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REGULARITIES OF SHOCK WAVE PROPAGATION IN MINE WORKINGS UNDER THE GAS DYNAMIC PHENOMENA

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Abstract. The feasibility of assessing the speed of shock wave propagation in mine workings by recording acoustic events in the massif using multichannel seismoacoustic methods was explored. The results in relative units are presented following the principle of normalization and considering functional dependencies. A physical model of the impact of gas-dynamic phenomena on the network of mine workings is substantiated. The model is based on the laws of gas dynamics and takes into account a release of methane and dust with variable concentrations during the formation of the aerodynamic environment in the mine atmosphere under the effect of outburst in the condition of real topology of the network of mine workings, ventilation equipment, and structures using as an example the workings and accidents occurred at the O.F. Zasiadko mine. The regularities of formation of aerodynamic environment in the mine atmosphere of dead-end workings during a gas-dynamic phenomenon were established. It was determined that outside the region of solid-phase outburst (coal, rock), a gas flow is formed, and its state and properties can be controlled by changing aerodynamic resistance and atmospheric pressure in the workings. Seismoacoustic and gas-dynamic parameters were formulated, along with the conditions for sequential development of the processes at methane-dust-air mixtures outbursts in the mine workings. The propagation of air shock waves was studied. The analysis and methodological approaches to describing the process in the form of correlation dependencies were performed. This allows justifying the use of source energy pressure equation and identifying areas of gas-laden zone to establish the nature of pressure increase in emergency workings. The parameters of air shock wave propagation in dead-end workings under different initial and excess gas pressure depending on the aerodynamic resistance and geometric parameters of the workings were determined with accounting availability of obstacles causing changes in front resistance and relative speed of air shock wave fronts. This made it possible to reveal the peculiarities of the dynamics of air shock waves in the network of mine workings taking into account losses at the junctions of various types of obstacles, the formation of an explosive environment under the coal and gas outbursts in the dead-end workings, which leads to disrupts of normal ventilation regime causing ventilation flow reversals and contamination of fresh air streams with gas.

Keywords: mine workings, control, seismoacoustics, properties, shock wave.

1. Introduction

Low effectiveness of the combined use of ventilation and complex degassing systems in modern high-performance coal mines hinders the timely elimination of a danger of local methane accumulations at the junction of mine workings, as well as in certain sections of the mine ventilation system. Emergency situations arise from sudden methane outbursts, the formation of localized fire centers and their subsequent development [1–5]. An analysis of the causes of these events indicates an insufficient effectiveness of operational mine ventilation control and a critically low level of using methods for monitoring the state of gas-bearing coal-rock massif [6–9]. Solving this problem is of significant scientific and practical importance for ensuring labor safety and prevention of accidents in coal mines.

The aim of this study is to investigate the regularities of gas-dynamic phenomenon (GDP) propagation along the network of mine workings.

To achieve this goal, the following task must be addressed: to substantiate the research methodology and investigate the regularities of the GDP propagation along the network of mine workings; and on the basis of the obtained results, to specify parameters of the outburst process behavior within the network of mine workings, including the parameters, which take into account a potential occurrence of methane-dust-air mixture explosions and fire development, which is an urgent scientific task.

2. Methods

The methodology of the research was comprehensive and consisted of analysis of aerodynamic environment formation in mine workings during an outburst event. Dynamics of methane concentration changes were studied on the basis of data from the automatic methane control (AMC) that monitored methane content in the atmosphere of the workings. Gas factor was studied by analyzing dynamics of the methane background concentrations during the operation of mining combine and coal extraction, and by data from automatic methane control of the state of the mine workings. The volume of methane released during the GDP was proposed to be determined based on measurements of methane concentration and of air flow in the outgoing ventilation streams in the dead-end workings where the GDP had occurred. Methane concentration was determined from the chart string of the AMC equipment, while air flow in the location of the methane sensors installed was measured from the graphs of self-recording devices of remote control. Shift-based and daily printouts were used. Indicators of the methane background concentration were determined by their minimum values under the outburst (in m^3), taking into account the cross-section of the mine workings in the light. Models of the air shock wave formation and propagation along the mine workings were developed based on classical gas flow equations with shock wave formation [10–15]. Experimental studies included modeling of physical processes during the air shock wave occurrence and propagation close to the conditions in mine workings and their interaction with various obstacles and means for explosion protection. For data entry, boundary conditions were set for each working.

When the shock wave moves along the workings, fragments of rock and objects generate acoustic effects, which are assessed by the energy of acoustic emission. The relationship between the speed of the shock wave in the air of the working V_w and the speed in the rock massif V_r is shown in Figure 1.

