Research on the Forecast of Outburst Danger in Crosscut Exposing

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Abstract: The outburst in crosscut exposing is known as one of the heaviest in coal mine. So it is necessary to be forecasted before exposed. This is always the key work of preventing outburst in coal mine. Based on the research of the theory of outburst danger forecast in crosscut exposing, the paper took the on-site case in Zhangji Coal Mine of Huainan Mining Group. The drills were arranged reasonably before exposing, and then the parameter ΔP and f were measured in laboratory. So the danger of coal and gas outburst was forecasted by the comprehensive index method. If that was the danger face, the prevention measures should be taken according to regulations. When excavating got to the vertical distance of 5 and 3 m to coal seam, the boreholes were used to release pressure and to drainage gas. Then, it was tested by measuring the parameter k_1 and ΔP. The exposing went on after it was out of danger. In a word, as the multi-parameter indexes were used to forecast the outburst danger during the crosscut exposing, the safety were improved.

Key words: crosscut exposing; forecast of outburst danger; drill; parameter
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1. Introduction

During the coal mine production, it is more propitious to happen outbursting in exposing crosscut than in exposing coal seam drift, uphill or downhill, and coal face. So it is the most dangerous and one of the heaviest natural disasters in coal mines, which can not only influence the normal production seriously, but also endanger the safety of the workers in the coal mine. Therefore, crosscut outburst forecast is always the focal point and difficult point of outburst prevention and it is of great practical significance to do the forecast work well.

Before the crosscut exposed, the main tasks of coal and gas outburst forecast embody three aspects. First, by making sure whether or not the excavating gets to the outburst danger belt, the preventing measures can be taken in time. Second, when the excavating is in the outburst danger belt, we can find when the danger is coming and so the workers can be got out in time by constantly testing the outburst danger of exposing face. Then, it is made sure whether or not the exposing face goes out of the outburst danger belt. So, through forecast the outburst prevention can be guided and the engineering quantity of outburst prevention measures can be reduced, and also the staff safety can be ensured through constantly testing the outburst danger of exposing face.

2. Methods of the Outburst Forecast during Crosscut Exposing

To the coal and gas outburst danger forecast during the crosscut exposing, there are two major effective methods which are the comprehensive index method and the method of gas desorption index for drilling bits.

2.1. Comprehensive Index Method

First of all, two pressure measured boreholes should be played at least from the crosscut exposed face to the coal seam in order to test the gas pressure in coal seam. Then the higher gas pressure is taken as standard. In the process of drilling, we should take a coal sample in every single meter, test their consistent coefficient f, and then get the minimum of the two pressure measured boreholes to do the average as the average consistent coefficient of the soft coal layer. After that, the two coal sample should be mixed of which the consistent coefficient is least, and the initial gas releasing rate ΔP can be tested. According to the "Rules of coal and gas outburst prevention", the comprehensive indexes D and K are calculated by the following formula:

$$D = (0.0075H/f-3)\ (P-0.74) \quad (1)$$

$$K = \Delta P/f \quad (2)$$

Where D and K----comprehensive indexes of outburst danger in coal seam;

H----deep of excavating;

P----gas pressure of coal seam which depends on the higher of the boreholes, MPa;

ΔP----initial gas releasing rate of the soft coal layer;

f----consistent coefficient of the soft coal layer through testing the coal samples with granularity between 10 and 15 mm.

The critical values of comprehensive indexes D and K are determined by the actual measured datas in coal mine. If there are no actual measured datas, the outburst danger can be determined by the critical values of Table 1.

Table 1. The critical values of the comprehensive index method in outburst danger forecast

Comprehensive index D	Comprehensive index K	
	Anthracite	*The others*
0.25	20	15

If the coal sample granularities of the pressure measured boreholes are less than 10-15 mm, the coal samples with granularity between 1 and 3 mm can be taken to determine $f_{1\sim3}$, and then the standard f can be converted by the f_{1-3} (when $f_{1-3}>0.25$, $f=1.57\times f_{1-3}-0.14$; when $f_{1-3}\leq0.25$, $f=f_{1-3}$).

2.2. Method of Gas Desorption Index for Drilling Bits

While the crosscut exposed face gets to the minimum vertical distance of 3-10 m to coal seam, two Φ50-75 mm forecasting boreholes should be played in the coal seam. When the boreholes are drilled to the intended location, the gas desorption indexes Δh2 and k1 should be measured. The critical values of drilling bits index are determined by the actual measured data in coal mine. If there are no actual measured datas, the coal outburst danger in front of crosscut can be determined by the critical values of Table 2.

Table 2. The critical values of the gas desorption index for drilling bits

Coal sample	Δh_2(Pa)	K_1 (ml/gmin$^{0.5}$)
Dry coal	200	0.5
Moist coal	160	0.4

3. Research on the Major Forecast Indexes

The distance of the experimental crosscut exposed face is 253 m from the bottom point to the return airflow rise of Xi'er 13-1 coal seam, the elevation of up-changing point is -587.855 m, the elevation of down-changing point is -630.116 m, the azimuth of constructed roadway is 291°, and the slope is 12°. The construction sequence begins with excavating as oblique lane from 13-1 coal seam floor and then through the 13-1 coal seam as crosscut and last to the return airflow rise of Xi'er 13-1 coal seam. By the way, the roof and floor of 13-1 coal seam are mostly mudstone and sandy mudstone which is friable, with rich plant fossils in the roof rock and a thickness of about 0.4 m 13-2 coal seam in the position of 5 m to the floor.

