UDC 622.411.332.023.623:622.83 DOI: https://doi.org/10.15407/geotm2021.158.003

THE INFLUENCE OF WORKING SEAM THICKNESS ON PERMEABILITY OF BARRIER PILLARS NEAR ISOLATED FIRE SECTIONS

[1]Krukovskyi O.P., [1]Minieiev S.P., [1]Krukovska V.V., [2]Belikov I.B.

[1]Institute of Geotechnical Mechanics named by N. Poljakov of NAS of Ukraine, [2]Central Staff of the State Militarized Mine Rescue Service of Ukraine

ВПЛИВ ПОТУЖНОСТІ ВУГІЛЬНОГО ПЛАСТА, ЩО ВІДПРАЦЬОВУЄТЬСЯ, НА ПРОНИКНІСТЬ БАР'ЄРНИХ ЦІЛИКІВ ПОБЛИЗУ ІЗОЛЬОВАНОЇ ПОЖЕЖНОЇ ДІЛЬНИЦІ

[1]Круковський О.П., [1]Мінєєв С.П., [1]Круковська В.В., [2]Бєліков І.Б.

[1]Інститут геотехнічної механіки ім. М.С. Полякова НАН України, [2]Центральний штаб ДВГРС України

ВЛИЯНИЕ МОЩНОСТИ ОТРАБАТЫВАЕМОГО УГОЛЬНОГО ПЛАСТА НА ПРОНИЦАЕМОСТЬ БАРЬЕРНЫХ ЦЕЛИКОВ ВБЛИЗИ ИЗОЛИРОВАННОГО ПОЖАРНОГО УЧАСТКА

[1]Круковский А.П., [1]Минеев С.П., [1]Круковская В.В., [2]Беликов И.Б.

[1]Институт геотехнической механики им. Н.С. Полякова НАН Украины, [2]Центральный штаб ГВГСС Украины

Abstract. The study of filtration permeability of the barrier pillar between the isolated fire section and the worked longwall ventilation drift was completed using the mathematical model developed by the authors for coupled processes of rock deformation and gas filtration. The problem is solved involving a finite element method implemented in the author's programme. When solving, the parameters of width of the barrier pillar and thickness of the mined coal seam were varied. The article presents the results of calculating the values of geomechanical parameters, permeability coefficients and gas pressure in the filtration area.

It is shown that with an increase in thickness of the coal seam, intensity of the crack formation process increases in the barrier pillar. With small pillar width, the coal seam along its entire length is in a disturbed state, as well as the rocks of its roof and soil. The filtration areas around the worked longwall ventilation drift and the isolated conveyor drift are connected both along the coal seam and along the host rocks. This means that at a certain value of the pressure drop, filtration of fire gases into the mine workings of the worked excavation section is possible. With a greater width of the pillar, between disturbed rocks around the mine workings of the worked section and isolated fire one, there is a barrier made of undisturbed rocks. That impermeable barrier prevents gas filtration from one mine workings to another. Its width decreases with an increase in the thickness of the coal seam.

Based on the results of calculating gas pressure, it is shown that methane from the coal seam moves into atmosphere of the mine workings, where gas pressure has lower values. At the same time, for the accepted conditions, with a pillar width of 20 m and a seam thickness of 0.4 m, gas is filtered from the mine workings of isolated fire section into the adjacent excavation section along the disturbed rocks of the seam roof. In the rest of the cases, the areas of low pressure around the mine workings are separated by zones of higher pressure, exceeding pressure of fire gases in the isolated section. Filtration of fire gases into atmosphere of the worked excavation section is impossible under such conditions.

Keywords: mining safety, barrier pillar, isolated fire section, deformation of the rocks, gas filtration, seam thickness.

1 Introduction

A coal mine is a high-risk mining enterprise; during production activities, hazardous and harmful factors may arise in its underground workings [1]. These factors include underground fires. They can be caused by spontaneous combustion of coal due to oxidative processes or an external thermal impulse. Underground fires can continue for long periods of time until the smoldering seam is depleted.

They can spread over large areas along mine workings and cracks in the rock, and they are extremely difficult to extinguish, which is associated with the difficulty or impossibility of access to the seat of fire [2, 3].

If it is impossible to extinguish the fires, the workings of the emergency section are isolated using explosion-proof bulkheads. A barrier pillar must be left between the emergency section and the existing mine workings. At certain values of permeability of pillar rocks and pressure drop, fire gases may leak into the atmosphere of the adjacent excavation section [4]. Therefore, the calculation of the width of the barrier pillars must be performed on the basis of two conditions: ensuring their stability and gas impermeability.

For example, the 7th southern longwall of block 10 of “Pokrovske” Mine Administration was mined near the excavation section of the 7th southern “bis” longwall of block 10, in the workings of which there was an explosion of a methane-air mixture and a fire. The emergency section was isolated with explosion-proof bulkheads. A barrier pillar was left between the intermediate drift of the 7th southern “bis” longwall of block 10 and the ventilation drift of the 7th southern longwall of block 10. The average thickness of the coal seam in this area is 1.45 m.

At the same mine, the 3rd southern longwall of block 7 was mined near the isolated fire section of the 2nd southern longwall of block 7. The seam thickness in the mining area is 0.97 m. A barrier pillar is left between the conveyor drift of the 2nd southern longwall of block 7 and the ventilation drift of the 3rd southern longwall of block 7.

The thickness of the coal seam in the mining area of the 3rd southern longwall of block 7 is 1.5 times less than in the area of the 7th southern longwall of block 10. In this regard, the question arises: how will the thickness of the coal seam affect the permeability of the barrier pillar? Is it possible to leave smaller pillars at a lower seam thickness? Therefore, the purpose of this work is to study the filtration permeability of the barrier pillar between the isolated section and the preparatory drift of the new longwall, depending on the thickness of the mined coal seam.

2 Methods

To calculate the permeability of a coal-rock mass, it is necessary to determine the parameters of its stress state, which is described by a system of equations:

$$\sigma_{ij,j} + X_i(t) = 0, \tag{1}$$

where $\sigma_{ij,j}$ - are derivatives of the components of a tensor of main stresses along horizontal axis x and vertical axis y, Pa/m; $X_i(t)$ - is projections of the external forces effecting per unit of body volume, N/m^3.

A Coulomb-Mohr criterion is used to describe mathematically a process of rock transition into a disturbed state. A stress-strain state of rocks is analysed with the help of following geomechanical parameters characterizing different-component nature of a stress field (Q^*) and geostatic pressure relief of the rocks (P^*):

$$Q^* = \frac{\sigma_1 - \sigma_3}{\gamma H}; \quad P^* = \frac{\sigma_3}{\gamma H}, \tag{2}$$

where σ_1, σ_3 - are maximum and minimum components of a tensor of the main pressures, Pa; γ - is average weigh of the overlying rocks, N/m^3; H - is mining depth, m.

