The Estimation of a Possibility of Outburst Origin in Long Mine Workings

Jindřich Lát[1]***, Vlastimil Hudeček, Petr Michalčík*** *a* ***Petr Urban***

Výpočet možnosti vzniku průtrže v dlouhých důlních dílech

The article brings results of the evaluation of a possibility of coal and gas outburst origin on the basis of calculation of active forces that try to induce an outburst and passive forces that prevent an outburst from occurring. The analysis of outbursts from the Paskov Mine, Staříč plant, shows that decisive indicators, by which a proneness to coal and gas outburst origin is evaluated, indicated an increased hazard characterizing the 2nd hazard degree and requiring certain preventive measures only in a small number of the coal and gas outbursts. The aim of this contribution is to point out other influences participating in a possible origin of coal and gas outbursts (e.g. strength of coal matter, parameters of a mine working, its cross-section, circumference, and daily advance, variability in seam thickness, influence of tectonic disturbance level), and by using the mathematical model to indicate possibilities of the application of this model in a case of evaluation of coal seam proneness to coal and gas outbursts.

Key words*: Mining, outbursts of rock and gas, forecasting and preventing outbursts, metods of prevention.*

Introduction

Problems of rock and gas outbursts are still topical. According to [1] and other sources, this hazard is very serious in many countries, for example in China, Ukraine, in the area of Kemerovo (Russia), Poland.

In the framework of solving the grant task No. GAČR 105/05/013, VŠB-TU Ostrava 2005, we focused our attention to the methods of forecasting the mentioned phenomenon too. From the detailed analysis of forecasting methods in the Czech Republic as well as abroad it follows that the existing methods do not express a possibility of outburst origin with sufficient reliability.

The Analysis of Statistical Data

By the previous analysis of statistical data from the Paskov Mine, Staříč plant, it was proved that indicators (gas pressure and initial desorption rate), which participated decisively in the forecast of hazard of coal and gas outbursts and in the prevention of this gas-dynamical phenomenon, indicated an increased hazard of the origin of coal and gas outbursts (henceforth referred to as CGO) only in a small number of outbursts.

In a case of measuring the pressure of gases, over-limit values above 250 kPa, indicating an increased hazard of CGO, were recorded merely in 34 cases, which was 33 % of all CGO cases in the Paskov Mine, Staříč plant. Values of gas pressure measured before CGO in the Paskov Mine, Staříč plant, before the registered CGOs are processed in Fig. 1.

The even lower frequency of over-limit values above 2.5 cm^3 $(10\ g.\ 35\ s)^{-1}$ was found at the measurement of initial desorption rate. In 89 cases of measurement, values corresponding to the degree without hazard, or the 1st hazard degree were found. Merely the values of measurement of 9 cases characterised the 2nd degree of hazard of coal and gas outbursts. Maximum values of desorption rate before CGO are shown in Fig. 2.

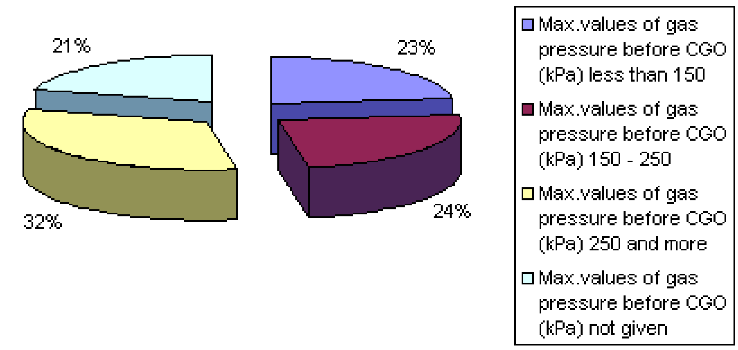

Fig. 1. Maximum values of gas pressure before CGO.

