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Petr URBAN, Vlastimil HUDEČEK
VŠB - Technical University of Ostrava, Czech Republic

THE EXPERIENCE OF MANAGEMENT OF RESEARCH INTO AND PREVENTION AGAINST OUTBURSTS OF COAL AND GAS IN DONBAS AND THE CZECH REPUBLIC

Summary. In underground mining, outbursts of coal and gases represent still a considerable hazard. For this reason, mainly European localities thus endangered have been closed preferentially. However, the seriousness of the problem has not been reduced in active mines in this way, which is documented by a series of recent outbursts in China, Poland, Australia and especially in Ukraine (Donbas). Therefore, experience just from Ukraine and a comparison with results from the Czech Republic are presented in the submitted article.

DOŚWIADCZENIA W PROWADZENIU BADAŃ ZAPOBIEGAJĄCYCH WYRZUTOM WĘGLA I GAZU W DONBASIE I W REPUBLICE CZESKIEJ

Streszczenie. Wyrzuty węgla i gazów w górnictwie podziemnym ciągle stwarzają poważne zagrożenie. Z tego też względu zaniechana została eksploatacja w większości złóż europejskich, w których zagrożenie to występowało. W czynnych kopalniach w dalszym ciągu zagrożenie stanowi poważny problem. Uwypukliło się to w trakcie niedawnych wyrzutów w Chinach, w Polsce, w Australii, szczególnie na Ukrainie (Donbas). Dlatego w artykule za celowe uznano pokazanie i porównanie doświadczeń z Ukrainy i z Republiki Czeskiej.

Introduction

Similarly to other countries, Ukraine provides information on a coal and gas outburst hazard with difficulty. What is especially complicated is the finding of integrated statistical compilations of the numbers of outbursts and outburst intensity. A certain overview was published in [1] from Donbas. In this contribution different opinions on the issue of the influence of depth of mining on the outburst hazard are presented. One opinion based on practical experience confirms that with the increasing depth of mining, proneness to outbursts increases. Another opinion rested on the laws of rock mechanics supposes that a tendency towards outbursts diminishes with the depth of mining.

Brief Statistics of Outbursts in Donbas

To explain the actual state, the statistics for outbursts occurrence depending upon the depth of mining are presented in [1]. The value of this overview is beyond question; the overview includes **5866 cases of outbursts** happened in Donbas **in the period from 1951 to 2001,** see Table 1.

Table 1

Cases of outbursts in Donbas depending upon the depth of occurrence

Parameter	Depth interval (m)			
	0–300	301–600	601–900	901–1200
Number of outbursts	159	1558	2140	2009
Total amount of ejected coal (thousand t)	722	15 585	30 523	33 207
Average intensity of one outburst (t)	45.4	100.03	142.6	165.3

Data presented in Table 1 document that with the depth of mining the number of outbursts grows. A decline in the range of depth from 901 to 1 200 m is connected with a smaller number of seams mined in this depth range. In spite of this the average intensity of one outburst is higher than that in the depth range of 601–900 m. This also evidences the degree of hazard.

However, cases also occur when in particular working fields the outburst hazard diminishes with depth. As an example, mines of the company Šachtěrskantracit (e.g. Šachtěrskaja Glubokaja, and others) can be given, where the outburst hazard and the gas capacity of seams decrease depending upon the depth of occurrence. What is of importance is the finding that these working fields are situated within the boundaries of a broad syncline.

Rules Associated with Geological Development

From the point of view of outburst hazard, the location of the working field on the limbs of the syncline is of considerable importance. On the limbs of the syncline indications of tectonic compression are there in contrast to expansion in the central part. At such a tectonic situation, the coal-bearing formation is subject to compression in the plane of occurrence, which worsens degassing, and thus causes an increase in the outburst hazard.

On the contrary, in the central part of the syncline, the expansion of the formation takes place, and thus with the advance of mining operations into the greater depth in the centre of syncline, the stress conditions weaken. In this way the long-term migration of gas through the formation to the surface is made easier, the natural gas capacity of seams decreases and also the hazard of outburst is reduced.