As a result of mining operations, an initial stress field is redistributed, that stipulates certain changes in filtration permeability k of a coal-rock mass [5, 6]. It was previously shown that k values at each point of the study area depend on the stress state of the rock at this point as follows [7, 8]:

- $k = 0$ within the zone of equal-component compression and elastic deformations ($Q^* < 0.6$; $P^* > 0.25$);
- $k = k_{min}$ within the area of initial fissuring ($0.6 < Q^* < 0.8$; $P^* > 0.1$);
- $k = e^{0.26Q*-4.65}$ within the area of intense cracking ($0.8 < Q^* < 1.2$; $P^* > 0.1$);
- $k = k_{max}$ in terms of rock breaking ($Q^* > 1.2$; $P^* < 0.1$).

It means that:

$$k = \begin{cases} 0 & \text{for } Q^* < 0.6;\ P^* > 0.25; \\ k_{\min} & \text{for } 0.6 < Q^* < 0.8; \\ e^{0.26Q^* - 4.65} & \text{for } 0.8 < Q^* < 1.2;\ P^* > 0.1; \\ k_{\max} & \text{for } Q^* > 1.2;\ P^* < 0.1, \end{cases} \tag{3}$$

where $k_{\min}$ - is minimal value of a permeability coefficient required for the beginning of a filtration process, m^2; $k_{\max}$ - is permeability within the zone of breaking, m^2.

The equation of plane gas filtration, in terms of the available gas-bearing rocks within the filtration area, is as follows [9]:

$$\frac{k}{2M\mu}\left(\frac{\partial^2 p^2}{\partial x^2} + \frac{\partial^2 p^2}{\partial y^2}\right) + q(t) = 0, \tag{4}$$

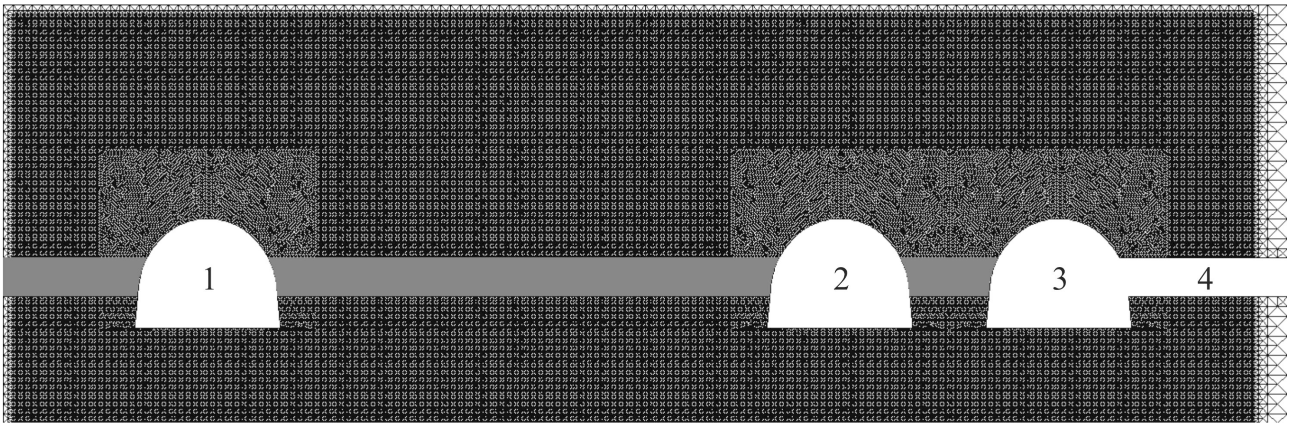
where p - is gas pressure, Pa; m is porosity; μ is gas viscosity, Pa·s; x, y - are coordinates, m; $q(t)$ - is function of gas emission, Pa/s.

There are following boundary conditions for this problem:

$$\begin{gathered} u_x\big|_{\Omega_1} = 0; \quad u_y\big|_{\Omega_2} = 0; \\ p\big|_{\Omega_3} = p_0; \quad p\big|_{\Omega_4} = 0.1 \text{ MPa}, \end{gathered} \tag{5}$$

where u_x, u_y - are components of a displacement vector, m; p_0 - is coal pressure of methane, MPa; Ω_1 - is vertical boundaries of the external contour; Ω_2 - is horizontal boundaries of the external contour; Ω_3 - is zone beyond the filtration zone; Ω_4 - is internal contour (mine working).

The problem is solved involving a finite element method implemented in the author's programme. A central part of a finite-element grid for the area of rocks, which include the mine workings, a pillar between them and a mined-out space, is represented in Fig. 1.



1 – the worked longwall ventilation drift; 2 – the isolated fire section conveyor drift;
3 – the unsupported ventilation drift of the previously worked excavation field;
4 – the mined-out space

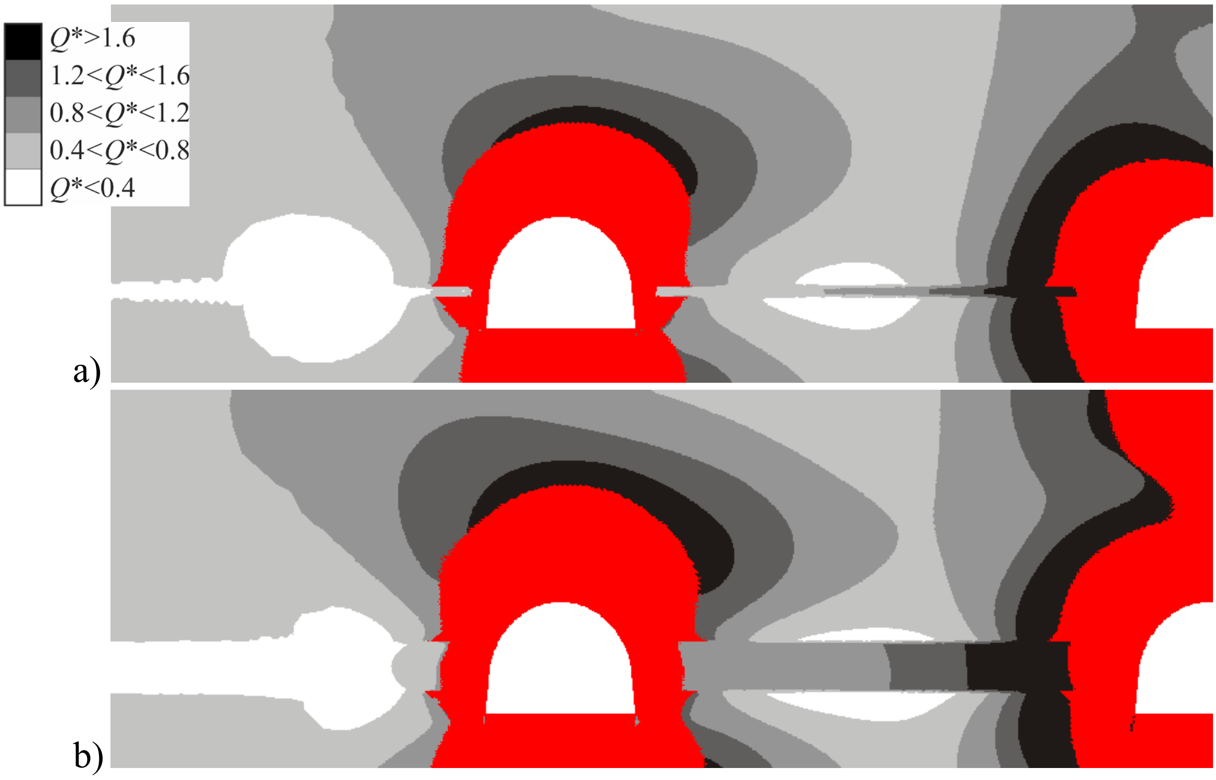
Figure 1 – The central fragment of the finite-element grid