[1] *prof.Ing.Jindřich Lát,DrSc., Prof.Ing.Vlastimil Hudeček,CSc., Ing.Petr Michalčík, Ing.Petr Urban,Ph.D.*, Institute of Mining Engineering and Safety, VŠB-Technical University of Ostrava, 17.listopadu 15, 708 33 Ostrava, Czech Republic, vlastimil.hudecek@vsb.cz
(Recenzovaná a revidovaná verzia dodaná 15. 6. 2007)

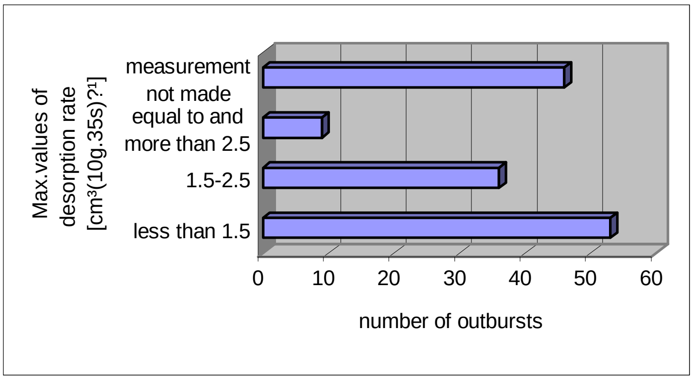

Fig. 2. Maximum values of desorption rate before CGO.

The justification of measured low values of gas pressure and initial desorption rate before the outburst consists probably in the point of measurement in the face and in a short advance ahead of the face. This area is affected by previous blasting operation, and the concentration of stress and the increased content of gases closed behind an impermeable layer will manifest themselves only if the advance ahead of the progressing face of mine working is greater. This hypothesis is confirmed by caverns which are produced by coal and gas outbursts, are situated from 5 to 10 m before the face, and reach considerable sizes. From the drawing documentation of cases of latest outbursts in the Paskov Mine, Staříč plant [2] it is evident that caverns after outbursts are situated from 5 to 10 metres ahead of the face (in some extraordinary cases even more). A cavern reaches almost always as far as the zone of tectonic disturbance, or a change in the character of the seam, which is confirmed also by statistical analyses of coal and gas outbursts occurred in the Paskov Mine, Staříč plant, with which a tectonic disturbance or a zone of tectonic disturbances was registered in 82 % of all outburst events. Thus, at this distance ahead of the face, the concentration of influences able to induce coal and gas outbursts is higher.

For these reasons, it is therefore desirable to extent the forecasting methods to the exploration of a greater zone in front of the mine working driven. As for available means, especially exploratory boreholes situated always about 6 m ahead of the face can be used for this purpose.

That is why we recommend the drilling of 3 advance boreholes of 50 mm diameter in seams of 2nd hazard degree; the boreholes are to be situated in the axis of mine working in the left and the right working wall, orientated in the direction of driving and being always 6 m ahead of the face. The boreholes in the left and the right working wall make with the axis of mine working an angle of 10^0 with a deflection from the axis to the working wall. If at least one of parameters, i.e. the zone of tectonic irregularity, a change in seam character, an increased gas emission and the return rate of debris is verified, these circumstances are evaluated as indicator of outburst hazard. (This measure is taken, to a considerable extent, from German regulations on protection against coal and gas outbursts).

A Mathematical Model of Estimation of a Possibility of Coal and Gas Outburst Origin

From previous works it is known according to [3] that the pressure of gas, desorption, the strength of coal mass and also the parameters of mine working, its cross-section, circumference and daily advance, and last but not least, variability in seam thickness and the influence of tectonic disturbance level participate in outburst origin. In [3] a mathematical model was built for these parameters. However, on the basis of present knowledge and especially by using [2], it is possible to simplify markedly the original procedure. In certain cases the estimation given below can be then used as check tool for more detailed evaluation of forecast. Such cases will be especially changes in seam character and geological position, changes in the cross-section or advance of mine working.

