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Discussion on Classification of Outburst Coal Seam Based on Outburst Intensity

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Abstract: With the development of outburst prevention technology and the improvement of management level in China's outburst mines in the new era, the classification of outburst coal seams has important guiding significance for the further refinement, improvement, and enhancement of China's outburst mine gas prevention and control system. Therefore, it is necessary to further classify outburst coal seams. Through the analysis of outburst accidents with deaths of more than or equal to 3 people since 2000, a large number of basic gas parameters in the laboratory, and previous research results, in-depth discussions were conducted on the methods and basis for classification of outburst coal seams, as well as related issues such as judgment rules and critical values of indicators. It is proposed to divide outburst coal seams into two levels: 'general outburst coal seams' and 'severe outburst coal seams'. A classification method for outburst coal seams based on outburst strength has been established. The judgment rules for severe outburst coal seams have been established, including the amount of coal thrown out S, the amount of gas emitted per ton of coal Q_0 and the number of outburst times N. The critical values of the judgment indicators have been determined. Through the research, it will provide an important basis for the determination of mining procedures, outburst prevention planning and mining replacement planning, etc.

Keywords: Coal Seam of Outburst, Outburst Intensity, Classification Basis, Classification Index, Judgment Rule, Critical Values of Judgment Index, Hierarchical Management

1. Introduction

There are significant differences in the occurrence and risk of gas outburst in outburst mines in China, such as the intensity of outburst ranging from tens of tons to thousands of tons, and the distribution of original gas pressure in coal seams ranging from 1MPa to 9MPa. Although as many as 19 provinces in China have experienced outburst accidents, the degree of outburst danger shows significant differences. From the records of gas outburst accidents in coal seams in the past few decades, some outburst coal seams have experienced outburst accidents with group casualties, while some coal seams, although outburst coal seams have never experienced outburst accidents. Therefore, how to prevent and manage coal seams with severe outburst hazards is the key to curbing outburst accidents, and the main basis for selecting reasonable outburst prevention measures is to accurately and reliably classify the degree of coal seam outburst hazards.

There have been some studies on the classification of outburst hazard levels both domestically and internationally, but they all focus on the classification of "outburst mines". The former Soviet Union, Poland, and other countries mainly used outburst intensity to classify outburst mines, while domestically they mainly used outburst harmful indicators and outburst dangerous indicators to classify outburst mines, which are divided into two levels, three levels, and four levels [1-9].

Relevant issues related to the classification of outburst coal seams have been discussed through the statistics and analysis of a large number of outburst accidents since 2000, gas storage parameters of coal seams with outburst accidents, laboratory parameters, etc. Drawing on the classification methods of outburst mines, a classification method for outburst coal seams has been established, and corresponding outburst prevention measures have been proposed. This has important guiding significance for the further refinement, improvement, and enhancement of the gas prevention and control system in China's outburst mines.

2. Classification Method for Outburst Coal Seams

The classification of outburst coal seams should follow the overall principle of 'clear objects, appropriate levels, simple methods and obvious effects'. Considering the differences in the occurrence of gas in outburst coal seams in China, the level of mine technical personnel, existing outburst prevention measures and the convenience of supervision, outburst coal seams are divided into 'general outburst coal seams' and 'severe outburst coal seams' based on the degree of outburst danger.

Drawing on the classification method of outburst mines to classify outburst coal seams mainly involves two categories of methods, including outburst harmful indicators and outburst dangerous indicators. The outburst harmful indexes are mainly applicable to mines that have already experienced outburst accidents. For mines that have not experienced outburst accidents, they are mainly determined based on the coal seam outburst dangerous index. Among many outburst harmful indicators such as 'outburst intensity, outburst frequency, and outburst type proportion' in outburst mines, outburst intensity can most intuitively reflect the degree of harm caused by coal seam outburst. Therefore, outburst coal seams can be classified based on outburst intensity.

2.1. Classification Indexes Based on Outburst Intensity

When using outburst intensity for classification, coal ejected S, coal gas emission per ton Q_0, and outburst frequency N are used as the classification indicators for outburst coal seams.