3 Results and discussion

The calculations were performed for the mining and geological conditions of "Pokrovske" Mine Administration with a pillar width L_p = 20 м ($x \in$ [83 m; 103 m]) и L_p = 30 м ($x \in$ [73 m; 103 m]) for cases when the thickness of the mined coal seam m varies within 0.4-2.0 m.

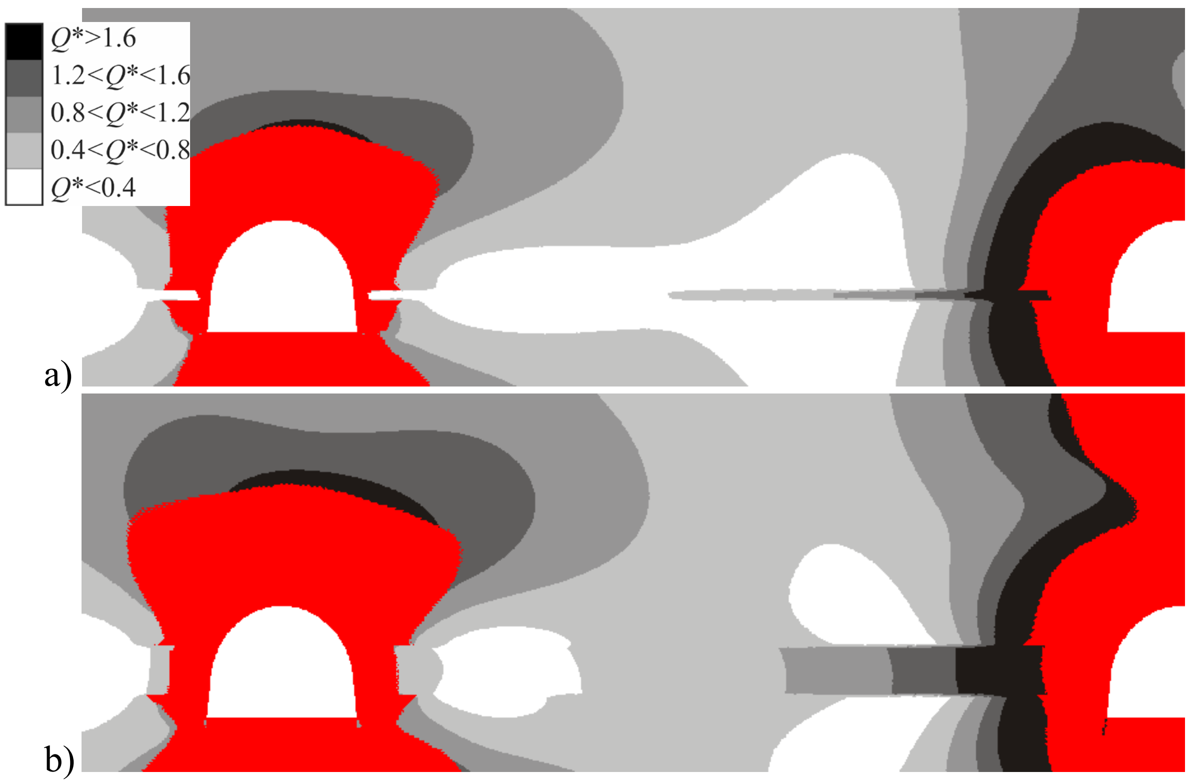
The results of calculating the values of Q^* parameter, which characterizes different-component nature of the stress field, and zones of inelastic deformations (red colour) are shown in Fig. 2 and 3. Zones of inelastic deformations and areas of disturbed rocks, where the values of Q^* parameter are very high (Q^* > 1.6), surround the isolated area (on the right) and the ventilation drift of worked longwall. Zones of inelastic deformation indicate the destruction of rocks around the mine workings and mined-out space.

With a pillar width L_p = 20 m and a seam thickness m = 0.4 m, the minimum Q^* value in the coal seam between workings is Q^* = 0.4, Fig. 2 a, at m = 2.0 m the minimum Q^* value is 0.8, Fig. 2 b. Hence, it follows that the intensity of cracking increases with an increase in thickness of the coal seam in the barrier pillar. At m = 2.0 m, in most of it, a process of intense cracking occurs, when uncontrolled growth of cracks takes place, deformations rapidly increase due to the propagation of cracks and loosening of the rock [10]. In the area of intense fracturing, permeability coefficients increase by 2-3 orders of magnitude.



a – m = 0.4 m; b – m = 2.0 m

Figure 2 – The distribution of Q^* values and zones of inelastic deformations, L_p = 20 m



