V. (2011). *Zakonomernosti razvitiya maksimal'nikh osedaniy i naklonov poverkhnosti v mul'de sdvizheniya*. Dnepropetrovsk: Natsyonal'nyy gornyy universitet.

Petlovanyi, M. (2016). Influence of Configuration Chambers on the Formation of Stress in Multi-Modulus Mass. *Mining of Mineral Deposits*, *10*(2), 48-54. https://doi.org/10.15407/mining10.02.048

Russkikh, V., Demchenko, Y., Salli, S., & Shevchenko, O. (2013). New Technical Solutions During Mining C_5 Coal Seam Under Complex Hydro-Geological Conditions of Western Donbass. *Mining of Mineral Deposits*, 257-260. https://doi.org/10.1201/b16354-48

Salehnia, F., Collin, F., & Charlier, R. (2016). On the Variable Dilatancy Angle in Rocks Around Underground Galleries. *Rock Mechanics and Rock Engineering*, *50*(3), 587-601. https://doi.org/10.1007/s00603-016-1126-6

Salmi, E.F., Nazem, M., & Karakus, M. (2017). The Effect of Rock Mass Gradual Deterioration on the Mechanism of Post-Mining Subsidence Over Shallow Abandoned Coal Mines. *International Journal of Rock Mechanics and Mining Sciences*, (91), 59-71. https://doi.org/10.1016/j.ijrmms.2016.11.012

Suchowerska Iwanec, A.M., Carter, J.P., & Hambleton, J.P. (2016). Geomechanics of Subsidence Above Single and Multi-Seam Coal Mining. *Journal of Rock Mechanics and Geotechnical Engineering*, *8*(3), 304-313. https://doi.org/10.1016/j.jrmge.2015.11.007

Yagunov, A.S. (2007). Issledovanie vliyaniya vysokikh skorostey podviganiya ochistnogo zaboya na kharakter i parametry protsessa sdvizheniya poverkhnosti. *Vestnik Nauchnogo Tsentra po Bezopasnosti Rabot v Ugol'noy Promyshlennosti*, (2), 36-43.

ABSTRACT (IN UKRAINIAN)

Мета. Експериментальне визначення в різних гірничо-геологічних умовах зміну кутів повних зрушень порід при віддаленні очисних вибоїв від розрізних печей.

Методика. На підставі експериментальних даних про параметри осідання земної поверхні і розміри очисних виробок графічним способом визначені кути повних зрушень підроблених порід.

Результати. Встановлені зміни кутів максимального осідання земної поверхні від співвідношення розмірів очисної виробки і глибини ведення робіт.

Наукова новизна. Мінімальним значенням кутів зрушення над розрізною піччю відповідають максимальні осідання земної поверхні.

Практична значимість. Отримані результати дозволяють судити про можливі межі зон зрушення підроблених порід з розривом їх суцільності.

Ключові слова: *кути, зрушення, повна підробка, земна поверхня, пласке дно, мульда, розрізна піч, очисний вибій*

ABSTRACT (IN RUSSIAN)

Цель. Экспериментальное определение в разных горно-геологических условиях изменения углов полных сдвижений пород при удалении очистных забоев от разрезных печей.

Методика. На основании экспериментальных данных о параметрах оседания земной поверхности и размерах очистных выработок графическим способом определены углы полных сдвижений подработанных пород.

Результаты. Установлены изменения углов максимального оседания земной поверхности от соотношения размеров очистной выработки и глубины ведения работ.

Научная новизна. Минимальным значениям углов сдвижения над разрезной печью соответствуют максимальные оседания земной поверхности.

Практическая значимость. Полученные результаты позволяют судить о возможных границах зон сдвижения подработанных пород с разрывом их сплошности.

Ключевые слова: *углы, сдвижение, земная поверхность, плоское дно, мульда, разрезная печь, очистной забой*

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