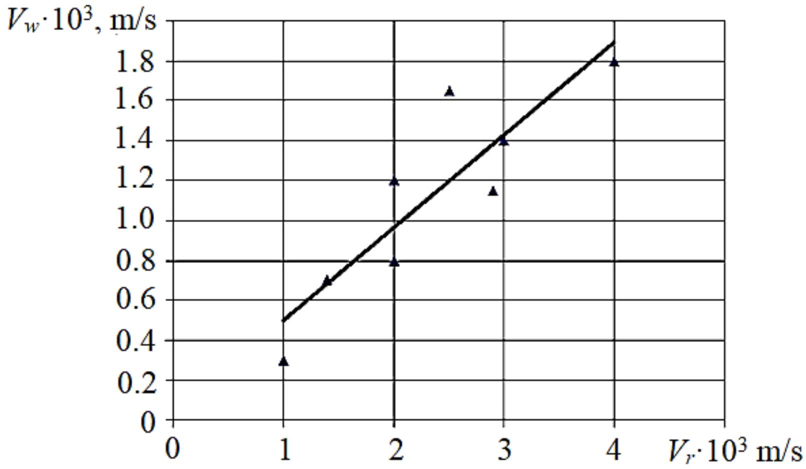


Figure 1 – Relationship between the shock wave during GDP in the workings atmosphere and elastic oscillations in the rock mass

The speed of the GDP shock wave propagation was estimated from the data of multichannel seismoacoustics based on hodographs of traveling waves by measuring the time intervals. As a result of the works in mine, the speeds of elastic waves in disturbed zones, solid rocks, and coal seams were obtained. The hodographs were necessary to determine the limits of time intervals during the movement of shock wave front with rock and coal fragments in the air of the workings under the GDP with taking into account their topology. Wave field was researched by the seismic survey station PASSAT-M. Seismoacoustic (SA) events were registered with the control equipment and device ARES-5/E. For this purpose, geophones were installed in the mine workings with fixating of their coordinates; hence, a polygon was created. Knowing the distance between the points of acoustic signal reception, the speed and the time of elastic waves in the rock mass, spatial locations of the event centers are determined.

Acoustic events were recorded as energy of destruction of the coal-bearing rock mass with the fixation of the spatial position in time. The catalog "Berta" contains more than 17,000 observations. The state in the face area was assessed by the ARAMIS M/E station and the ЗУА-98 instrument using the standard methodology [3, 4, 7]. Acoustic events were recorded with spatial-time reference for each working. Figure 2 shows a copy of the mining operation plan, the polygon layout, and the location of acoustic events during the advance of preparatory workings of the western panels 17 and 18 along the layer m_3 at the O.F. Zasiadko mine [7].

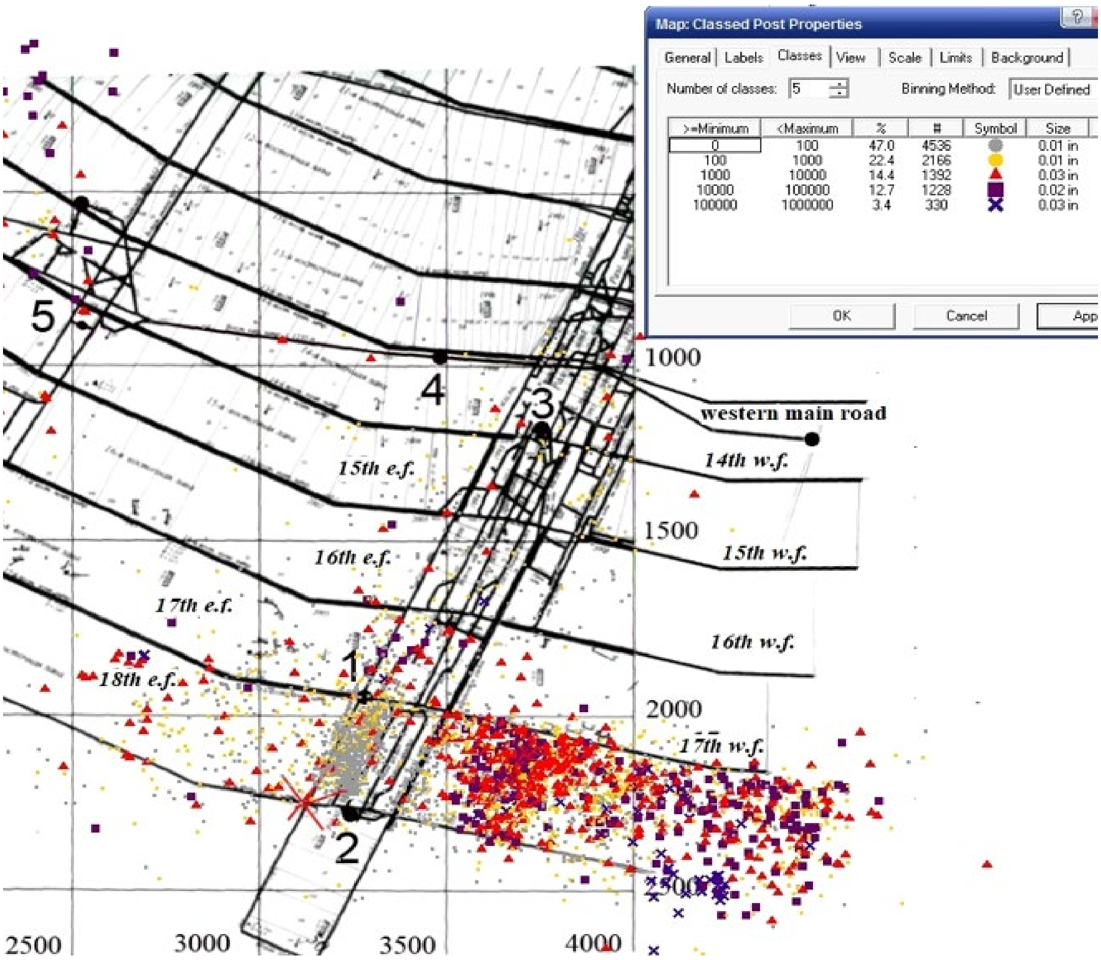


Figure 2 – Distribution of acoustic events during mining operations in the western panels 17 and 18 along the layer m_3 at the O.F. Zasiadko mine