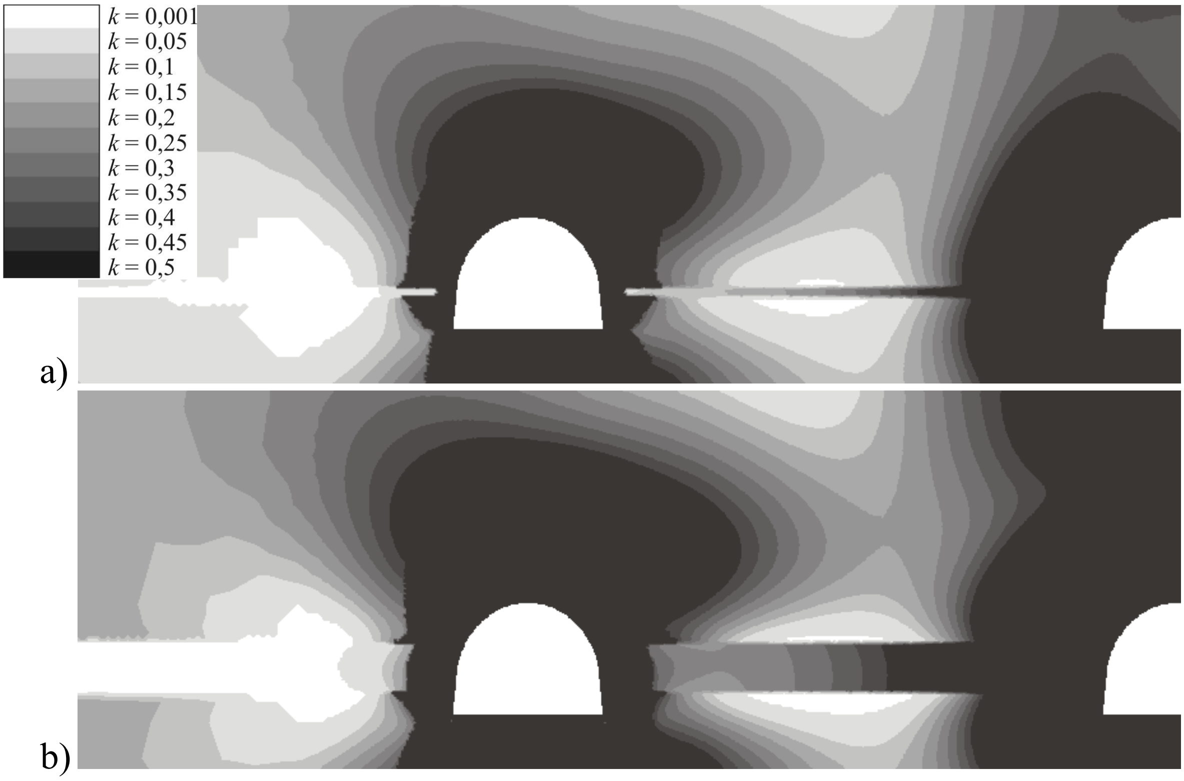
a – m = 0.4 м; b – m = 2.0 м

Figure 3 – The distribution of Q^* values and zones of inelastic deformations, L_p = 30 m

In both of these cases, in rocks of the roof and floor of the seam, there are areas where the minimum values of Q^* parameter are enclosed in the interval $0.4 < Q^* < 0.8$. These are the areas of the beginning of microcracking, where the accumulation of single, non-interacting defects occurs [10].

With a greater width of the pillar and m = 0.4 m, Fig. 3 a, between the disturbed rocks around the mine workings of the worked section and isolated fire one, there is a barrier made of undisturbed rocks preserved in a monolithic state ($Q^* < 0.4$). The width of this barrier decreases with an increase in the thickness of the coal seam.

Figures 4 and 5 show the distribution of the values of the permeability coefficients in the coal seam, rocks and pillars of various widths, at m = 0.4 m and m = 2.0 m. It can be seen that thickness of the seam affects permeability of the rocks between the workings of the isolated section and worked one.

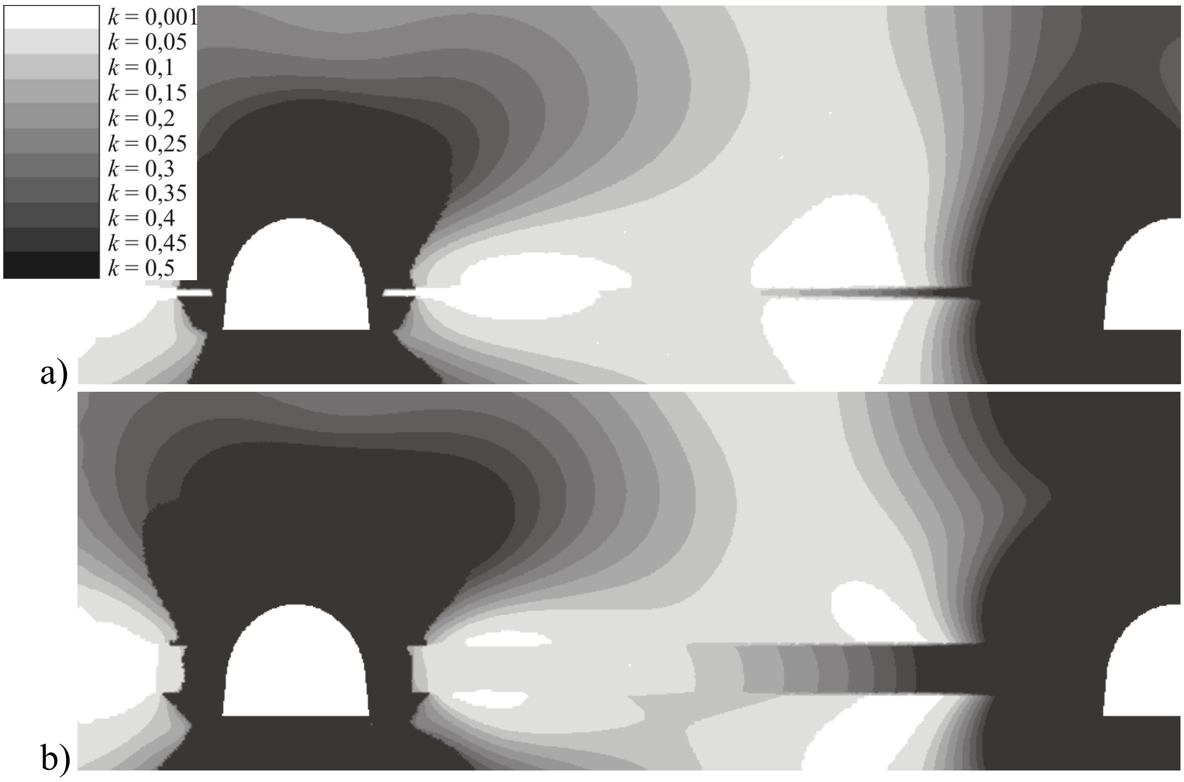


a – m = 0.4 m; b – m = 2.0 m

Figure 4 – Distribution of the values of permeability coefficients of the coal-rock mass, L_p = 20 м

With the pillar width L_p = 20 m, Fig. 4, the filtration areas around the ventilation drift of the active longwall and the isolated conveyor drift of the fire section are connected both along the coal seam and along the host rocks. Moreover, with an increase in the seam thickness, its filtration permeability increases significantly along the entire length of the barrier pillar. This means that at a certain value of pressure drop, filtration of fire gases into the workings of the worked excavation section is possible.