A Procedure for Performing the Estimation of Possibility of Outburst Origin

In the estimation, we take into account new knowledge obtained recently. Above all, it is verified that the measurement of gas pressure and desorption by the existing methods expresses only a small share of real values occurring in the rock mass. By laboratory tests, see [3], it was verified that for the desorption of gas from coal mass into vacuum and re-desorption, pressures of values of several MPa (1 to 5 MPa) were required. However, by the measuring needle we obtain values of the order of kPa. In [3] this fact is discussed in more detail and by using an equation it was derived that the real seam pressure can be relatively reliably determined by conversion from desorption; in the best case from long-term desorption, but minimally desorption per 1 minute.

In [3] the dependence given below was found and verified (by measurements in the laboratory and in situ):

$$p_s = A.Q_{RH}.T \qquad (1)$$

p_s is the real seam pressure (Pa) acting when the coal substance is disturbed
A is a conversion value derived in [3] A= 500 840 $kg.J.m^{-6}.K^{-1}$
Q_{RH} is desorbable gas-bearing capacity ($m^3.kg^{-1}$)
T is the temperature of coal mass in the rock mass (K)

In equation (1) the value "A" is a constant and the value "T" is practically determined as 293 K. The desorbable gas-bearing capacity Q_{RH} can be obtained in laboratory, but for practical purposes it can be obtained by conversion from desorption "v_1" , or better from "$v_{1,1}$". In practice, desorption measured per 35 s is used for measurement. That is why it should be converted to desorption per 1 minute. It holds true that $v_{1,1} = 1.7 . v_1$ (v_1 is desorption per 35 s). For the determination of Q_{RH} the following relation will be used:

$$Q_{RH} = 2.23 . v_{1,1} \qquad (2)$$

If $v_{1,1}$ is given in cm^3 $(10g.1min).^{-1}$, then Q_{RH} will be calculated in m^3 1000 kg^{-1}

To facilitate the calculation, we derived for practical application directly the relation between the values of desorption per 35 s, or per 1 min. and "p_s" on the basis of equations (1, 2).

p_s the seam pressure of gas by conversion from desorption per 1 min., according to Fig. 3.

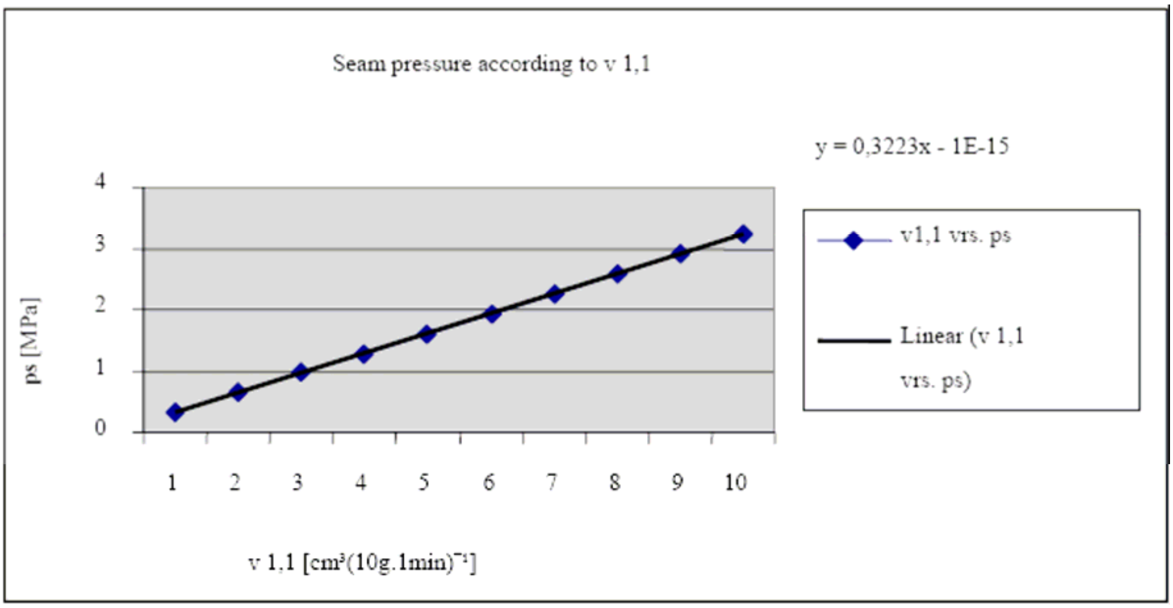

Fig. 3. Determination of seam pressure according to $v_{1,1}$.