The amount of coal thrown S represents the scale and destructive capacity when an outburst occurs. The gas emission quantity Q_0 per ton of coal indirectly reflects the size of the coal seam gas content, changes in gas adsorption capacity and ability to destroy coal bodies. The outburst frequency N (multiple occurrences of outburst) indicates that the gas control of the outburst coal seam is difficult under existing outburst prevention measures, and the coal seam is always in a high-risk state of outburst danger. However, there is no necessary relationship between the gas emission quantity Q_0 and the number of outburst times N per ton of coal and the severity of coal seam outburst, so it is necessary to further determine the judgment rules based on statistical data.

2.2. Source and Calculation Method of Grading Indicators

2.2.1. Source of Indicators

The three indicators, namely the amount of coal thrown out S, the amount of gas emitted per ton of coal Q_0, and the number of outburst occurrences N, mainly come from the investigation report of outburst accidents. At the same time, reference should also be made to the previous outburst record cards of mine outburst accidents.

2.2.2. Indicator Calculation Method

For outburst accidents that have already occurred, the grading index value can be calculated using the data provided by the outburst card or investigation report. If necessary, the amount of coal thrown S and the amount of gas emitted per ton of coal Q_0 can be further calculated to strive for accurate grading results, and the accounting method should be carried out in accordance with current standards and specifications; The number of protrusions N is mainly calculated based on the number of protrusions recorded.

2.3. Source and Calculation Method of Classification Indexes

2.3.1. Judgment Rules

Reasonable judgment rules are one of the keys to improving judgment accuracy. When using the outburst intensity judgment, the amount of coal thrown S can be used as a separate judgment rule. Previous studies on the classification of outburst mines have also used this indicator separately, and China has also used this indicator separately when dividing the risk level of coal and gas outburst. However, the gas emission quantity Q_0 per ton of coal cannot be used solely for judgment. Although Q_0 reflects the occurrence status of coal seam gas at the outburst site, under the current outburst prevention system, the outburst site is basically in the state after the implementation of outburst prevention measures, and the classification of outburst coal seams must be in the original state. In addition, even if the original gas pressure is similar, the difference in Q_0 after the outburst may be huge.

It is feasible to determine the combination of gas emission quantity Q_0 per ton of coal and coal emission quantity S, because the characteristics of severe outburst coal seams are high gas content, difficult to control, high intensity, high accident level, and strong destructive power when outburst occurs. Although the coal emission quantity S cannot reach the large outburst intensity, if the gas emission quantity Q_0 per ton of coal reaches a certain value at the same time, it will also throw the coal out for a long distance, or even cause gas back-flow, and the coal seam outburst will have a wide range of impact, it can cause a large number of casualties.

The number of outburst occurrences N cannot be used separately for judgment. Although this indicator is used in the classification of outburst mines both domestically and internationally [10], it is not used separately, but combined with the amount of coal thrown out S. If a certain coal seam has indeed experienced several outburst occurrences, but the amount of coal thrown out is only ten or dozens of tons, which is relatively small and does not cause damage or casualties, it indicates that the coal seam itself does not have the attribute of high-level or large-scale outburst accidents, so it is not scientific or rigorous to determine that the coal seam is a serious outburst coal seam solely based on the number of outburst occurrences.

2.3.2. Critical Value of Indexes

The critical value of the judgment index is the core content of the classification of outburst coal seams. The determination of the critical value of the classification index is based on the statistical analysis of the outburst accidents and coal seam gas data from 2000 to 2019, as well as the results of a large number of laboratory gas parameter measurements.

1) Determination of the critical value of the amount of coal thrown out S

According to the statistics of 75 major and particularly major outburst accidents (with a death toll ≥10 people) and 202 larger outburst accidents (with a death toll 3-9 people) that occurred nationwide from 2000 to 2019, the amount of coal thrown S is divided into 7 levels, and the proportion is calculated based on different intensity levels. The results are shown in tables 1 and 2.

