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EVALUATION OF GAS EVOLUTION OUTSIDE THE EXTRACTION SECTION AT THE ACTIVATION OF COAL-BEARING STRATUM DISPLACEMENT

Об'єктом дослідження є процеси газовиділення з підроблюваних джерел в межах експлуатованої виїмкової дільниці та за її межами під впливом активізації зсовування порід. До теперішнього часу не встановлені кількісні залежності газовиділення з підроблюваної (очисними виробками) вуглепородної товщі при активізації її зсовування. Труднощі вивчення газовиділення в даному випадку полягають в потребі проведення необхідних замірів витрати метану у виробках і дегазаційних свердловинах ділянки та крила шахтного поля протягом усього періоду відпрацювання виїмкового стовпа. Чистота експерименту забезпечена експлуатацією тільки однієї лави в крилі шахтного поля. Схема провітрювання виїмкової дільниці та розташування пунктів вимірів в гірничих виробках дозволили встановити зони виділення метану у вироблений простір експлуатованої та зупинених лав. У роботі представлений аналіз змінення, маловивченого в даний час, газовиділення за межами експлуатованої виїмкової дільниці у вироблений простір зупинених лав. Визначено основні фактори, що впливають на змінення рівня газовиділення, як в межах виїмкової дільниці, так і за його межами.

Методикою проведення експериментів передбачалося, що рівень газовиділення з підроблюваної вуглепородної товщі визначається видобутком вугілля та ступенем розвитку очисних робіт на виїмковій ділянці. На підставі експериментальних даних встановлено залежності газовиділення від видобутку вугілля та ступеня розвитку очисних робіт в межах виїмкової дільниці. Поза виїмковою ділянкою газовиділення з виробленого простору зупинених лав відбувається при достатньому розвитку очисних робіт в крилі шахтного поля та визначається інтенсивністю видобутку вугілля на експлуатованій ділянці. При повній підробці земної поверхні та вуглепородної товщі газовиділення з виробленого простору зупинених лав в початковий період експлуатації чергової лави може в кілька разів перевищувати метановиділення в межах діючої виїмкової дільниці.

Проведені дослідження показали, що механізм процесу газовиділення в межах виїмкової ділянки та за його межами протікає під впливом різних впливаючих чинників.

Ключові слова: *виїмкова ділянка, шахтне поле, видобуток вугілля, вуглепородна товща, вироблений простір.*

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1. Introduction

The relationship of gas evolution from the undermined coal-bearing stratum with the activation of rock movement was established relatively recently [1, 2]. For this reason, the quantitative dependencies of this type of gas evolution on influencing factors have not yet been established. The relevance of the issue under consideration is evidenced by the absence of any recommendations in normative documents [3–5] on the safe development of gas-bearing coal seams in the case of manifestation of methane emission during activation of the shift of the undermined coal-bearing stratum. Thus, *the object of research* is the processes of gas evolution from undermined sources within the boundaries of the exploited extraction section and beyond its boundaries under the influence of activation of rock displacement. *The aim of research* is to establish the main influencing factors determining the gas evolution within the exploited extraction section and beyond its boundaries under the influence of the activation of the shift of the undermined coal-bearing stratum.

2. Methods of research

The difficulties in studying gas evolution in this case are the need for lengthy measurements of methane consumption in mine workings and degassing systems of the mine field section and wing over the entire period of mining of the extraction column. For the purity of the experiment, only one lava should be operated in the wing of the mine field. The ventilation scheme of the extraction section and the location of the measurement points in the mine workings made it possible to establish methane emission zones in the worked out space of the exploited and stopped lavas [6, 7].

Such conditions of the experiments corresponded to the 9th western lava during mining of an anthracite layer ℓ_2^v with a thickness of 0.9 m of Izvestia newspaper mine of the Donbassanthracite State Enterprise (SE) (Khrustalny, Luhansk Region, Ukraine). Prior to the start of its operation, treatment work in the wing of the mine field was not carried out for two months. The necessary observations were carried out from the start of operation of the extraction section to the termination of the cleaning operations for coal mining for 394 days.