Likewise, conversion according to the equation presented below can be used:

$$p_s = 0.3222 . v_{1,1} \qquad (3)$$

An Example of Calculation for Seam Pressure Determination

It was measured that $v_1 = 2\ cm^3(10g.35s)^{-1}$.

$v_{1,1} = 1.7*v_1 = 1.7*2 = 3.4\ cm^3(10g.1min)^{-1}$
$Q_{RH} = 2.23*v_{1,1} = 2.23*3.4 = 7.58\ m^3\ 1000kg^{-1} = 0.0075\ m^3kg^{-1}$
$p_s = 500\ 840*0{,}0075*293 = 1113481.1\ Jm^{-3} = 1113481.1\ Nm^{-2} = 1.1$ MPa
Alternatively, in a simplified way according to the equation derived here (3) $p_s = 0.3222*3.4 = 1.095$ MPa.

Furthermore, it was verified (besides other findings according to [2]) that the strength of coal matter participated by means of various influences in outburst origin. In mine workings driven we meet minimally two various values of strength. It is usually the strength of coal matter in the face of undisturbed seam and then the strength of coal matter in the disturbed zone. We can easily measure the strength of undisturbed coal matter in the face of the mine working with a penetrometer and express it usually in the indicator "f". This is the dimensionless coefficient according to Protodjakonov. In addition to this quantity, the strength of disturbed coal exists as well. We are most interested in this value in the zone in front of the mine working if the concentration of stress and gas content occurs there as a potential hazard source. The determination of the value is not easy. Abroad (Australia, see [4]) equipment on the bit of drilling rod exists, which by reading pulses evaluates properties of the seam. According to our information in the Czech Republic such equipment is not available yet; thus we must accept a simpler solution. In the procedure for estimation, its lower reliability is expressed by a selection of lower value of strength in the disturbed zone of the seam. We design it "f_1".

As for the influence of the circumference of mine working, coal seam and daily advance on the origin of outburst, many opposite opinions exist in our professional circles. In the procedure for estimation, we used prevailingly statistical data as a basis [2], and by variant calculations we looked for dependences which had these input parameters corresponding to a possibility of outburst origin.

According to the variant calculations, coefficients "k" and "z" were determined.

The value of 10 MPa is a conversion value when converting the dimensionless strength according to Protodjakonov to the uniaxial compression strength in MPa.

Into the procedure for calculation, the following input parameters are introduced according to the above-mentioned description.

$v_{1,1}$ desorption in $cm^3.(10g.1min)^{-1}$, further it holds true that $v_{1,1} = 1.7 .v_1$ (v_1 is desorption per 35 s).

f_1 the strength of coal matter 6 m ahead of the face; if a tectonic irregularity is found by the exploratory borehole, f_1 is taken as 0.3, in a case of completely broken coal up to 0.1 (this corresponds to the accepted classification of rocks). At unchanged position, without tectonic disturbance $f_1 = f$

f the strength of coal matter found by the penetrometer in the bench of lowest strength in the face of mine working

l the daily advance of mine working (m)

O_d the circumference of the whole shape of mine working (m)

k the coefficient according to geological position irregularity and variability in thickness as follows: 1.5 for variability in thickness < 10 and 2 for variability in thickness > 10.

O_s the circumference of seam in the face of mine working (m)

z if strong coal is found by the borehole for desorption taking (length of 3 m), z is taken as z=1; if disturbed coal, or tectonic irregularity is found by this borehole, then the value z = 0.3 (m) is used.

10 MPa is the coefficient of conversion for the strength of coal matter from the value of f (dimensionless) to MPa

We accepted the procedure for the estimation of possibility of outburst origin according to the active and the passive force, see [5]. However, we markedly simplified rules presented there and mainly corrected them according to new knowledge and statistical data [2].