The amplitude-frequency characteristic of the air shock wave was determined by overlaying the geophones and the micro-outbursts recorded by the sound-receiving equipment SRE-98. The methodological approach to assessing the relationship between SA parameters and the mechanical effects of the shock wave propagation to the walls of the mine workings is based on adhering to the normalization principle when identifying signals recorded by different sources. As an objective parameter for the assessment, a function normalized to the SA unit is taken, which is defined from experimentally measured single pulse or pulse series to the functions of their changes

$$F(x)=\frac{u_k(x)}{u_k'(x)C(a,b,c)},$$

where $u_k(x)$ – experimental seismoacoustic curves of events; $u'_k(x)$ – theoretical seismoacoustic curves of events; $C(a, b, c)$ – capacity of the considered array of events; $F(x)$ is a reduced function with norm $F(x)_{C(a,\, b,\, c)}$.

Figure 3 shows a screenshot of an acoustic event during the propagation of a shock wave in the working of the western panel 18 at the O.F. Zasiadko mine.

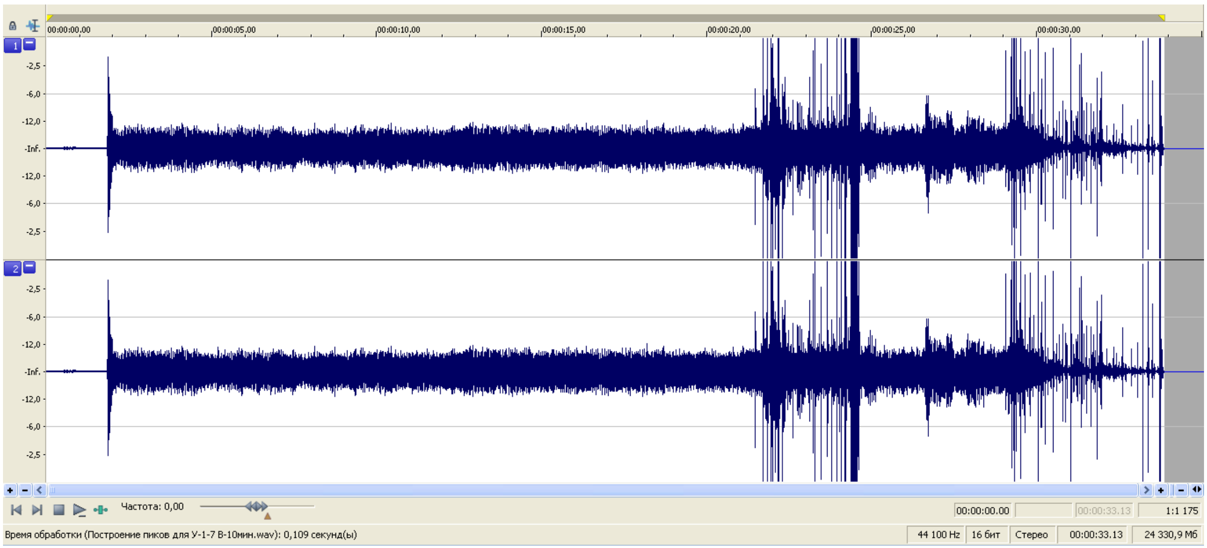


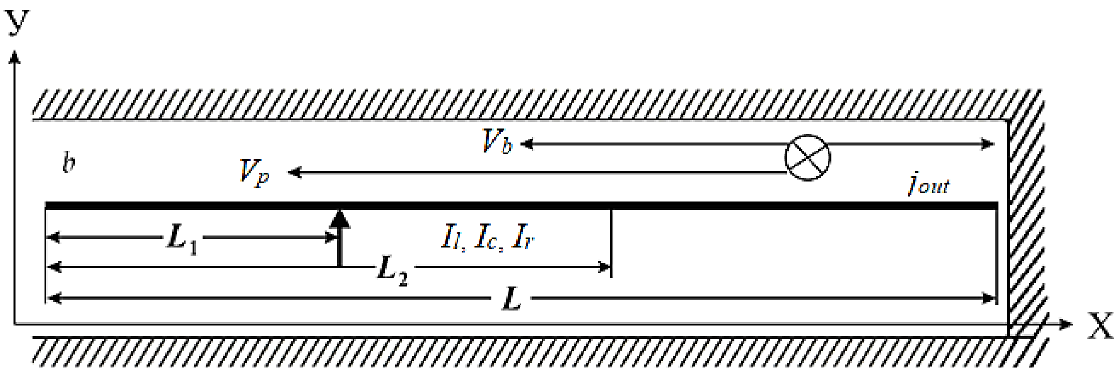
Figure 3 – Screenshot of an acoustic event in the preparatory working of the western panel 18, layer m_3, O.F. Zasiadko mine

According to the processing programs, SA information is scaled, stretched in time, and the amplitude-frequency and amplitude-time spectra of events and their energetic characteristics are determined. Determination of gas releases is carried out experimentally with the help of wells that are drilled from the face. All wells are drilled to the rise with elevation angles from 15° to 60° with different lengths and directions. The wells are equipped with self-recording manometers (MTC 712-КИ MGGA) for measuring gas pressure.