With the pillar width L_p =30 m, Fig. 5, the filtration areas around the ventilation drift and the isolated fire section are practically not connected, between them there is an impermeable barrier, that is, an area in which coal and rocks permeability is close to zero. And in this case, we can see that at m = 2.0 m (Fig. 5 b) filtration permeability of the coal seam is higher than at m = 0.4 m (Fig. 5 a).



a – m = 0.4 m; b – m = 2.0 m

Figure 5 – Distribution of the values of permeability coefficients, L_p = 30 м

The graphs of the change in filtration permeability of the coal seam in the studied interval for L_p = 20 m and L_p = 20 30 m are shown in Fig. 6

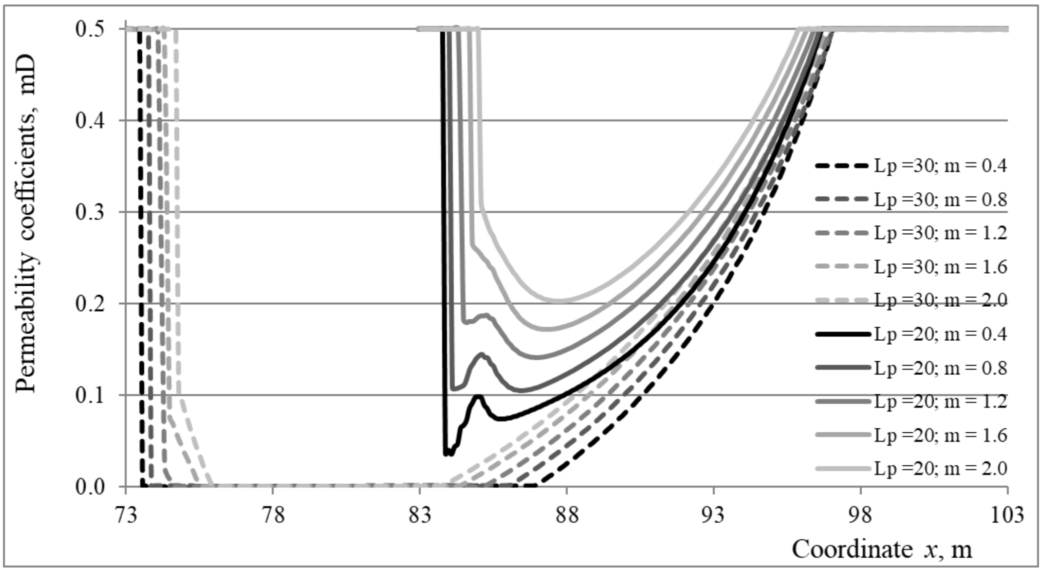


Figure 6 – Change in the values of permeability coefficients of the barrier pillar (in the coal seam) depending on thickness of the seam, at L_p = 20 m and L_p = 30 m

It should be noted that on the horizontal parts of the curves of the change in the permeability coefficients (Fig. 6, L_p = 30 m, $x \in$ [74; 87]), their values are not always zero, here permeability coefficients can take on very small values, of the order of 10^{-3} mDa.

In order to more clearly show the change in insulating characteristics of the pillars with increasing the coal seam thickness, we will consider the values of minimum permeability of the barrier pillars (Fig. 7) and the length of the impermeable part of the pillar (Fig. 8). It can be seen that at L_p = 20 m, an increase in the seam thickness from 0.4 m to 2 m leads to an increase in the minimum permeability of the barrier pillar by about 5 times. In this case, a pillar between workings №1 and №2 at the seam thickness $m \in$ [0.4; 2.0] has filtration permeability across the entire width.

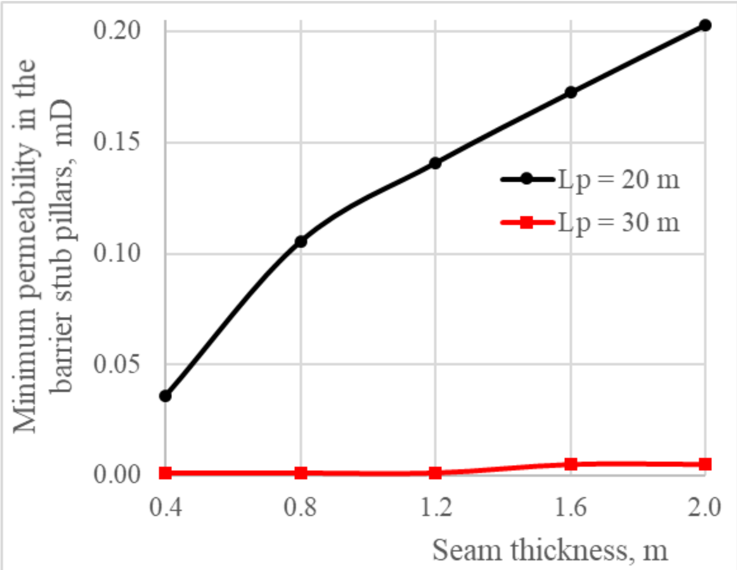


Figure 7 – Minimum permeability of the barrier pillar depending on thickness of the mined coal seam

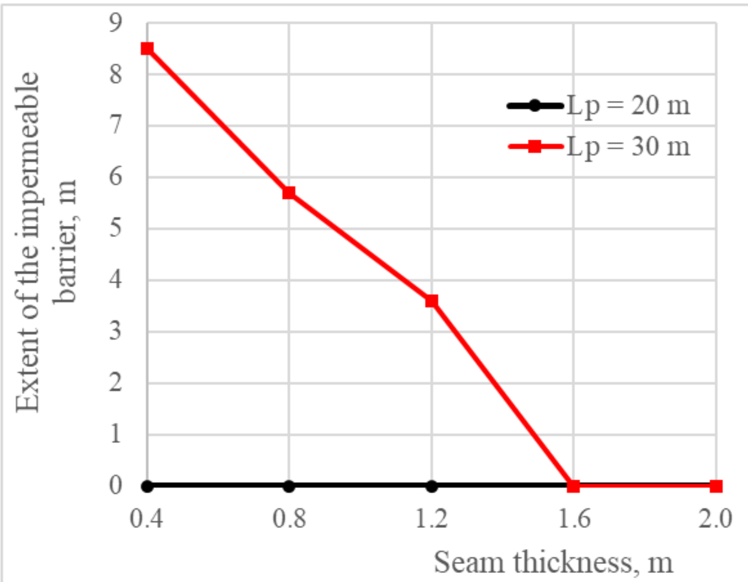
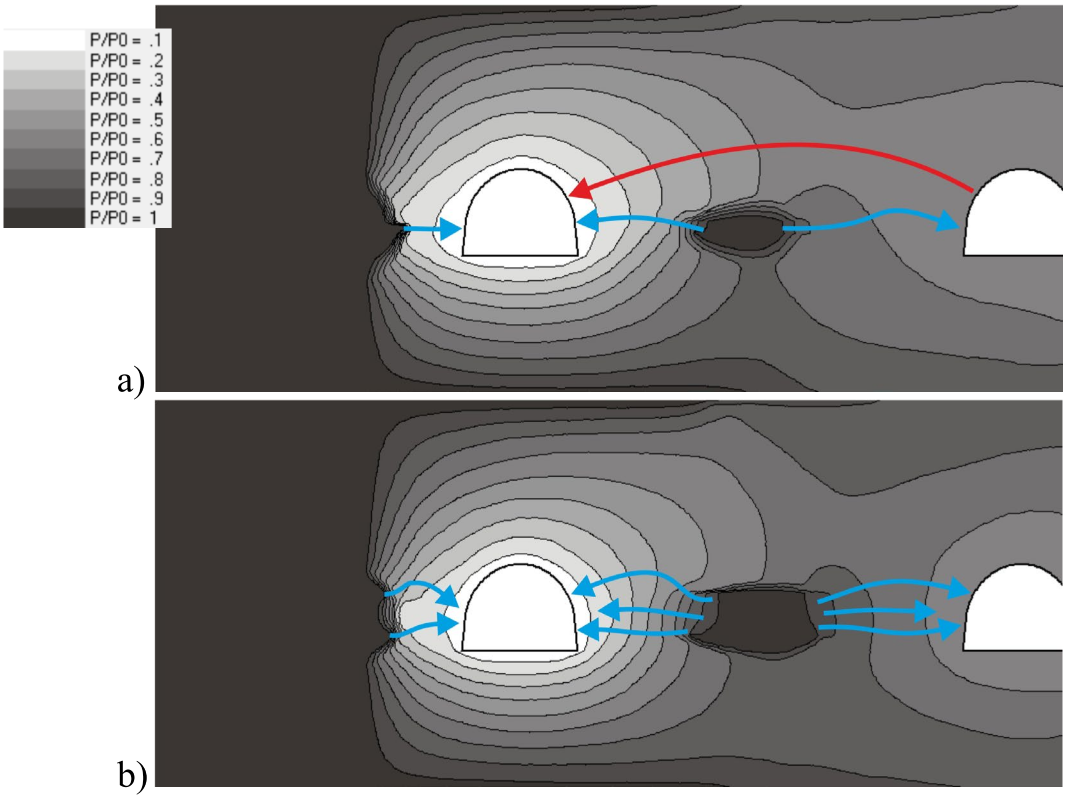