As an example of different spatial locations in relation to the tectonic fault, extraction areas of the mines given below can be stated. The Trudovskaja Mine is situated at the southwest margin of the Kalmius-Toreckaja Depression. The Zasjad'ko Mine is there more westward on the rising limb of this depression. The height difference of the seam estimated is 40 m. In the Trudovskaja Mine, the l_4 Seam is not hazardous from the point of view of coal and gas outburst occurrence, the gas capacity of the seam is lesser than 5 m^3/t, whereas in the Zasjad'ko Mine this seam is highly hazardous with the gas capacity of more than 25 m^3/t. These marked differences are a result of more difficult gas migration towards the surface due to the compression of the coal-bearing layer.

The fact that tectonic structure and stress conditions of the rock mass of coal-bearing formation are one of fundamental factors that influence the risk of outbursts in coal seams and cause also other dynamic events in mines is confirmed by manifestations of outbursts at rather small depths below the surface. Cases of such outbursts are not exceptional in Donbas, for example in the Zapadnaja Mine.

To reduce the hazard of outbursts, or to eliminate this hazard at increasing the depth of mining, it is necessary to orientate mining works into the strain-free zones of the coal-bearing formation.

There is not any substantial difference in opinions on the influence of depth on coal and gas outbursts between workers concerned with problems of coal and gas outbursts in Ukraine and those in the Czech Republic. The dependence was proved also by statistical processing the data obtained from outbursts in the mines of the Ostrava-Karviná Coalfield. In [2, 7] the analysis of data from the Staříč, Paskov, Šverma, Odra and Heřmanice Mines was made. The analysis has proved that the increase in depth is not the only indicator of the increasing hazard of possible occurrence of coal and gas outbursts. In addition to the depth, the influence of other indicators was confirmed as well. They are the gas capacity of the coal seam, the distance between the seam and the Carboniferous, the composition of overburden by reason of gas migration, tectonic setting and physical-mechanical properties of the seam mined.

Forecasting the Occurrence of Coal and Gas Outbursts

The goal of forecast is to delimit the space and to specify the time when the occurrence of anomalous event can be expected. The basis for effective forecast evaluation is the analysis of reasons and factors that cause the occurrence of the anomalous event. Capabilities of forecast are in the decisive way affected by the level of exploration of the space for which the forecast is to be made and the level of understanding of factors causing the occurrence of anomalous event [12]. Any universal and reliable method of outburst forecasting is not known yet.

At present, several parameters, which evaluate comprehensively and with certain accuracy the main factors contributing thanks to their presence to outburst occurrence and development, are introduced in the majority of countries. Great attention is simultaneously paid to mine-geological conditions for mining operation performance.

One of the decisive parameters of forecasting the outburst hazard for coal seams is the intensity of gas desorption from coal.

Measurement of Desorption as Outburst Hazard Forecast

According to [3] the seismic-acoustic monitoring of hazards of outbursts in faces and the seismic-acoustic evaluation of effectiveness of hydraulic influencing in development mine workings are used in the Zasjad'ko Mine. Practice required verifying the reliability of seismic-acoustic parameters in another way.

For this purpose, desorbometry was used according to the methodology presented in [4]. After this methodology, the zone before the face of the 10^{th} west formation, the l_1 Seam was tested. Results were obtained that proved that the section was without any outburst hazard in that part where seismic forecasting promised "hazardous conditions". Any indications of hazard did not manifest themselves in the seam, which resulted in conclusions that desorbometric parameters were more reliable and that the next observation of them was required.

The desorbometric forecast is based on the parameter ΔP that showed the promising laboratory assessment of coal failure. In [3, 11] it is stated that this parameter is more reliable in those cases when the coal is saturated with CO_2 in contrast to that saturated with CH_4. Furthermore, it is expected that this reliability is connected with insufficient evaluation of rules of kinetics of methane desorption from disturbed coal. The expression of this rule was derived from experiments done in the Donets Polytechnic Institute and is expressed by the following equation

$$q = q_0 . t^{-d} \tag{1}$$

q – the rate of desorption of gas from the coal sample in the time t that has passed from the beginning of desorption (m^3/min.1 t), a ton is considered here and below as dry matter without ash

q_0 – the hyperbola constant within the period of measurement [m^3/(min.t)]

$$q_0 = a_x (x_n - x_1) \tag{2}$$

a_x – the coefficient of proportionality; it depends on the degree of coal breaking, coal rank and temperature [$min^{(-1+d)}$]

x_n and x_l corresponding to the original gas capacity and gas yielding capacity of the sample at the atmospheric pressure of methane above the sorbent (m^3/t)

d – the parameter of degree, constant for the given test lasting 10-30 min and more.

