Study on Outburst Risk Prediction Sensitivity Indexes and Its Critical Value of the Stress-dominated Outburst Coal Seam

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Abstract. According to that outburst in the mining area is the dominant stress type and they occur near the geological structure, taking Sangshuping NO.2 coal mine as the research background, the drilling cuttings weight S, gas desorption index of drilling cuttings Δh2&K1 in the investigated area were statistically analysed by combining laboratory analysis with field investigation. The study determines that the sensitive indexes of outburst risk prediction in NO.3 coal seam working face are the drilling cuttings weight S and gas desorption index of drilling cuttings Δh2; the critical values of normal and abnormal geological conditions are determined, which provides basis for prediction of No.3 coal seam working face in test area.

1. Introduction
The sensitive indexes and its critical value of working face outburst risk prediction are the key indexes parameters for preventing and controlling of outbursts in the mine, they are the basis for regional verification, outburst risk prediction of working face, effect test of the working face’s outburst prevention measures. The phenomenon of small indicators prominent in some mine working faces may lead to the causes of false alarm, such as insensitive index, field test error, and the change of disaster mechanism, which makes the existing test methods and indicators unable to meet the prediction demand of working face, etc. [1, 2].

The "detailed rules for prevention and control of coal and gas outburst" recommends the critical values of different prediction methods, but they all require investigation to determine the sensitive indicators and critical values. The main indicators are the amount of drilling cuttings, the gas desorption index of drilling cuttings, and the initial velocity of gas emission from boreholes. Therefore, it is important to investigate the sensitive index and its critical value according to the mine gas geological conditions to improve the accuracy of outburst risk prediction.

The sensitive index should be able to reflect the coal seam outburst risk, and its critical value can clearly distinguish the outburst risk and non-outburst risk. It is usually determined by combining the statistical analysis of measured data and laboratory test [3-6]. The outburst type of NO.3 coal seam is mainly extrusion, which shows that the stress plays a leading role. The research takes the Sangshuping NO.2 mine in the north of the mining area as the background, the NO.3 coal seam’s firmness coefficient is 0.2~0.56, its firmness coefficient is generally greater than 0.4; the coal seam failure types are mostly...
2. Sensitivity analysis of working face outburst risk prediction indexes

2.1. Analysis of drilling cuttings gas desorption index \( K_1 \)

The relationship of \( K_1-P \) is analyzed by taking soft slicing coal samples in the north and south of NO.3 mining section, as shown in Fig.1. The \( K_1 \) value of gas desorption index is \( 0.13-0.26 \text{mL/(g·min}^{0.5}\text{)} \), when the gas pressure is 0.74 MPa, it is much less than \( 0.5 \text{ mL/g·min}^{0.5} \) that the critical value is recommended by the “Rules for prevention and control of coal and gas outburst”. The critical value is too small to accurately reflect the risk of coal seam outburst; at the same time, there are some errors in the test itself, it causes that the margin of error is too high, From the point of view of laboratory analysis, \( K_1 \) should not be used as a sensitive index.

![Figure 1. \( K_1-P \) curve of coal sample](image)

From June 2015 to November 2017, there were 450 cycles of \( K_1 \) prediction test for working face outburst risk, the index \( K_1 \) value is \( 0.01-0.60 \text{mL/(g·min}^{0.5}\text{)} \), the distribution range of \( K_1 \) tested in excavation face in test area is shown in table 1. The index \( K_1 \) that exceeded the standard is 1 prediction cycle, The maximum \( K_1 \) is \( 0.60 \text{ mL/(g·min}^{0.5}\text{)} \), the prediction indexes mainly focus on \( 0.10-0.30 \text{mL/(g·min}^{0.5}\text{)} \), it’s 80.5% of the total prediction cycles

| \( K_1 \) distribution range mL/(g·min\(^{0.5}\)) | 0\(\leq K_1 < 0.1 \) | 0.1\(\leq K_1 < 0.2 \) | 0.2\(\leq K_1 < 0.3 \) | 0.3\(\leq K_1 < 0.5 \) | \( K_1 \geq 0.5 \) |
|---|---|---|---|---|---|
| Percentage of the total prediction cycles | 11.3% | 49.6% | 30.9% | 8.0% | 0.2% |
| \( \Delta h_2 \) distribution range /Pa | 0\(\leq \Delta h_2 < 50 \) | 50\(\leq \Delta h_2 < 100 \) | 100\(\leq \Delta h_2 < 150 \) | 150\(\leq \Delta h_2 < 200 \) | \( \Delta h_2 \geq 200 \) |
| Percentage of the total prediction cycles | 0.5% | 13.7% | 84.8% | 0.8% | 0.2% |
| S distribution range /kg/m | 1\(\leq S < 2 \) | 2\(\leq S < 3 \) | 3\(\leq S < 5 \) | 5\(\leq S < 6 \) | S\(\geq 6 \) |
| Percentage of the total prediction cycles | 0.6% | 91.1% | 7.5% | 0.2% | 0.6% |
2.2. Analysis of drilling cuttings gas desorption index $\Delta h_2$