As the forecast indexes differ from one coal mine to the other, and even differ from the different places in the same coal mine, the scientific experiments need to be taken to figure out the proper critical values of outburst indexes for the actual scene. And so the reliability and validity can be ensured.

3.1. Consistent Coefficient of Coal

The physical property of coal is one of the three major outburst factors. To the outburst danger forecast of crosscut exposed face in Zhangji coal mine, the coal consistent coefficient f can obviously reflect the outburst danger of coal face to a certain extent. The author measured the coal consistent coefficient by drop-weight method that the power consumption A is directly proportional to the increasing surface area S of broken material. When the A and the average diameter of material before broken are of a certain value, the consistent coefficient f of material is proportional to crushing ratio, and if the crushing ratio gets lager the f gets smaller. The consistent coefficient of coal sample is calculated by the following formula:

$$f_{10-15}=20n/h \tag{3}$$

Where f_{10-15}----the measured consistent coefficient of coal samples with granularity between 10 and 15 mm;

n----times of drop-weight;

h----height of measured powder by cylinder, mm.

The coal samples were got from Zhangji coal mine with granularity between 1 and 3 mm to take experiment and the consistent coefficient were measured. Then, according to the article 30 of "Rules of coal and gas outburst prevention", if the granularities of soft coal samples are less than 10-15 mm, the consistent coefficient f can be converted by the f_{1-3}(when $f_{1-3}>0.25$, $f_{10-15}=1.57\times f_{1-3}-0.14$; when $f_{1-3}\leq0.25$, $f_{10-15}=f_{1-3}$). The measured results were listed in Table 3.

Table 3. The measured results of the coal consistent coefficient

Times of drop-weight(n)	Height of powder (h)	f= 20n/h	$f_{1-3}>0.25, f=1.57\times f_{1-3}-0.14$; $f_{1-3}\leq0.25$, $f=f_{1-3}$	Average
3	212	0.283	0.304	
3	217	0.277	0.295	0.266
3	301	0.199	0.199	

3.2. Gas Desorption Index for Drilling Bits

The gas desorption index for drilling bits K_1 mainly reflects the gas content and the gas desorption speed of coal seam. Its changing rules can well reflect not only the capacity of coal adsorption and the content of gas desorption but also the destruction degree of coal. The author took both laboratory test and field test to determine the critical value of K_1. The relation of the gas desorption index for drilling bits K_1 and the gas pressure

is calculated by the following formula:

$$K_1 = AP^B \quad (4)$$

Where K_1----gas desorption index for drilling bits;
P----gas pressure, MPa;
A and B----constant, 0<A,B<1.

After the experiments of coal samples were taken from Zhangji, the K_1-P variation relationship could be shown in Fig.1. It shows that if the gas pressure of coal sample gets bigger the K_1 gets larger, and when the pressure is 3.35 MPa the gas desorption index for drilling bits is 0.85. Furthermore, if the K_1 of crosscut is much larger, the dynamic phenomena such as caving and roof falling correspondingly gets much stronger while exposing the coal and passing through the coal doors.

3.3. Initial Gas Releasing Rate of Coal

The initial gas releasing rate ΔP which is related with the geological structure is one of the important para-

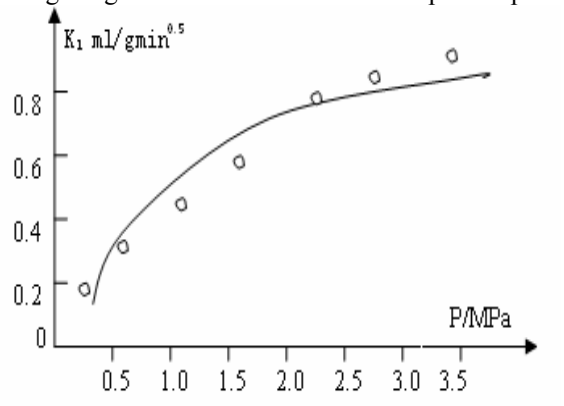

Figure 1. Relation curve of the gas desorption index for drilling bits and the gas pressure P of 13-1 coal sample

-meters in the comprehensive index method. When it is near the fault or in the coal seam of increased angle or in the folded structure, the initial gas releasing rate gets much bigger. Generally, when the ΔP of coal is larger than 10, there is outburst danger. Otherwise, there isn't. Table 4 shows the measured datas of initial gas releasing rate in 13-1 coal seam. The biggest data of initial gas releasing rate of coal seam is 14, which is bigger than the index of reference in article 26 of "Rules of coal and gas outburst prevention". Therefore, it is the outburst danger coal seam.