When planning the experimental methods, let's proceed from the generally accepted position that the level of gas evolution from the undermined coal-bearing stratumwill be determined by coal mining and the degree of development of treatment works in the extraction section. To establish these dependencies in certain periods of operation, lava was recorded (Table 1):

– duration of these periods;

– total $\sum A$ and average $\bar{A}$ daily coal production;

– average gas evolution within the extraction section $\bar{I}_a$ and from the worked out space of stopped lavas $\bar{I}_{ws}$;

– total amount of gas evolution within the extraction section $\sum I_a$ and from the worked out space of stopped lavas $\sum I_{ws}$;

– removal of the L coal face from the split furnace.

The different duration of the observation periods in the initial period of the lava operation (May-July) was caused by a change in the number of workings along which the outgoing ventilation air jets were diverted beyond the extraction section. In the future, experimental data recorded over time periods equal to a month were used.

3. Research results and discussion

As the extraction section was operated (removal of the coal face from the split furnace), production changed significantly (Fig. 1). The rate of increase in the total amount of gas evolution in the mine field wing $\sum I_c$ was significantly higher than the increase in coal production ($\sum A$) before the main roof precipitated when the working face was removed from the cutting furnace to 87 m.

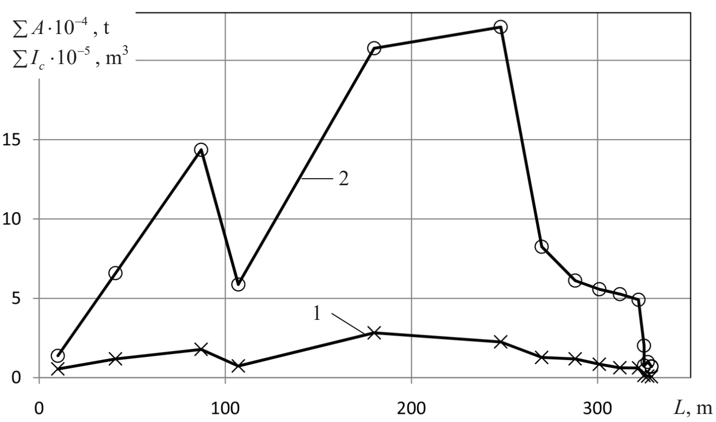

Fig. 1. Change in coal production $\sum A$ and total gas evolution in the wing of the mine field $\sum I_c$ during certain periods of operation of the 9th west lava when the coal face is removed from the cutting furnace L

Table 1

Information on the performance indicators of the 9th western lava during mining of an anthracite layer ℓ_2^v of 0.9 m of Izvestia newspaper mine