Figure 8 – Length of the impermeable part of the pillar depending on thickness of the mined coal seam

At L_p = 30 m and m <1.6 m, there is always an impermeable area in the pillar coal seam. Such a barrier prevents gas filtration from one mine working to another one, Fig. 8. At $m \geq$ 1.6 m, the pillar is completely permeable, but it has a section where the filtration permeability is very low. Due to this, to start the process of filtering fire gases into the mine workings of the worked excavation section, a significantly greater pressure drop between the worked section and isolated fire one will be required.

The results of calculating relative gas pressure p/p_0 in fractured-pore space of coal-rock mass (under the condition p_0 = 6 MPa, the pressure drop in the workings of the worked and isolated sections Δp = 3 MPa) are shown in Fig. 9 (L_p = 20 m) and Fig. 10 (L_p = 30 m). It can be seen that gas pressure in the filtration area surrounding mine workings and mined-out space is lowered, p/p_0 < 1. Methane from the coal seam with seam pressure of 6 MPa moves to the atmosphere of the mine workings, where the pressure is lower.



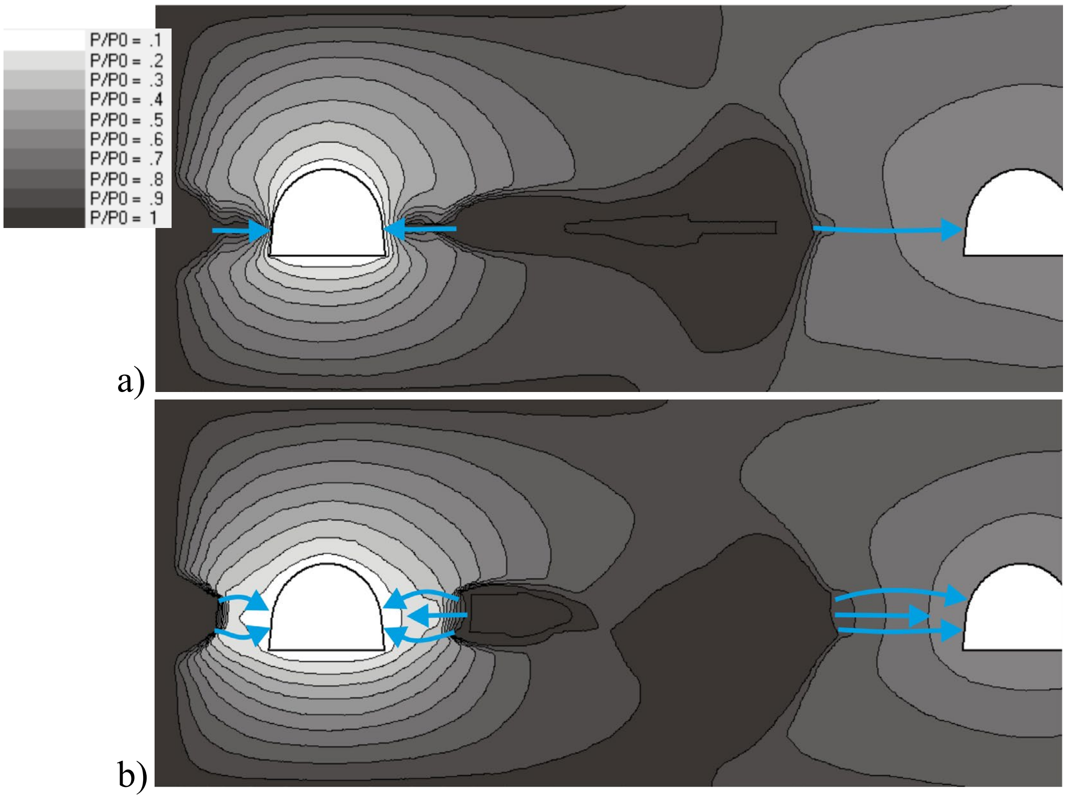
a – m = 0.4 m; b – m = 2.0 m

Figure 9 – Relative gas pressure in fractured-pore space of coal-rock mass, L_p = 20 m

At the same time, as can be seen from Fig. 9 a, the gas pressure in the fractured space of argillite, which forms the roof of the coal seam, smoothly changes from 3 MPa (pressure of fire gases in the isolated section) to 0.1 MPa in the worked ventilation drift. This means that at L_p = 20 m and m = 0.4 m, gas filtration from the workings of the isolated fire section into the workings of the adjacent excavation section occurs along the disturbed rocks of the seam roof. At L_p = 20 m and m = 2.0

m, a higher pressure drop Δp is required to start the process of fire gases filtration into the atmosphere of worked mine workings.