The main material for establishing the regularities of gas and solid phase distribution along the network of mine workings during the gas-dynamic phenomena were acoustic observations, which were supported by the results of gas monitoring during accidents at the O.F. Zasiadko mine and other mines in 2001–2017, as well as by analysis of publications. Based on the analysis of the research results [1, 4], the model of the gas-dynamic phenomenon impact on the network of mine workings was substantiated. The base of the model was the study of the causes and the conclusions of the commissions for the analysis of catastrophic consequences at the O.F. Zasiadko mine.

3. Theoretical part

Figure 4 shows a schematic model of GDP propagation.



I_l, I_r, I_h – gas release from the seam and layered accumulation of methane in the roof and face, m³/s; X, Y – coordinates of the workings along the length and height, m; j_{out} – intensity of gas release sources, m³/(m³·s); b – aerodynamic resistance relative to the considered section of the workings, Pa·s/m³; V_p – shock wave; V_b – reflected shock wave; L – length of the working, m,; $L2$ – length of the working blocked by rock, m; L_1 – slope, m.

Figure 4 – Model of GDP propagation along the network of mine workings

The model is used for operational forecasting of aerodynamic condition in the network of mine workings under the GDP. The model includes comprehensive information about the aerodynamics and the composition of the mine atmosphere, which is essential for timely and effective technological decision-making. Due to the multi-factorial nature of the process, heat exchange is not considered for substainiation of the model and description of the gas mixture flow in the workings.

The model appropriateness is substantiated by the analysis of its properties and parameters, which fully describe the process and peculiarities of gas movement, as well as the interaction of rock fragments with the walls of the workings [10–12]. The ventilation processes are determined by the spatial topology of the workings and by layout and modes of ventilation equipment operation (main ventilation fan, local ventilation fans, ventilation structures of the mine).

For each working, the following parameters are specified: length L, cross-sectional area S, aerodynamic resistance coefficient b. To establish how the workings are interconnected, initial and end numbers of nodes are fixed for each working. In the constructed model of the air shock wave propagation in the network of mine workings, it is assumed that the workings can be interconnected at a certain angle. Therefore, for each working, the angles at which they connect to each other are set.

The parameters and the spread of the shock wave at rock, coal, and gas outburst are interrelated to each other by the following formulas [1, 4]:

$$V_f = a_0 \sqrt{\frac{P_0 + 0.86 P_f}{P_0}}; \tag{1}$$

$$\rho_f = \rho_0 \frac{6P_f + 7P_0}{7P_0 + 7P_f}; \tag{2}$$

$$V_s = \frac{a_0\left(\frac{P_f}{P_0} - 1\right)}{1.4\sqrt{\frac{P_0 + 0.86P_f}{P_0}}}; \tag{3}$$

$$P_f = \frac{P_0}{0.86}\left[\left(\frac{V_f}{a_0}\right)^2 - 1\right], \tag{4}$$

where V_f – speed of the shock wave front, km/s; a_0 – speed of sound in undisturbed environment, km/s; P_0 – pressure in undisturbed environment, MPa; P_f – pressure at the front of the shock wave, MPa; ρ_f, ρ_0 – gas density at the front of the shock wave and in undisturbed environment, kg/m^3; V_s – flow rate behind the shock wave front, km/s.

The aerodynamic resistance of the system, at which the process of rock mass ejection into the workings occurs, consists of the resistance of the mine ventilation network (MVN), the resistance of the transport channel and the resistance to the transportation of the solid phase through the channel. In most cases, the values of aerodynamic resistance in the MVN remain constant.

The resistance of the transport channel increases during the outburst because the channel length increases. An increase of aerodynamic resistance is accompanied by a decrease of kinetic energy of the gas flow, which leads to a loss of the gas ability to transport the solid phase. The solid phase settles in the transport channel of the outburst.

The cross-sectional area of the transport channel decreases. This leads to an increase of kinetic energy due to the narrowing of the channel and restoration of the transport ability of the gas. These processes are repeated until the total aerodynamic resistance of the system reaches its critical value. At the same time, the transport channel is blocked, and the ejection of the solid phase into the working stops.

An increase of the total pressure in the outburst cavity causes an increase of the slope length. At the same time, an increase of adjustable aerodynamic resistance leads to a significant decrease of the slope length.

Table 1 presents the results of the impact of resistance on the formation of aerodynamic environment in the mine workings under the GDP [4, 13–16].