Table 4. Measured results of initial gas releasing rate ΔP

Sample number	Mercury pressure gauge reading				ΔP (mmHg)	ΔP (average)
	h_1	h_1'	h_2	h_2'		
1	205	84	210	81	8	8
	200	90	210	82	8	
2	197	93	201	88	9	9
	194	96	198	91	9	
3	205	86	214	82	13	14
	201	92	207	83	15	

3.4. Comprehensive Index of Crosscut Outburst

In the actual crosscut exposed work, there is seldom to judge the outburst danger by using a single index, for any single index is hard to be measured accurately as it is influenced by many factors. Besides, the index in different place of the same coal seam is also different. So it is always with a great chance by judging with a single index, and it could easily lead to misjudgments. Therefore, the paper took multi-parameter to forecast the outburst danger during the excavating process of crosscut exposed face.

After the initial gas releasing rate ΔP and the consistent coefficient f were measured, the comprehensive index D and K could be calculated (showed in Table 5). It shows that the K of all the three coal samples is bigger than the critical value 15 which is specified in "Rules of coal and gas outburst prevention". So it is an outburst danger crosscut. According to the article 102 of "Coal mine safety regulation", the method by using boreholes to pre-drainage gas is taken for coal and gas outburst prevention.

Table 5. Measured results of outburst forecast parameters of crosscut

Number	Initial gas releasing rate (ΔP)	Consistent coefficient (f)	Comprehensive index		Gas pressure (P)	Gas desorption index for drilling bits (K_1)
			K	*D*		
1	8	0.283	28.27	35.75	3.35	0.85
2	9	0.277	32.49	36.70		
3	14	0.199	70.35	54.14		

4. Measures Tested for Outburst Prevention

The exposing length is 38 m which is from the crosscut roof which is 2 m from the floor of 13-1 coal seam and to the position when the roadway all gets to the coal seam. According to the requirements of the distance which is from the crosscut roof to the coal seam floor and the requirements of the reaming hole construction, the excavating should stop when it reaches 10 m distance to the 13-1 coal seam in order to expose the 13-1 coal seam safely. Two pressure holes and exploring holes then should be played, and coal samples should be taken in the field and laboratory to measure the index f, k_1 and ΔP. Later, excavating can be continued until 5 m to the 13-1 coal seam.

When the crosscut roof reaches 5 m and 3 m distance to the floor of 13-1 coal seam, the reaming technique of pressure relief and gas drainage should be taken to prevent outburst danger (showed in Fig.2). The effect of reaming holes reaches to 3-5 m outside the roadway contour along the coal seam strike and reaches totally into the coal seam by leaving 5 m advanced distance along the dip. The whole controlling area is 471.2 m^2 (12.4×38).

After outburst prevention measures are taken, the effectiveness of measures must be tested to confirm whether or not they worked. Only when it is safe in footage after forecast, can it be advanced. The effect tested indexes include gas desorption index for drilling bits K_1 and initial gas releasing rate ΔP for five tested holes. And the results are shown in Table 6.

Meanwhile, the coal samples of before and after me-

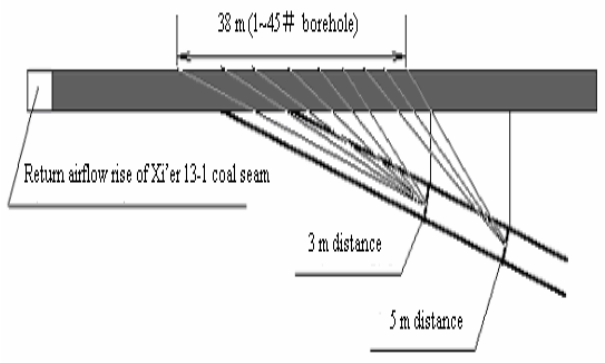

Figure 2. The profile chart of drilling arrangement at 3 m and 5 m from crosscut to the coal seam floor

Table 6. The effect tested results of outburst prevention

Hole number	K_1 ml/g · $min^{0.5}$	ΔP q/L · min^{-1}	Critical value	
			K_1	ΔP
1	0.187	7.2		
2	0.116	6.8		
3	0.089	4.7	0.5	10
4	0.095	4.9		
5	0.102	5.5		

-asures from exposed face in the field were got to test the coal consistent coefficient variation before and after blasting. And the tested results are shown in Table 7.

Table 7. The tested results of coal consistent coefficient

Tested sample	Before measures	After measures
f	0.266	0.8

Based on the testing results above and referred to "Rules of coal and gas outburst prevention", all the tested indexes are less than the critical values of outburst danger and the coal consistent coefficient correspondingly increases. That is to say, the outburst prevention measures are effective that the outburst danger of crosscut exposing is relieved after the measures taken, and so it is safe for crosscut exposing.

5. Conclusions

During the crosscut exposing, there are many factors influencing the coal and gas outburst danger, such as occurrence conditions, stability of coal seam, properties of adjoining rock, hydrogeology condition, gas content of coal seam, gas pressure of coal seam, initial gas releasing rate, coal consistent coefficient, etc. The author used multi-parameter to forecast the coal and gas outburst danger during crosscut exposing in Zhangji coal mine. The accuracy of forecast was improved and the safety of coal exposing was ensured.

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