Observation date	The observation period, days.	Removal of the coal face from the cutting furnace, L, m	Coal mining, t		Average gas evolution, m^3/min		Amount of gas evolution, thousand m^3		The ratio $\sum A$, $\sum I_a$, $\sum I_{ws}$ to their values for the entire period of lava operation			The ratio $\bar{A}$, $\bar{I}_a$, $\bar{I}_{ws}$ to indicators for the entire period of the lava operation		
			Total, $\sum A$	Daily average, $\bar{A}$	At the section, $\bar{I}_a$	From the worked out space of stopped lavas, $\bar{I}_{ws}$	At the section, $\sum I_a$	Outside the section, $\sum I_{ws}$	$\frac{\sum A}{141687}$	$\frac{\sum I_a}{4430.9}$	$\frac{\sum I_{ws}}{6312.5}$	$\frac{\bar{A}}{360}$	$\frac{\bar{I}_a}{7.8}$	$\frac{\bar{I}_{ws}}{11.1}$
03.V–14.V.1985	12	10	5484	457	1.9	6.1	32.8	105.4	0.039	0.007	0.017	1.27	0.24	0.54
15.V–31.V.1985	17	41	11815	695	5.0	21.9	122.4	536.1	0.083	0.028	0.085	1.93	0.64	1.97
01.VI–19.VI.1985	19	87	17841	939	12.6	40.9	344.7	1119.0	0.125	0.078	0.177	2.61	1.62	3.68
20.VI–27.VI.1985	8	107	7384	923	18.2	32.8	209.7	377.9	0.052	0.047	0.060	2.56	2.33	2.95
28.VI–31.VII.1985	34	180	28254	831	13.6	28.8	665.9	1410.0	0.199	0.150	0.223	2.31	1.74	2.59
VIII.1985	31	248	22537	727	15.3	34.2	683.0	1526.7	0.159	0.150	0.242	2.02	1.96	3.08
IX.1985	30	270	12750	425	10.7	8.4	462.2	362.9	0.090	0.104	0.057	1.18	1.37	0.76
X.1985	31	288	11842	382	8.5	5.2	379.4	232.1	0.084	0.086	0.037	1.06	1.01	0.47
XI.1985	30	301	8460	282	7.8	5.1	337.0	220.3	0.060	0.076	0.035	0.78	1.00	0.46
XII.1985	31	312	6231	201	6.5	5.3	290.2	236.6	0.044	0.065	0.037	0.56	0.83	0.48
I.1986	31	322	6138	198	8.2	2.8	366.0	125.0	0.043	0.083	0.020	0.55	1.05	0.25
II.1986	28	325	1372	49	5.5	1.5	221.8	60.5	0.010	0.050	0.001	0.14	0.71	0.14
III.1986	31	325	0.0	0.0	1.7	0.0	75.9	0.0	0.0	0.017	0.000	0.00	0.22	0.00
IV.1986	30	327	990	33	2.3	0.0	99.4	0.0	0.007	0.022	0.000	0.09	0.29	0.00
V.1986	31	329	589	19	1.6	0.0	71.4	0.0	0.004	0.016	0.000	0.05	0.21	0.00
VI.1986	30	329	0,0	0,0	1.6	0.0	69.1	0.0	0.00	0.016	0.000	0.00	0.21	0.00
Σ	394	–	141687	–	–	–	4430.9	6312.5	1.000	1.000	1.000	–	1.00	1.00

In Fig. 1:

1, 2 – curves, respectively, changes in coal production and gas production;

× – coal mining during certain periods of exploitation of extraction section;

○ – total gas evolution (to mine workings and degassing wells) in the wing of the mine field in the considered time periods.

Based on the experience of cleaning operations, under the considered conditions, the sludge of the main roof occurs when the working face is removed from the split furnace to a distance of 80–120 m [8–10]. The outrunning growth rate of gas evolution in the mine field wing compared to an increase in coal production indicates the presence of a gas evolution source from the undermined coal-bearing strata outside the extraction section. This source is not directly related to the development of treatment works in the extraction section (with the removal of the working face from the split furnace). To confirm this assumption, let's examine the dependences of gas evolution within the extraction section $\sum I_a$ and beyond its boundaries $\sum I_{ws}$ on the amount of coal mined ΣA (Table 1, Fig. 2). In the initial period of lava exploitation (when the bottomhole moves away from the split furnace to 87 m), the gas evolution to the local workings and degassing wells (straight line 1) was significantly lower compared to the amount of gas evolution after the main roof was precipitated (curve 2). The averaging curve 2 is located above the three experimental points obtained before the main roof precipitation. This situation indicates the influence on gas evolution from the undermined coal-bearing stratum within the extraction section until the main roof is precipitated by only one factor – coal mining.

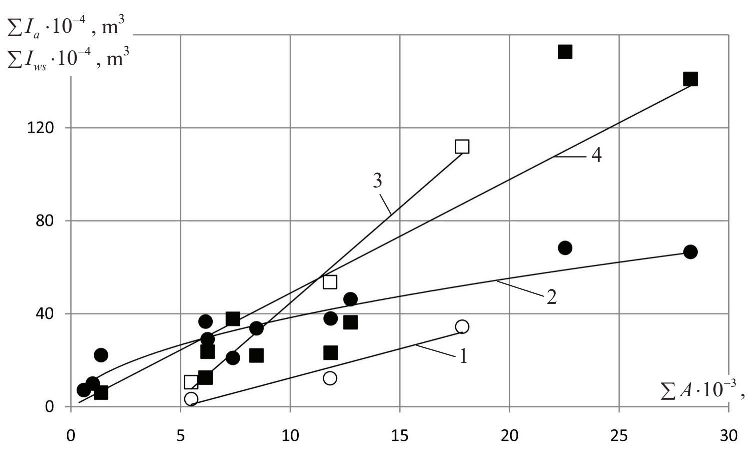

Fig. 2. The dependence of the amount of gas evolution in certain periods within the extraction section $\sum I_a$ and from the worked out space of the stopped lavas $\sum I_{ws}$ from coal mining ΣA before and after the main roof precipitation