Table 1. *Proportion of coal thrown out in major and particularly major outburst accidents in China from 2000 to 2019.*

Intensity level	S≥1 000 t	S≥600 t	S≥500 t	S≥400 t	S≥300 t	S≥200 t	S<200 t
Number of occurrences	23	42	51	63	69	75	0
Proportion/%	30.7	56	68	84	92	100	0

Table 2. *The amount of coal thrown out during larger outburst accidents in China from 2000 to 2019, S Proportion situation.*

Intensity level	S≥1 000 t	S≥500 t	S≥400 t	S≥300 t	S≥200 t	S≥100 t	S≥0 t
Number of occurrences	2	5	40	67	146	168	202
Proportion/%	1.0	3.0	19.8	33.2	72.3	83.2	100

From table 1, it can be seen that the amount of coal thrown out S during both major and particularly major outburst accidents is greater than 200 tons. From table 2, it can be seen that the proportion of S≥200 t when a major outburst accident occurs is as high as 72.3%. Therefore, it is not appropriate to set the critical value of coal throwing S to 200 t, because when S≥200 t, lager, major and particularly major accidents may occur. However, according to table 2, the proportion of lager accidents occurring when S≥500t is only 3.0%, while the proportion of S≥500t occurring when major and particularly major protruding accidents occur is 68.0%. It indicates that when S≥500t, the probability of major and particularly major outburst accidents is higher, and when S<500t, the probability of larger outburst accidents is higher.

Based on the comprehensive consideration of China's national defense emergency management and research status, determine the critical value of a single indicator for the amount of coal thrown out. Firstly, when dividing the risk level of coal and gas outburst according to the outburst intensity in China, the outburst intensity (S) of 500 t is used as the boundary point for 'general outburst coal seams' and 'severe outburst coal seams'. Secondly, previous studies on the classification of outburst mines have also taken the outburst intensity (S) of 500 tons as the critical value.

2) Determination of the critical value for determining the combination of the amount of coal thrown out S and the amount of gas emitted per ton of coal Q_0

In the 75 crane and major outburst accidents (with a death toll ≥10 people) counted in table 1, the amount of coal thrown S is above 200 tons. In the larger outburst accidents (with a death toll 3-9 people) counted in table 2, only 27.7% of the coal thrown S is below 200 tons. The Upper Silesian and Lower Silesian coalfields in Poland also consider outburst intensity≥200t as one of the most severe outburst mine judgment indicators, so 200t≤S<500t is considered as the combination judgment threshold.

According to table 1, 75 major and extraordinary outburst accidents occurred from 2000 to 2019 (including 24 major and particularly major outburst accidents with 200 t≤S<500 t) and 93 larger outburst accidents (out of 202 larger outburst accidents, 93 can be counted as per ton of coal gas emission Q_0). Taking into account the two indicators of coal ejection S and per ton of coal gas emission Q_0 in outburst accidents, they are divided into four levels, take 200 t≤S<500 t and Q_0 ≥40 m^3 as the starting point for grade classification, and calculate the proportion of outstanding accidents at different grades, as shown in tables 3 and 4.

Table 3. *Proportion of different grades in major and particularly major outstanding accidents from 2000 to 2019.*

Grade	200 t≤S<500 t Q_0≥40 m^3	200 t≤S<500 t Q_0≥60 m^3	200 t≤S<500 t Q_0≥80 m^3	200 t≤S<500 t Q_0≥100 m^3
Number of occurrences	24	18	15	6
Proportion/%	32.0	24.0	20.0	8.0

Table 4. *Proportion of different grades in larger outstanding accidents from 2000 to 2019.*

Grade	200 t≤S<500 t Q_0≥40 m^3	200 t≤S<500 t Q_0≥60 m^3	200 t≤S<500 t Q_0≥80 m^3	200≤S<500t Q_0≥100 m^3
Number of occurrences	68	50	17	8
Proportion/%	73.1	53.8	18.2	8.6