Table 1 – Impact of aerodynamic resistance on the environment Formation under the GDP

Initial barometric pressure P, mm WG	Total pressure in GDP core P_1, Pa	Total pressure at the GDP outlet P_2, Pa	Aerodynamic resistance b, Pa·s/m³	Length of the blocked working L - $L_2 \cdot 10^2$, m	Length of the outburst slope L - $L_1 \cdot 10^2$, m		Angle of slope of solid phase outburst, deg
					min	max	
0.3	160	120	17.2	1.6	5.5	8.0	21.1
	360	280	16.8	3.1	12.6	15.0	11.8
	760	600	11.8	7.9	19.6	25.3	7.3
5.3	400	82	8.9	2.6	5.9	8.5	23.1
	800	94	7.0	7.7	14.8	25.1	12.8
	1000	158	5.7	10.5	14.7	25.2	9.8
15.7	600	23.5	4.7	2.2	0.6	- 0.387	22.1
	800	47.5	4.0	7.3	11.6	18.4	16.1
	1200	192.5	3.4	13.5	16.5	26.5	10.1

The analysis of the obtained dependences indicates that an increase of total inlet pressure causes an increase of the length of the blocked transport channel, while an increase of aerodynamic resistance reduces its length.

With an increase of initial barometric pressure P from 0.2 mm WG to 0.6 mm WG, the time $t_к$ of the process decay decreases from $4.5 \cdot 10^{-3}$ s to $20 \cdot 10^{-3}$ s, with other things being equal.

Previous studies showed that the amount of free gas energy released during the expansion of compressed gas depends on the initial and final value of P_{ni}.

The control impact in the form of a solid obstacle effectively affects the outburst flow and reduces duration and energy of the outburst, and, as a result, the mass of the outburst.

The GDP in the dead-end working leads to filling a part of the working with coal and rock in the interval of 20–40 m and filling with gas with a high concentration of methane under high pressure.

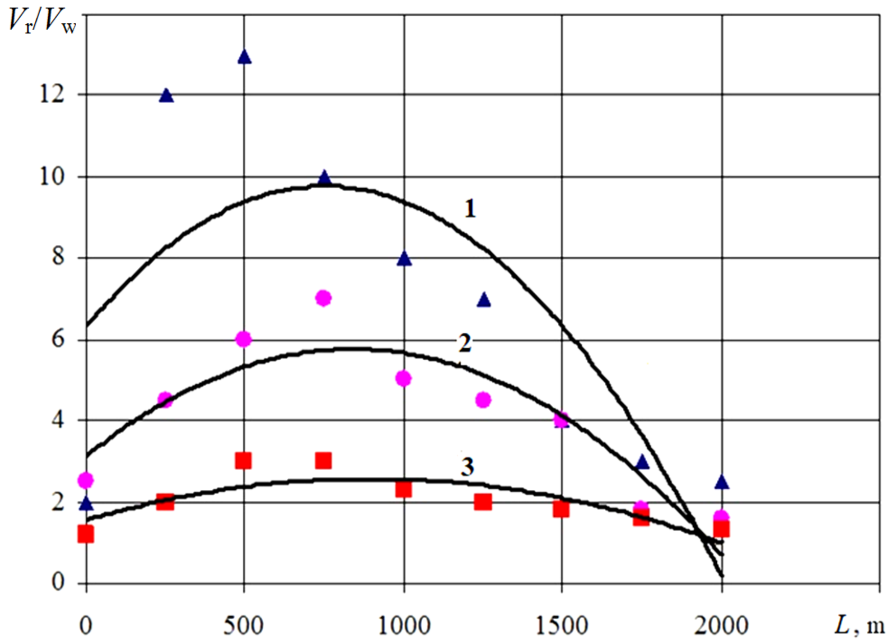
Developing methods to prevent or localize this phenomenon focuses on controlling the gas flow of outburst outside the zone of solid phase outburst. In this way, it is impossible to prevent the GDP occurrence, but it is possible to prevent its development and limit the negative impact on the network of workings, and, thereby, to increase the safety of mining the prone-to-outburst coal seams.

Thus, the main parameters of the GDP are the speed of the shock wave, the pressure of the shock wave front and the concentration of methane in the working atmosphere.

The speed of the shock wave front and its intensity, which arises under the action of the formed pulse during the GDP, are determined in the process of propagation solely by the properties of the environment.

4. Results and discussion

Fig. 5 demonstrates the dependence of the ratio of shock wave speeds V_r in the rock mass and V_w in the atmosphere of working, in conventional units, along the gas-laden zone of the dead-end working on the power of the GDP.



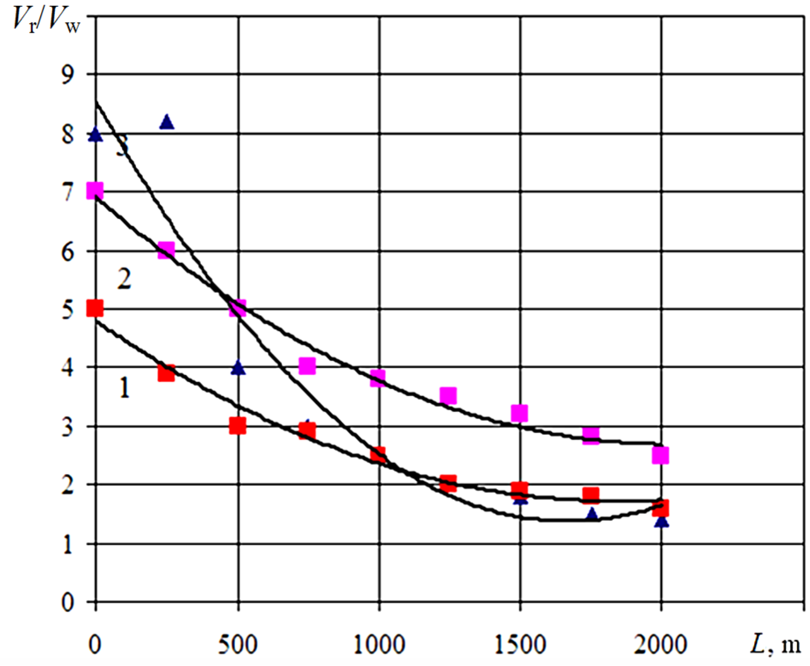
amount of outburst coal: 1 – 32 tones, 2 – 13 tones, 3 – 4 tones