In the rest of the cases that were considered, the areas of low pressure around the mine workings are separated by zones of higher pressure, exceeding pressure of fire gases in the working №2 (p > 3 MPa), fig. 10. Filtration of fire gases into atmosphere of the worked excavation section is impossible under such conditions.



a – m = 0.4 m; b – m = 2.0 m

Figure 10 – Relative gas pressure in fractured-pore space of coal-rock mass, L_p = 30 m

4 Conclusions

The study of filtration permeability of the barrier pillar between the isolated fire section and the worked longwall ventilation drift was completed using the mathematical model developed by the authors for coupled processes of rock deformation and gas filtration. The problem is solved involving a finite element method implemented in the author's programme. When solving, the parameters of width of the barrier pillar and thickness of the mined coal seam were varied. The article presents the results of calculating the values of geomechanical parameters, permeability coefficients and gas pressure in the filtration area.

It is shown that with an increase in thickness of the coal seam, intensity of the crack formation process increases in the barrier pillar. With small pillar width, the coal seam along its entire length is in a disturbed state, as well as the rocks of its roof and soil. The filtration areas around the worked longwall ventilation drift and the isolated conveyor drift are connected both along the coal seam and along the host rocks. This means that at a certain value of the pressure drop, filtration of fire gases into the mine workings of the worked excavation section is possible.

With a greater width of the pillar, between disturbed rocks around the mine workings of the worked section and isolated fire one, there is a barrier made of undisturbed rocks. That impermeable barrier prevents gas filtration from one mine workings to another. Its width decreases with an increase in the thickness of the coal seam.

Based on the results of calculating gas pressure, it is shown that methane from the coal seam moves into atmosphere of the mine workings, where gas pressure has lower values. At the same time, for the accepted conditions, with a pillar width of 20 m and a seam thickness of 0.4 m, gas is filtered from the mine workings of isolated fire section into the adjacent excavation section along the disturbed rocks of the seam roof. In the rest of the cases, the areas of low pressure around the mine workings are separated by zones of higher pressure, exceeding pressure of fire gases in the isolated section. Filtration of fire gases into atmosphere of the worked excavation section is impossible under such conditions.

REFERENCES

1. State Committee of Ukraine for Industrial Safety, Labor Protection and Mining Supervision (2010), *NPAOP 10.0-1.01-10: Pravyla bezpeky u vugilnykh shakhtakh* [NPAOP 10.0-1.01-10: Safety rules in coal mines], LIHA ZAKON, Kyiv, Ukraine.

2. Ayubov, E.N., Lukyanovich, A.V., et al. (2013), *Pozhary i vzryvy* [Fires and explosions], : FGBU VNII GOChS (FTs), Moskow, Russia.

3. Mineev, S., Smolanov, S., Belykov, Y. and Samopalenko, P. (2018), "Justification of the choice of emergency ventilation modes for extinguishing underground fires'', *Modern engineering and innovative technologies*, no.05-02, pp.16-21, https://doi.org/10.30890/2567-5273.2018-05-02-010

4. Kokoulin, I., Bunko, T., Yashchenko, I., Papirnyk, R., Belikov, A., Myroshnychenko, V. and Otchenashev, O. (2020), "Identification of zones of influence of exogenous fire damaging factors", *E3S Web of Conferences, II International Conference Essays of Mining Science and Practice,* no.168 (2020). https://doi.org/10.1051/e3sconf/202016800049

5. Durucan, S., Daltaban, T.S., Shi, J.Q. and Foley, L. (1993), "Permeability characterization for modeling methane flow in coal seams", *Proceedings of the International Coalbed Methane Symposium*, Tuscaloosa, Alabama, 453-460.

6. Bai, M., Meng, F., Elsworth, D. et al. (1997), "Numerical modeling of stress-dependent permeability", *International Journal of Rock Mechanics & Mining Sciences*, no.34:3-4, pp.2.e1-2.e14. https://doi.org/10.1016/S1365-1609(97)00056-7

7. Krukovska, V.V. (2015), "Simulation of coupled processes that occur in coal-rock massif during mining operations",*Geo-Technical Mechanics,* no.121, pp.48-99

8. Krukovskyi, O., Krukovska, V. and Wen, Zhang (2020), "Outburst cavity formation in the working face driven along the outburst-prone coal seam", *E3S Web of Conferences, II International Conference Essays of Mining Science and Practice*, 168 (2020). https://doi.org/10.1051/e3sconf/202016800052

9. Basniev, K.S., Kochina, I.N. and Maksimov, V.M. (1993), *Podzemnaya gidromehanika* [Underground fluid mechanics] Nedra, Moskva, Russia.

10. Vynohradov, V.V. (1989), *Geomehanika upravleniya sostoyaniem massiva vblizi gornykh vyrabotok* [Geomechanics of massif state control near mine workings], Naukova dumka, Kyiv, Ukraine.

СПИСОК ЛИТЕРАТУРЫ

1. НПАОП 10.0-1.01-10 Правила безпеки у вугільних шахтах. К.: ТОВ «ЛІГА ЗАКОН», 2010. 170 с.

2. Аюбов Е.Н., Лукьянович А.В., и др. Пожары и взрывы. Москва: ФГБУ ВНИИ ГОЧС (ФЦ), 2013. 145 с.

3. Минеев С., Смоланов С., Беликов И., Самопаленко П. Обоснование выбора аварийных вентиляционных режимов при тушении подземных пожаров / Modern engineering and innovative technologies, 2018. №05-02. С. 16-21. https://doi:10.30890/2567-5273.2018-05-02-010

4. Kokoulin I., Bunko T., Yashchenko I., Papirnyk R., Belikov A., Myroshnychenko V. Otchenashev O. Identification of zones of influence of exogenous fire damaging factors / E3S Web of Conferences, II International Conference Essays of Mining Science and Practice, 168 (2020). https://doi.org/10.1051/e3sconf/202016800049

5. Durucan S., Daltaban T.S., Shi J.Q., Foley L. Permeability characterization for modeling methane flow in coal seams. Proceedings of the International Coalbed Methane Symposium, Tuscaloosa, Alabama, 1993. 453-460

6. Bai M., Meng F., Elsworth D. et al. Numerical modeling of stress-dependent permeability. International Journal of Rock Mechanics & Mining Sciences. 1997. 34:3-4. 2.e1-2.e14. https://doi.org/10.1016/S1365-1609(97)00056-7

7. Krukovska V.V. Simulation of coupled processes that occur in coal-rock massif during mining operations / Geo-Technical Mechanics, 2015. no. 121. P.48-99.

8. Krukovskyi O., Krukovska, V., Wen Zhang. Outburst cavity formation in the working face driven along the outburst-prone coal seam / E3S Web of Conferences, II International Conference Essays of Mining Science and Practice, **168** (2020). https://doi.org/10.1051/e3sconf/202016800052

9. Басниев К.С., Кичина И.Н., Максимов В.М. Подземная гидромеханика. М.: Недра, 1993. 416 с.

10. Виноградов В.В. Геомеханика управления состоянием массива вблизи горных выработок. К.: Наукова думка, 1989. 192 с.