In Fig. 2:

1, 2 – direct proportional and nonlinear dependences of gas evolution within the extraction section, respectively, before and after the main roof precipitation;

3, 4 – direct changes in the dependence of gas evolution from the worked out space of stopped lavas, respectively, before and after precipitation of the main roof;

○, ● – experimental data on gas evolution within the extraction section, respectively, before and after the main roof precipitation;

□, ■ – experimental data on gas evolution from the worked out space of stopped lavas, respectively, before and after precipitation of the main roof.

During this period (before the main roof was precipitated), an increase in coal production had a significantly greater effect on the growth of gas evolution from the worked out space of stopped lavas. This is clearly seen from the mutual arrangement of lines 1 and 3 (Fig. 2).

The removal of the working face from the split furnace had practically no effect on the deviation of the experimental data from the averaging curve (2) of the dependence $\sum I_a = f(\sum A)$ obtained during the operation of the extraction section after the main roof was upset (Fig. 2). The gas evolution from the worked out space of the stopped lavas was determined mainly by the level of coal production and did not depend on the position of the working face relative to the split furnace. This is confirmed by the close correlation dependence (correlation coefficient $r=0.91$) obtained by processing the experimental data for the entire period of operation of the extraction section (line 4).

In addition, it should also be noted that prior to the settlement of the main roof, the gas evolution from the worked out space of the stopped lavas exceeded the gas evolution within the extraction section by 3.2–4.4 times (Table 1). They depended only on the level of coal mining (Fig. 2, lines 1, 3). This ratio of gas evolution is due to a large degree of underworking of the carbonaceous stratum and the earth's surface by stopped extraction sections. The ratio of the size of the worked out space (B) of stopped lavas to the depth of mining (N) was more than five, which indicates the complete underworking of the coal-bearing stratum and the earth's surface.

The obtained experimental data on the results of processing the observation results for a separate mining section made it possible to establish the total amount of coal mined $\Sigma A=141687$ t. To it corresponded the amount of gas $\sum I_a=4430.9$ thousand m^3 emitted within the extraction section. From the worked out space of stopped lavas for the entire period of exploitation of the excavated section $\sum I_{ws}=6312.5$ thousand m^3 stood out. According to these data, during the operation of the lava (394 days), an average of 360 tons of coal was mined per day, which corresponded to an average gas evolution (7.8 m^3/min) within the extraction section and 11.1 m^3/min from the worked out space of stopped lavas. These experimental data made it possible to establish a change in the ratio of gas evolution within the extraction section $\sum I_a$ and $\bar{I}_a$, and beyond its boundaries $\sum I_{ws}$ and $\bar{I}_{ws}$ in certain periods, differing in coal production.

The change in coal production during certain periods of lava exploitation ΣA and $\bar{A}$ was evaluated by their relation to coal mining $\sum A_{st}$ and $\bar{A}_{st}$ during the mining of the entire extraction column (Table 1). In a similar way, a change in gas evolution $\sum I_a$, $\sum I_{ws}$ and $\bar{I}_{ws}$, $\bar{I}_a$ was established, and, in certain periods of lava exploitation, in relation to these parameters to indicators during the mining of the extraction column:

$$\frac{\sum I_a}{\sum I_a^{st}},\ \frac{\bar{I}_a}{\bar{I}_a^{st}}\ \text{and}\ \frac{\sum I_{ws}}{\sum I_{ws}^{st}},\ \frac{\bar{I}_{ws}}{\bar{I}_{ws}^{st}}.$$

The relative change in coal production and gas production during certain periods of operation of the section was determined using the parameters characterizing the mining of the extraction column as a whole:

$$\sum A_{st} = 141687 \text{ t},$$

$$\sum I_a^{st} = 4430.9 \text{ thousand m}^3,$$

$$\sum I_{ws}^{st} = 6312.5 \text{ thousand m}^3,$$

$$\bar{A}_{st} = 360 \text{ t/day},$$

$$\bar{I}_a^{st} = 7.8 \text{ m}^3\text{/min},$$

$$\bar{I}_{ws}^{st} = 11.1 \text{ m}^3\text{/min}.$$

The relative change in gas evolution within the extraction section and from the worked out space of stopped lavas was described by different dependences (Fig. 3). The relative gas evolution within the extraction section before the main roof was precipitated was significantly lower compared to subsequent relative gas evolution values.