Figure 5 – Dependence of the ratio of shock wave speeds V_r in the rock mass and V_w in the working atmosphere along the gas-laden zone of the dead-end working on the power of the GDP

Coal and gas outbursts create conditions for the shock wave core to move depending on the topology of the mine workings. Having an initial speed of tens of meters per second, the broken rock receives a great kinetic energy ($0.5 \cdot 10^3$ kJ/ton), which ensures its movement along the working with a significant dynamic effect on technological equipment and various types of obstacles. When a coal mass of 55 tons is outburst, the maximum speed is observed at a distance of 256–1300 m from the outburst center. This fact explains the complexity of implementing control impacts on the solid phase in the zone of outburst.

Fig. 6 shows the dependence of ratio of the shock wave speeds V_r in the rock mass and V_w in the working atmosphere on the installed equipment (conveyor 1, fan 2, attached equipment 3) at an outburst power of 10 ton.

Coal and gas outbursts generate air fluctuations in the mine atmosphere. The amplitude-frequency characteristic of the direct and reflected wave propagation along the gas-laden zone in a dead-end working depends on the outburst power, aerodynamic resistance, and geometric parameters of the working [13–15].



1 – conveyor; 2 – fan; 3 – attached equipment

Figure 6 – Dependence of the ratio of the shock wave speeds V_r in the rock mass and V_w in the working atmosphere on the installed equipment along the gas-laden zone in the dead-end working at an outburst power of 10 tones

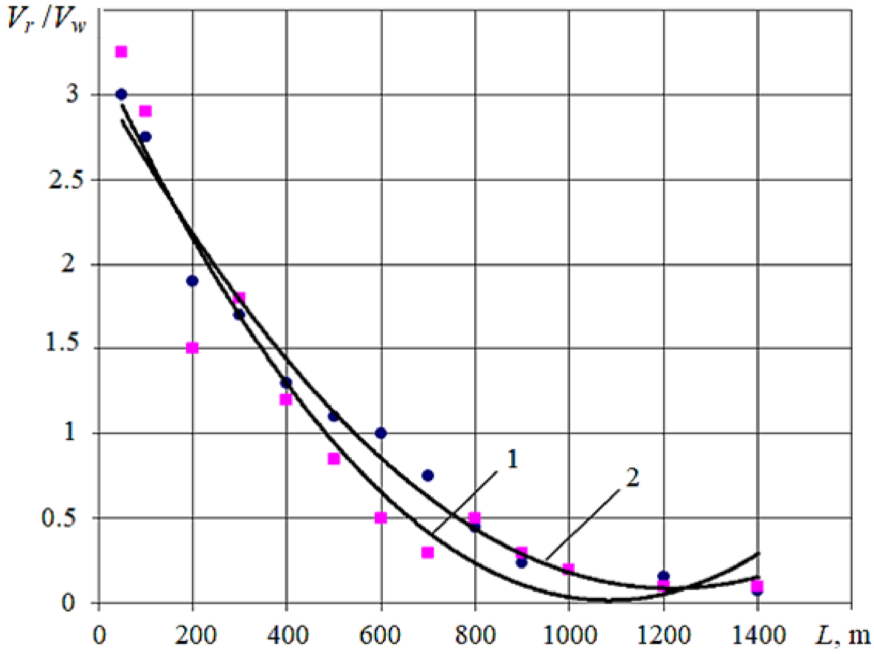
Since a working is an ideal waveguide, wave and gas-dynamic processes and their accompanying combinations are formed under the GDP. The amplitude of the shock wave is formed by the dimensions of the working. Taking into account the topology, slope, support, and attached equipment, it is equal to 0.76 of the diameter of the working. The frequency characteristic lies within 16-75 Hz, when summarizing measurements of SCE-98 (sound-capturing equipment).

According to the Weibull distribution, the frequency range at outbursts is 19-23 Hz. Amplitude-time characteristics of the GDP are determined by a sharp rise of amplitude following with a gradual decrease up to background values with an infra-low frequency. When designing means for reducing the damaging factors of coal and gas outbursts, the speed of the dust-gas-air mixture spreading, which varies from 0.3 km/s to 1.8 km/s, is taken into account.

The GDPs create direct and reflected shock waves along the gas-laden zone of the dead-end working (Fig. 7).

Direct shock wave has higher speed, but over time the wave decays due to the performance of work (ejection of rock fragments, transfer of dust, movement of equipment). The reflected wave, due to a smaller amount of work, is equal to the direct shock wave and even grows due to the superposition of oscillations at a distance of 1200 m.

Table 2 shows the parameters of the interaction between the front of the shock and reflected wave and the walls of the workings at the intersection of expanded area, curvatures and turns of the workings.