Later according to relations (1, 2) the desorbometric gas capacity was determined in the mine $x_e = (x_n - x_l)$ with using the value a_x ascertained in the laboratory. A necessity of laboratory determination of a_x was not required after finding the dependence of a_x on d in mine conditions any longer.

$$a_x = 0{,}04 + K_y (d - 0{,}5) \tag{3}$$

K_y – the coefficient dependent on the content of volatile matters V_{daf}

The procedure for the determination of desorbometric parameters is as follows: at drilling, slack coal is taken from the set depth 1 and closed in a special vessel. This is interconnected with a capillary and rates of desorption q_i are recorded at the corresponding time t_i that is observed by means of stop-watch already from the moment of drilling at the depth 1. Measurements are taken within the l intervals, $1.25 \leq t \leq 4$ minutes, and then d and q_0 are determined either on the graph or according to the following formula

$$q_0 = \sum_{i=1}^{n} q_i . t_i^{\ d} / n \tag{4}$$

n – the number of pairs of t_p and q_p that are to be processed; if they do not correspond to the common rule, it is useful to eliminate the first and the second pair. The graph of dependence of kinetic desorption is created in the co-ordinates ln$t$, ln$q$.

The parameters will be determined as a tangent of angle between the constructed kinetic curve and the axis lnt (graphically or arithmetically) and serve the purpose of evaluation of the proneness of structure of coal to outbursts. The value x_e will be determined by means of q_0 and the coefficient a_x calculated from formula (3).

$$x_e = q_0 / a_x \tag{5}$$

For the conditions of the Zasjad'ko Mine, the following inequalities were determined:

Safe zones $q_0 \leq 0.2$ 0.5 $d < 0.95$

Zones with the outburst hazard $q_0 \leq 0.85$ 0.9 m^3/(min t) $d > 0.95$.

In the hazardous zones the presented values are a signal of danger if taken at the depth l that exceeded the size of advance. Values of x_e serve as the parameter of effectiveness of anti-outburst measures or the influence of technical measures on the content of gas at degassing the zone before the face.

The mentioned desorbometric parameters were obtained under the following mine-geological conditions:

- the depth of 900–1200 m
- the content of volatile matters of 30–32 %
- coal water content of 0.9–1.1 %
- ash content of 8–12 %.

Obtained results are given in Table 2.

Table 2

Values of desorption and gas yielding content in particular workplaces of the Zasjaďko Mine

Mine working, seam index	l=1.5 m		l=2.5 m	
	q_0 m^3/(min t)	x_e m^3/t	q_0 m^3/(min t)	x_e m^3/t
10-east L_1	0.02–0.17	1.1±0.1	0.02–0.18	1.7±0.1
15-west gate m_3	0.2–0.49	4.5±0.7	0.15–0.37	4.6±0.4
9-east l_1			0.16–0.58	5.4±0.4
Inclined gate k_8	0.04–0.42	4.3±1.4	0.05–0.37	4.6±1.0
Gate before GDJa	0.32	3.3	2.18	20.1

Note: **GDJa** is a geomechanical event.

It follows from Table 2 that the lowest values of q_0 and x_e were found in the 10th east seam, where any influence of other mine workings did not manifest itself. The highest values of q_0 and x_e were found out immediately before a GDJa, when x_e was 20.1 m^3/t, which was close to the natural gas content of the seam, i.e. 22–24 m^3/t. Values of q_0 and x_e measured before the GDJa exceeded many times the parameters in development mine workings, when any indications of outbursts did not exist. When the 9th east seam was influenced by inclined mine workings in the underlying seam, increased values of q_0 and x_e were ascertained. This confirms mutual influences of additional pressures in the area in advance of the mine working, when the distance between seams was altogether 40 m.