About the authors

Krukovskyi Oleksandr Petrovych, Corresponding Member of NAS of Ukraine, Doctor of Technical Sciences (D. Sc), Deputy Director of the institute, Institute of Geotechnical Mechanics named by N. Poljakov of the National Academy of Sciences of Ukraine (IGTM of NAS of Ukraine), Dnipro, Ukraine, igtm@ua.fm

Minieiev Serhii Pavlovych, Doctor of Technical Sciences (D.Sc.), Professor, Head of the Department of Pressure Dynamics Control in Rocks, Institute of Geotechnical Mechanics named by N. Poljakov of the National Academy of Sciences of Ukraine (IGTM of NAS of Ukraine), Dnipro, Ukraine, sergmineev@gmail.com

Krukovska Viktoriia Viktorivna, Doctor of Technical Sciences (D. Sc), Senior Researcher, Senior Researcher in Department of Pressure Dynamics Control in Rocks, Institute of Geotechnical Mechanics named by N. Poljakov of the National Academy of Sciences of Ukraine (IGTM of NAS of Ukraine), Dnipro, Ukraine, igtm@ukr.net

Belikov Ihor Borysovych, Master of Science, First Deputy Chief of the Central Staff of the SMMSS of Ukraine, Kramotorsk, Ukraine.

Об авторах

Круковский Александр Петрович, член-корреспондент НАН Украины, доктор технических наук, заместитель директора института по научной работе, Институт геотехнической механики им. Н.С. Полякова Национальной академии наук Украины (ИГТМ НАН Украины), Днепр, Украина, igtm@ua.fm.

Минеев Сергей Павлович, доктор технических наук, профессор, заведующий отделом управления динамическими проявлениями горного давления, Институт геотехнической механики им. Н.С. Полякова Национальной академии наук Украины (ИГТМ НАН Украины), Днепр, Украина, sergmineev@gmail.com.

Круковская Виктория Викторовна, доктор технических наук, старший научный сотрудник, старший научный сотрудник отдела управления динамическими проявлениями горного давления, Институт геотехнической механики им. Н.С. Полякова Национальной академии наук Украины (ИГТМ НАН Украины), Днепр, Украина, igtm@ukr.net.

Беликов Игорь Борисович, магистр, заместитель начальника центрального штаба ГВГСС Украины, Центральный штаб ГВГСС Украины, Краматорск, Украина

Анотація. За допомогою розробленої авторами математичної моделі протікання зв'язаних процесів деформування вуглепородного масиву і фільтрації газу, виконано дослідження фільтраційної проникності бар'єрного цілика між ізольованою пожежною ділянкою і підготовчим штреком нової лави. Задачу було розв'язано із застосуванням методу скінченних елементів, який реалізований в авторській програмі. При розв'язанні варіювалися параметри ширини бар'єрного цілика і потужності вугільного пласта, який відпрацьовується. У статті наведено результати розрахунку значень геомеханічних параметрів, коефіцієнтів проникності і тиску газу в області фільтрації.

Показано, що зі збільшенням потужності вугільного пласта в бар'єрному цілику зростає інтенсивність процесу утворення тріщин. При малій ширині цілика вугільний пласт по всій його довжині знаходиться в порушеному стані, так само, як і породи його покрівлі і підошви. Області фільтрації навколо вентиляційного штреку діючої лави та ізольованого конвеєрного штреку пожежної дільниці зв'язані і по вугільному пласту, і по вміщуючих породах. Це означає, що при певному значенні перепаду тиску можлива фільтрація пожежних газів у виробки діючої очисної дільниці. При більшій ширині цілика між порушеними породами навколо виробок діючої і ізольованої пожежної ділянок знаходиться перемичка з непошкоджених порід – непроникна ділянка, що перешкоджає фільтрації газу з однієї виробки в іншу. Ширина цієї перемички зменшується зі збільшенням потужності вугільного пласта.

За результатами розрахунку тиску газу показано, що метан з вугільних пластів переміщається в атмосферу виробок, де тиск має менші значення. Разом з тим, для розглянутих в задачі умов, при ширині цілика 20 м і потужності пласта 0,4 м по порушеним породам покрівлі пласта відбувається фільтрація газу з виробок ізольованої пожежної дільниці в виробку сусідньої з нею очисної дільниці. В інших розглянутих випадках області зниженого тиску навколо виробок розділені зонами більш високого тиску, що перевищує тиск пожежних газів на ізольованій ділянці. Фільтрація пожежних газів в атмосферу діючих виробок за такими умовами неможлива.

Ключові слова: безпека ведення гірничих робіт, бар'єрний цілик, ізольована пожежна ділянка, деформування породного масиву, фільтрація газу, потужність пласта.

Аннотация. С помощью разработанной авторами математической модели протекания связанных процессов деформирования углепородного массива и фильтрации газа, выполнено исследование фильтрационной проницаемости барьерного целика между изолированным пожарным участком и подготовительным штреком новой лавы. Задача была решена с применением метода конечных элементов, который реализован в авторской программе. При решении варьировались параметры ширины барьерного целика и мощности отрабатываемого угольного пласта. В статье приведены результаты расчета значений геомеханических параметров, коэффициентов проницаемости и давления газа в области фильтрации.

Показано, что с увеличением мощности угольного пласта в барьерном целике растет интенсивность процесса трещинообразования. При малой ширине целика угольный пласт на всем его протяжении находится в нарушенном состоянии, так же, как и породы его кровли и почвы. Области фильтрации вокруг вентиляционного штрека действующей лавы и изолированного конвейерного штрека пожарного участка связаны и по угольному пласту, и по вмещающим породам. Это означает, что при определенном значении перепада давления возможна фильтрация пожарных газов в выработки действующего очистного участка. При большей ширине целика между нарушенными породами вокруг выработок действующего и изолированного пожарного участков находится перемычка из ненарушенных пород – непроницаемый участок, препятствующий фильтрации газа из одной выработки в другую. Ширина этой перемычки уменьшается с увеличением мощности угольного пласта.

По результатам расчета давления газа показано, что метан из угольного пласта перемещается в атмосферу выработок, где давление имеет более низкие значения. Вместе с тем, для рассмотренных в задаче условий, при ширине целика 20 м и мощности пласта 0,4 м по нарушенным породам кровли пласта происходит фильтрация газа из выработок изолированного пожарного участка в выработки соседнего с ним очистного участка. В остальных рассмотренных случаях области пониженного давления вокруг выработок разделены зонами более высокого давления, превышающего давление пожарных газов на изолированном участке. Фильтрация пожарных газов в атмосферу действующих выработок при таких условиях невозможна.

Ключевые слова: безопасность ведения горных работ, барьерный целик, изолированный пожарный участок, деформирование породного массива, фильтрация газа, мощность пласта.

The manuscript was submitted 02.02.2021