1 – reflected wave; 2 – shock wave front

Figure 7 – Dependence of the ratio of shock wave speeds V_r in the rock mass and V_w in the working atmosphere during the propagation of direct and reflected shock wave along the gas-laden zone of the workings

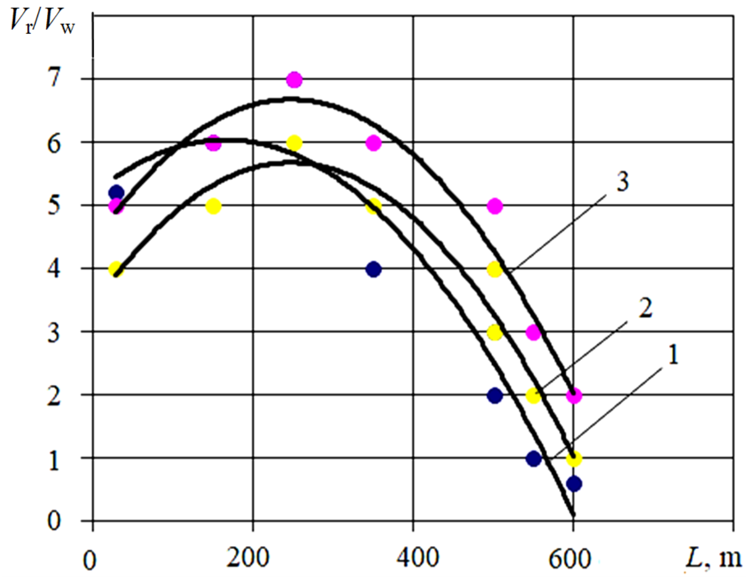
Table 2 – Parameters of propagation of the shock and reflected wave front in the atmosphere at the intersection of expanded area, curvatures and turns of the workings

Type of damage	Head-on resistance k, Pa·s/m^3	Aerodynamic resistance b, Pa·s/m^3	Speed of the shock and reflected wave front, V_r / V_w
Expansion of working	120	54	0.53/0.49
Narrowing of working	105	75	0.71/0.58
Curvature of working	280	15	0.63/0.52
Turns in working	333	230	0.62/0.31

The intensity of shock waves can be reduced through the construction of obstacles that absorb part of the energy of the shock wave pulse formed under the GDP. The reduction depends on the location of methane-air mixture outburst, volume of the mixture and location of the obstacles in the network of mine workings.

Fig. 8 shows the dependence of the ratio of shock wave speeds V_r in the rock mass and V_w in the working atmosphere on the presence of constructed obstacles and aerodynamic resistance.

In the absence of the rock plug and data on the length of the gas-laden zone, pressure is gradually increased by 0.2 MPa at a distance of 150 m from the dead-end working, and dynamics of air shock waves changes sharply. The speed of the waves decreases, the pressure increases when approaching the location of obstacles.



1 – collapses; 2 – overlays; 3 - barriers

Figure 8 – Dependences of ratio of shock wave speeds V_r in the rock mass and V_w in the working atmosphere along the gas-laden zone of the dead-end working on the presence of obstacles

Table 3 shows the results of determining the aerodynamic resistance with various obstacles.

Table 3 – Change of aerodynamic resistance in the working atmosphere depending on the type of obstacles

Type of obstacles	Area of workings, m^2	Area of obstacle, m^2	Aerodynamic resistance b, Pa·s/m^3
Collapses	11.2	5.5	110.5
Overlays	9.0	2.7	98.8
Barriers	10.8	1.5	41.5

Table 4 demonstrates the established dependencies and regularities of the GDP propagation along the network of workings.

The following designations are used in the table: C and C_0 – anomalous and initial concentration of methane in the workings, %; G and P – methane flow rate and pressure; D and D_0 – pressure at the shock wave front, MPa; X - width of the working, m.

The analysis of the regularities of the gas-dynamic phenomenon propagation along the mine network indicates that the existing means of prevention do not meet the requirements of the time. Various means are employed to protect underground structures, communication systems, and equipment against the action of air shock waves, but they do not provide an effective reduction of damaging factors such as: shock wave front, gas contamination of workings, danger of explosion of the methane-air mixture. The use of means to reduce damaging factors in the form of labyrinths and barriers creates great dynamic loads on their elements and, as a result, leads to their destruction. Moreover, the parameters of stoppings are not sufficiently scientifically substantiated. Existing methods of calculating stoppings for damping air shock waves are complex and do not take into account the variety of designs. Therefore, these innovative, including reusable means of protection designed on the basis of performed researches, can be used for developing new technical solutions.