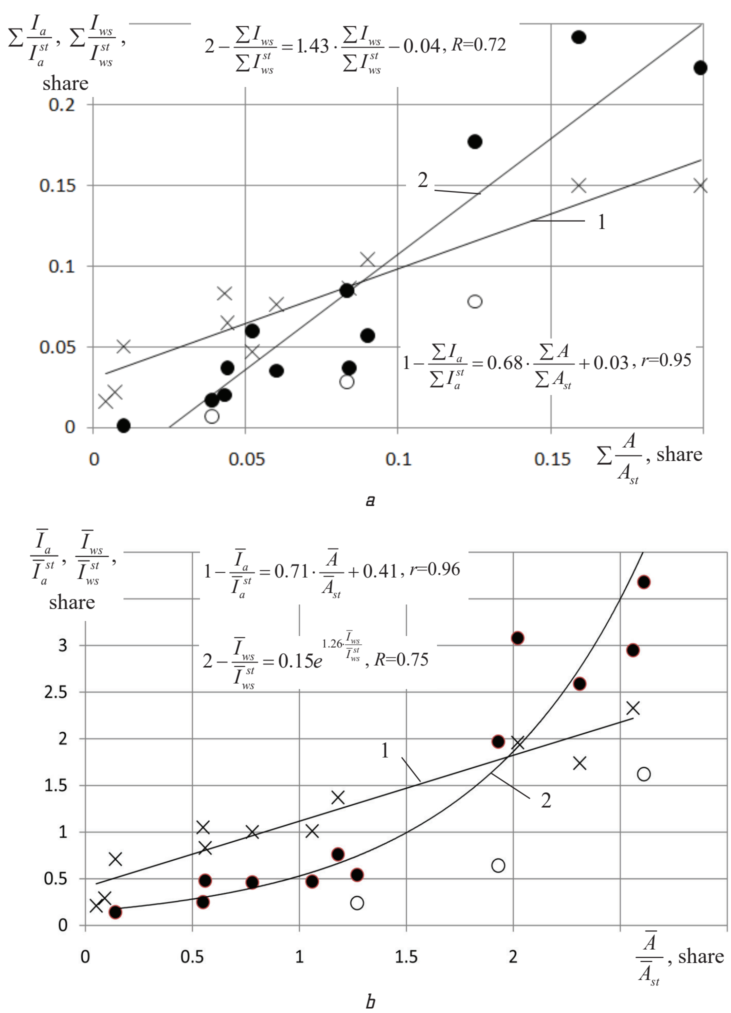

Fig. 3. Change in the relative gas evolution within the extraction section $\sum I_a / \sum I_a^{st}$ and $\bar{I}_a / \bar{I}_a^{st}$ beyond $\sum I_{ws} / \sum I_{ws}^{st}$ and $\bar{I}_{ws} / \bar{I}_{ws}^{st}$ from changes in coal production during certain periods of operation of the mining section of the 9th west lava $\sum A / \sum A_{st}$ and $\bar{A}/\bar{A}_{st}$: *a* – dependences $\sum I_a / \sum I_a^{st}$ and $\sum I_{ws} / \sum I_{ws}^{st}$ on the ratio of the total amount of coal mined $\sum A / \sum A_{st}$; *b* – dependences $\bar{I}_a / \bar{I}_a^{st}$ and $\bar{I}_{ws} / \bar{I}_{ws}^{st}$ on the ratio of average daily coal production $\bar{A}/\bar{A}_{st}$

For this reason, the experimental values of the relative gas evolution before the removal of the bottom face from the cutting furnace at a distance of 87 m do not coincide with the averaging curve (1) obtained for other periods of operation of the extraction section.