Through statistical analysis of the data on the amount of coal thrown out S and the amount of gas emitted per ton of coal during major and catastrophic accidents (with a death toll ≥10 people) from 2000 to 2019 (see tables 1 and 3), it can be concluded that in the combination judgment of S and Q_0, a critical value of 80 m^3 per ton of coal gas emission is considered appropriate. One is that the critical value S≥500 when using the amount of coal thrown out as a single indicator to determine severe outburst coal seams in table 1 accounts for 68.0%, which is relatively not high. However, in table 3, the rule of 200 t≤S<500 t and the amount of gas emitted per ton of coal Q_0≥80 m^3 accounts for 20.0%, and when the two indexes are combined (not intersecting), the proportion is as high as 88.0%, which is appropriate. The second is to analyze the proportion of different grades in larger outstanding accidents (with a death toll 3-9 people) from 2000 to 2019 (see table 4). In the case of 200 t≤S<500 t, when the critical value of Q_0 is 40 or 60 m^3, the probability of lager, major and particularly major accidents occurring is relatively high; When the critical value of Q_0 is 80 m^3, the misjudgment rate is 18.2%, and the misjudgment rate is less than 20%, which is acceptable.

Based on the above analysis, from the perspective of judgment accuracy, when the combination of the amount of coal thrown out S and the amount of gas emitted per ton of coal Q_0 is used for judgment, when 200 t≤S<500 t and the amount of gas emitted per ton of coal Q_0≥80 m^3, it is determined that the coal seam is a serious outburst coal seam.

3) Determination of critical value for the combination of outburst times N and coal throwing quantity S

According to the 202 larger (death toll≥3) outstanding accidents that can be counted, there are 141 accidents with 200t≤S<500t, accounting for 69.8%; In addition, through the analysis of some typical outburst accidents, such as the 8.30 accident at Sanhui No. 3 Mine in Chongqing, the 8.11 accident at Zhengzhong Coal Mine in Guizhou, and the 4.20 accident at Tao'er Coal Mine in Hebei, it was found that for outburst accidents with 200t≤S<500t, the coal accumulation length reached over 40 meters. Within the range of 40 meters, 79% of the total fatalities were caused by coal thrown and were buried, indicating that the distance of coal thrown at the moment of outburst reached over 40 meters, it is difficult for operators inside the mining face to escape. If the outburst of 200t≤S<500t frequently occurs, the possibility of a total death toll of more than 10 people is extremely high. The outburst of the 3# coal seam in the Xiayukou coal mine in Hancheng is a typical example, which is not allowed. Poland uses the rule of 'throwing coal S≥ 200t and frequently occurring' to determine the mines with the most severe outburst danger. Referring to the statistical data of coal and gas outburst accidents in China [11, 12], N≥3 times is determined as the critical value for combination judgment.

Based on the above analysis and drawing on foreign experience, when using the combination of outburst frequency N and coal ejected quantity S to determine, when 200 t≤S<500 t and N≥3, the coal seam is determined to be a severe outburst coal seam.

3. Graded Management and Measures

The management after the classification of outburst coal seams can refer to the relevant management methods for the identification of outburst coal seams (mines), and the classified coal seams should be based on natural mines with independent production systems. The focus of outburst prevention measures after classification is on outburst prevention measures for severely protruding coal seams.

Based on experience, severely protruding coal seams with coal seam group mining conditions are strictly prohibited from being used as the first mining layer, and a protective layer must be mined [13-16] (for single coal seams, pre drainage of gas through layer drilling or mining of soft rock are used as protective layers according to the actual situation). For the management of general outburst coal seams, the current 'Detailed Rules for the Prevention and Control of Coal and Gas Outburst', 'Coal Mine Safety Regulations', and relevant standards and specifications should be followed.

4. Conclusion

Through statistics and analysis of the research results on outburst accidents and outburst mine classification from 2000 to 2019, the outburst coal seams are divided into 'general outburst coal seams' and 'severe outburst coal seams' according to the degree of outburst danger. A classification method for outburst coal seams is established based on the outburst intensity (S of coal thrown out, Q_0 of gas emitted per ton of coal, and N of outburst times) as the classification indicators. The 'Detailed rules for the prevention and control of coal and gas outburst' issued and implemented in 2019 added recognition requirements for outburst coal seams. Although the classification of outburst coal seams is still in the exploration stage, with the development of outburst prevention technology and improvement of management level in China's outburst mines in the new era, it has important guiding significance for further refinement, improvement, and enhancement of China's outburst coal mine gas prevention and control system.

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