Table 4 – Regularities of the of GDP distribution along the network of workings depending on different factors

Factors	Established regularities	Correlation coefficient	Confidence interval
Gas	$C/C_0 = 24.273L^{-0.6616}$	0.8803	250÷1800
	$G = 0.2049P - 1.5165$	0.8102	40 ÷ 60
Parameters of pressure of shock wave front	$D/D_0 = 2 \cdot 10^{-6}L^2 - 0.0062L + 8.1215$	0.6133	500÷2000
Relative shock wave speed at presence of obstacles such as: …...collapses	$V_r/V_w = -0.3744X^2 + 18.563X + 436.7$	0.9514	6.0 ÷ 0.5
……overlays	$V_r/V_w = -0.3744X^2 + 18.563X + 336.7$	0.9514	5.0 ÷ 1.0
……barriers	$V_r/V_w = -0.321X^2+10.801X+ 513.48$	0.9181	6.5 ÷ 2.0
Wave front propagation: ……of shock wave	$V_r/V_w = 2 \cdot 10^{-6}X^2 - 0.0049X + 3.084$	0.9826	3.0 ÷ 1.2
........of reflected wave	$V_r/V_w = 3 \cdot 10^{-6}X^2 - 0.0059X + 3.2255$	0.9387	3.1 ÷ 1.2

5. Conclusions

On the basis of the performed researches, results processing, generalization and analysis of the data of observations on the topology of mine working and changes of shock wave speed, as well as control of gas-dynamic phenomena in the coal-bearing massif, the following conclusions were made:

1. The feasibility of assessing the speed of shock wave propagation in mine workings by recording acoustic events in the rock mass using multi-channel seismoacoustic methods and representing results in relative units adhering to normalization principles in the presences of functional dependencies was studied.

2. The physical model of the gas dynamic phenomenon impact on the network of mine workings was substantiated. The model is based on the laws of gas dynamics and takes into account the release of methane and dust with variable concentration during the formation of an aerodynamic environment in the mine atmosphere in the process of outburst, as well as in the conditions of real topology of the network of mine workings, ventilation equipment and structures on the example of workings and accidents occurred at the O.F. Zasiadko mine.

3. The regularities of the aerodynamic environment formation in the mine atmosphere of the dead-end workings in the course of gas-dynamic phenomenon were considered and it was established that a gas flow is formed outside the solid phase (coal, rock) outburst, the state and properties of which can be controlled by changing the aerodynamic resistance and atmospheric pressure in the workings.

4. The seismoacoustic and gas-dynamic parameters and conditions for the sequential development of processes during the outbursts of methane-dust-air mixtures in the mine workings were formulated.

5. The formation of air shock waves was studied. The analytical and methodical approaches to the description of the process in terms of correlation dependencies were developed. This allows substantiating the use of source energy pressure equation and identifying areas of gas-laden zone to determine the nature of pressure increase in emergency workings.

6. The parameters of propagation of air shock waves in dead-end workings (speed and pressure) with varying initial and excess gas pressure differences were established. They depend on aerodynamic resistance and geometric parameters of the workings, as well as the presence of obstacles causing differences in frontal resistance and relative speed of the air wave front. These findings made it possible to reveal the peculiarities of the dynamics of air shock waves in the network of mine workings taking into account losses at the junctions of various types of obstacles, the formation of an explosive environment during the coal and gas outbursts in the dead-end workings, which leads to disrupts of normal ventilation regime causing ventilation flow reversals and contamination of fresh air streams with gas.

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ЗАКОНОМІРНОСТІ ПОШИРЕННЯ УДАРНОЇ ХВИЛІ В ГІРНИЧИХ ВИРОБКАХ ПРИ ГАЗОДИНАМІЧНОМУ ЯВИЩІ

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Анотація. Досліджено можливість оцінювати швидкість посування ударної хвилі в гірничих виробках шляхом фіксування акустичних подій в масиві методами багатоканальної сейсмоакустики і відображення результатів з дотриманням принципу нормування у відносних одиницях при наявності функціональних зв’язків. Обґрунтовано фізичну модель впливу газодинамічного явища на мережу гірничих виробок, яка базується на законах газової динаміки і враховує виділення перемінної концентрації метану, пилу при формуванні аеродинамічного середовища у шахтній атмосфері під час протікання викиду, а також в умовах реальної топології мережі гірничих виробок, вентиляційного обладнання і споруд на прикладі виробок і аварій, які відбулись на шахті ім. О.Ф. Засядька. Встановлено закономірності формування аеродинамічного середовища в шахтній атмосфері тупикових виробок під час протікання газодинамічного явища і встановлено, що за межами відкиду твердої фази (вугілля, порода) утворюється газовий потік станом і властивостями якого можливо керувати шляхом зміни аеродинамічного опору і атмосферного тиску в виробках. Сформульовано сейсмоакустичні та газодинамічні параметри і умови послідовного розвитку процесів при викидах метанопилоповітряних сумішей в гірські виробки. Досліджено поширення повітряних ударних хвиль. Виконано аналіз і методичні підходи до опису процесу у вигляді кореляційних залежностей. Це дозволило обґрунтувати використання в рівнянні тиску енергії джерела і виділенні ділянок загазованої зони для встановлення характеру підвищення тиску в аварійній виробці. Встановлено параметри поширення повітряних ударних хвиль в тупикових виробках при різному початковому та надмірному перепадах газового тиску, від аеродинамічного опору і геометричних параметрів виробок, а також наявності перешкод, що викликають перепади лобового опору і відносної швидкості фронту повітряних хвиль. Це дозволило виявити особливості динаміки повітряних ударних хвиль в мережі гірничих виробок з урахуванням втрат в місцях сполучень різного виду перешкод, формування вибухонебезпечного середовища при викидах вугілля і газу в тупикових виробках, що призводить до порушень нормального режиму провітрювання, внаслідок чого відбувається перекидання вентиляційного потоку і загазованість свіжого струменя повітря.

Ключові слова: гірнича виробка, контроль, сейсмоакустика, властивості, ударна хвиля.