It is known that, in the case of pillar working, the seam area in front of the face is less prone to outbursts than development mine workings themselves. This proves that the results of desorbometry presented in Table 2 are in accordance with experience from mining operations in seams with the hazard of outburst and a steep increase in q_0 and x_e before the GDJa proves that they react sensitively to the increased outburst hazard.

Experience from Conditions of the Ostrava-Karviná Coalfield

Opinions in [3] correspond fully with our experience acquired from mines of the Ostrava-Karviná Coalfield. In [5, 8] a procedure is presented by which we determined relations between the gas content and desorption.

Many studies in this respect were carried out in the former Scientific-Research Coal Institute (VVUÚ) in Ostrava-Radvanice. In [5] taken conclusions from VVUÚ are presented and in [6] results of measurements in former mines of the Ostrava-Karviná Coalfield are given. As an example I state here, in a simplified way, how these values were ascertained objectively (Fig. 1).

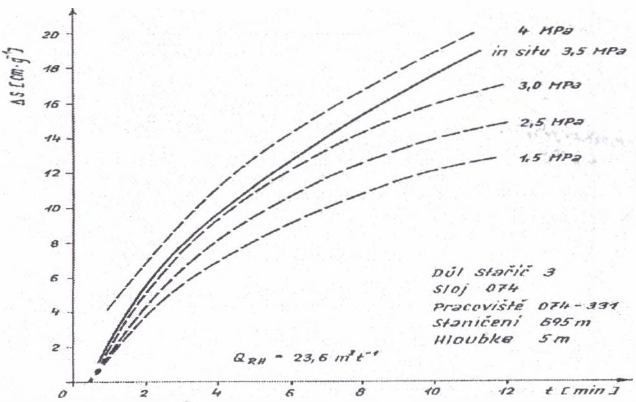

Fig. 1. Graph taken from VVUÚ (Scientific-Research Coal Institute) for the determination of sorption pressures

Rys. 1. Diagram zaczerpnięty z VVUU (Węglowego Instytutu Badawczo – Naukowego) służący do ustalenia ciśnienia sorpcyjnego

Δs in the diagram is the path of capillary in the desorbometer.

According to the procedure by VVUÚ the sample was allowed to be desorbed into the vacuum and the desorption curve was determined that corresponded to the pressure of *gas in situ*. After that the sample was saturated with CH_4 under various pressures from 1.5 to 4 MPa. By interpolation, the most probable value was derived that corresponded to the desorption curve *in situ*. For the calculation of gas yielding capacity, an equation from [5] was used.

$$p_s = A \cdot Q_{RH} \cdot T \tag{5}$$

p_s - seam gas pressure derived from Fig. 1.

A - the value derived in [12], A= 500 840 (kg J m^{-6} K^{-1})

T - the temperature of coal matter (^{0}K).

For the given example the gas yielding capacity is Q_{RH}=23.6 m^3 of CH_4 t^{-1}.

Further, we looked for a relation between $v_{1,1}$ (desorption per 1min) and the gas yielding capacity; see Table 3.

Table 3

Relation between $v_{1,1}$ [cm^3 (min kg)$^{-1}$] and Q_{RH} (m^3 t^{-1})

$v_{1,1}$ [cm^3(min kg)$^{-1}$]	Q_{RH} (m^3 t^{-1})
0	0
30	2
180	4
210	6
300	8
390	10
410	12
500	14
600	16

In [3], $v_{1,1}$ is designated as q_0 and Q_{RH} as x_e.

The coefficient for the conversion of our units [cm^3(min kg)$^{-1}$] to units [m^3(min t)$^{-1}$] is 10^{-3}; so that e.g. 410 [cm^3(min kg)$^{-1}$] is 0.41[m^3(min t)$^{-1}$] for Q_{RH}=12 (m^3 t^{-1}).

Thus conclusions in [3] are very close to our conditions and results.

Conclusion

From the presented overview of information it is evident that conclusions of researches into the area of coal and gas outbursts done in various localities do not differ in any main features. Differences follow from unique and very different depositional conditions of mined seams and legislation approved. [9, 10].

Since the year 2005, the evaluation of existing measures determined for seams with a hazard of coal and gas outbursts has been made with financial support provided by the grant project 105/05/0013. The evaluation will also cover results and experience of solving the given problems abroad.

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