The active force F_a, which tries to induce an outburst, will be calculated according to the following formula:

$$F_a = p_s.O_d.l.k.\frac{1}{f_1} \qquad (4)$$

The passive force which prevents the outburst from occurring will be calculated according to the following formula:

$$F_p = 10.f.z.O_s \qquad (5)$$

In both the equations, if p_s is inserted in MPa and quantities "O_d", "l", "O_s" in m, or "k", "f_1", "f", "z" as dimensionless, the calculated force is given in MN.

An outburst will occur, if:

$$F_a \geq F_p \qquad (6)$$

With reference to a rather simple procedure for the estimation of a possibility of outburst origin, as derived above, the program Excel is a suitable programming tool.

The printout of estimation of a possibility of outburst origin for several selected examples from the statistical ensemble [2]. Those cases were selected when input data, used as input parameters for the estimation, had been found before outbursts.

Tab. 1. Estimation of active and passive forces for a possibility of outburst origin with selected cases from the Paskov Mine.

Outburst No .	**Burst material** [ton]	**v1** [$cm^3(10g.35s)^{-1}$]	**v1,1** [$cm^3(10g.1min)^{-1}$]	**ps** [MPa]	**f1**
			v1*1,7	0,32*v1,1	
123	10300	1.3	2.21	0.7072	0.25
125		2.3	3.91	1.2512	0.1
126		0.6	1.02	0.3264	0.1
128		0.2	0.34	0.1088	0.1
129		2	3.4	1.088	0.1
130	4250	2.3	3.91	1.2512	0.75
135	5000	2	3.4	1.088	0.24
138		3.3	5.61	1.7952	0.4
139		2.4	4.08	1.3056	0.4
	1/f1	Od	l	k	Fa
	4	14	1.8	1.5	106.9286
	10	10	1	1.5	187.68
	10	10	0.5	1.5	24.48
	10	10	3.5	1.5	57.12
	10	10	3.5	1.5	571.2
	1.333333	14	4	1.5	140.1344
	4.166667	14	1.5	1.5	142.8
	2.5	12	2.1	1.5	169.6464
	2.5	12	4	1.5	235.008
Fp					
Outburst No.	f	Os	z	Fp	Fa-Fp
123	0.8	4.7	1	37.6	69.32864
125	0.8	7	1	56	131.68
126	0.8	7	1	56	-31.52
128	0.8	7	1	56	1.12
129	0.8	3.2	1	25.6	545.6
130	0.8	4.1	1	32.8	107.3344
135	0.8	4	1	32	110.8
138	0.8	4	1	32	137.6464
139	0.8	4	1	32	203.008

Conclusion

A procedure for the estimation of a possibility of outburst origin is presented, which takes into account, in addition to the indicators determined by safety regulations, the influences of other parameters. Their participation in outburst origin has been expected; however, it has been neither statistically, nor mathematically documented yet. Thus the submitted work can contribute to the higher reliability of forecasting a rock and gas outburst hazard.

This was worked out thanks to support from the Czech Science Foundation (project No. 105/05/0013).

References

[1] Lát, J.: Problematika průtrží je stále aktuální v celém světě. *Záchranář 4/2006, čtvrtletník OKD, HBZS, a.s. Ostrava Radvance.*

[2] Hudeček, V.: Statistické zhodnocení dat z průtrží uhlí a plynů Dolu Paskov, závod Staříč. *VŠB-TU Ostrava, 2007, 58 s.*

[3] Lát, J. Míček, D.: Využití výpočetních metod k řešení problematiky plynodynamických jevů v hlubinných dolech. *Uhlí 3/1991*.

[4] Hudeček, V., Urban, P.: Zahraniční zkušenosti, poznatky a trendy v oblasti průtrží hornin a plynů. *Monografie,VŠB-TU Ostrava 2005, 120 stran.*

[5] Murašev, V. I., Jevsejev, V. S.: Obosnovanija racionalnych parametrov prověděnija vyrabotok.