In Fig. 3:

1, 2 – averaging lines, respectively, changes in relative gas evolution both within the extraction section $\sum I_a / \sum I_a^{st}$ and $\bar{I}_a / \bar{I}_a^{st}$ from the worked out space of the worked lavas $\sum I_{ws} / \sum I_{ws}^{st}$ and $\bar{I}_{ws} / \bar{I}_{ws}^{st}$;

○, × – experimental gas evolution data within the extraction section, respectively, before and after the main roof precipitation;

● – experimental data on gas evolution outside the extraction section from the worked out space of stopped lavas;

r, R – respectively, the correlation coefficient and correlation ratio.

This is an additional confirmation of the influence in the initial period of lava exploitation of two main factors that determine gas evolution within the extraction section – coal mining and the degree of development of treatment works before the main roof settles.

After settlement of the main roof, ceteris paribus, the main influence is the level of coal production.

The relative gas evolution outside the extraction section from the worked out space of the stopped lavas was practically independent of the precipitation of the main roof within the exploited area.

This is confirmed by statistical processing of experimental data (Fig. 3, *b*, curve 2).

In this case, all experimental points are uniformly located relative to the averaging curve. This indicates that the gas evolution from the worked out space of the stopped lavas is associated with the intensity of mining of the exploited extraction site at all stages of the development of treatment works.

Studies have shown that the mechanism of the process of gas evolution within the extraction section and beyond its borders proceeds differently under the influence of influencing factors. Confirmation of the distinctive course of gas evolution is a significant scatter of experimental data between the pairs and, and (Fig. 4).

Fig. 4 shows:

1 – averaging direct changes $\sum I_a / 4430.9$ and $\sum I_{ws} / 6312.5$;

2 – averaging direct changes in relations $\bar{I}_a / 7.8$ and $\bar{I}_{ws} / 11.1$;

×, ■ – experimental data for determining, respectively, averaging lines 1 and 2;

r – correlation coefficients;

σ – standard deviation.

The standard deviations of these data pairs from the averaging lines (1, 2) are respectively 0.048 and 0.81.

The results of the studies allow to improve the requirements of regulatory documents [6, 7, 11] regarding the creation of safe mining conditions for the gas factor.

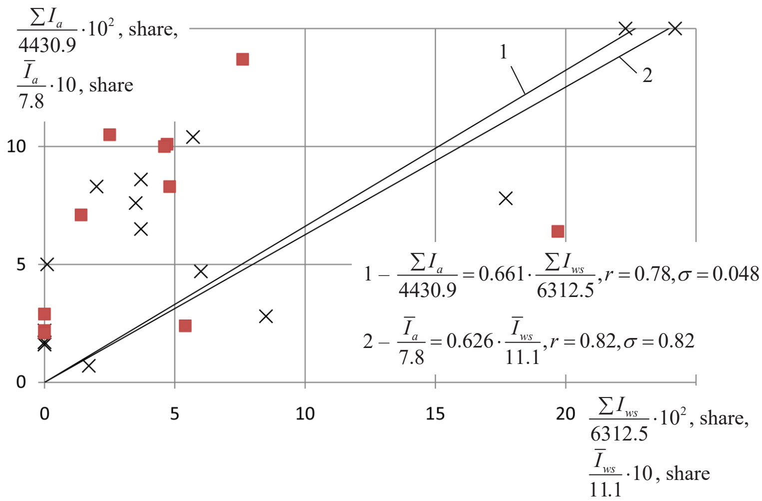

Fig. 4. A graph of the mutual dependence between the relative indicators of changes in gas evolution within the extraction section and beyond its boundaries from the worked out space of stopped lavas

4. Conclusions

1. Gas evolution within the extraction section depends on the level of coal production and the degree of development of treatment works within its boundaries. Out of the extraction area, gas evolution from the worked out space of stopped lavas with sufficient development of treatment operations in the mine field wing is determined by the intensity of coal mining in the exploited area.

2. When the Earth's surface and the coal-bearing stratum are completely undermined, the gas evolution from the worked out space of the stopped lavas during the initial period of operation of the next lava can be several times higher than the methane emission within the existing extraction section.

3. Change in gas evolution within and outside the extraction section during certain periods of lava exploitation takes place according to different dependences, which indicates the presence of distinctive features of the processes of methane evolution within the boundaries of the exploited mining section and the mine field wing.

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