The drilling cuttings gas desorption index $\Delta h_2$ has been tested for 895 times in the driving face of NO.3 coal seam in the investigation area. The value of $\Delta h_2$ is $40 \sim 220$ Pa, and the distribution is shown in Table 1. The value of prediction index is $50 \sim 150$ Pa under the normal condition, it’s 98.5% of the total prediction cycles. The index value $\Delta h_2$ of 2 prediction cycles in the test area exceeded 200 Pa (the recommended critical value). When the index value exceeds 200 Pa, The structure of coal seam in working face is disordered and its luster is dim, accompanied by outburst omens such as rib-fall and hole-spraying. When there are outburst omens, the $\Delta h_2$ value exceeds the reference critical value, it shows that $\Delta h_2$ can reflect the risk of coal seam outburst.

2.3. Analysis of drilling cuttings weight

A total of 1358 cycles of drilling cuttings were tested in No.3 coal seam, and the value was 2-18kg/m. The distribution of cuttings $S$ is shown in Table 1. Under normal conditions, the prediction indexes mainly focus on $2 \sim 5$kg/m, accounting for 98.6% of the total prediction. The $S$ index of the test area exceeded the standard 8 times (more than the reference index 6 kg/m), accounting for 0.6% of the total forecast. The outburst disaster in mining area belongs to stress-dominated disaster, it accords with the actual conditions of the mine, that The over limit times of drilling cuttings weight are higher than the drilling cuttings gas desorption indexes.

3. Determination of sensitive index for outburst risk prediction of working face

According to the test results of cuttings, the minimum value of prediction results is 7.2kg/m when the drilling cuttings amount exceeds the limit, and most of the indexes are less than 5kg/m when the indexes are not beyond the limit. The maximum amount of drilling cuttings is more than 3 times of the average amount of drilling cuttings in normal working face. The time difference of drilling cuttings amount in predicting outburst danger is obvious. It can be concluded that the drilling cuttings weight $S$ is sensitive to predict the outburst risk of working face in the test area.

Drilling cuttings gas desorption index $\Delta h_2$ is consistent with the statistical analysis result of drilling cuttings weight, the distribution of them is parabola along the hole depth, as show in Fig.2. The peak value is located at 6 ~ 8 meters along the hole depth, it is basically consistent with the stress distribution in front of the roadway, it concludes that $S$ and $\Delta h_2$ can reflect the outburst risk of working face.

![Figure 2. S and $\Delta h_2$ contrast curve of distribution law along the hole](image)

The drilling cuttings gas desorption index $K_1$ is analyzed that its sensitiveness is poor in the laboratory. At the same time, by comparing the indexes when abnormal occurs in 3303 cut-off combined roadway and North track roadway, when the drilling cuttings gas desorption index $\Delta h_2$ is out of limit, $K_1$ reflects
a great difference, as shown in Fig.3. In north track main roadway, $K_1$ and $\Delta h_2$ are both higher than the recommended critical value, but $K_1$ is lower than the recommended critical value. However, the $\Delta h_2$ of 3303 open-cut contact roadway is higher than the critical value, and $K_1$ is lower than the critical value, which indicates that the gas desorption index $K_1$ of drilling cuttings can’t increase with the increase of outburst risk, nor can it show obvious difference in whether there is outburst risk, and $K_1$ can’t be used as a sensitive index for outburst risk prediction.

**Figure 3.** $K_1$ and $\Delta h_2$ contrast curve of distribution law along the hole under the abnormal condition

4. **Determine the critical value of outburst risk prediction index of working face**

It is about 1% of the total prediction cycles, that sensitivity indexes test results is higher than recommended critical value. As the existing investigation work is carried out in the area where the regional measures are effective, the investigation indicators are in line with the actual situation of the investigation area. When determining the critical value of sensitive index, the accuracy of prediction should be considered. When the measured index value is less than the reference critical value, there is no abnormal in the process of the investigation area excavation. When the index exceeds the reference critical value, after the implementation of the advanced emission measures, the effect test and measurement index decreases significantly. Such as outburst prediction index of 3303 open-cut contact roadway, $S$ is 10kg/m, $\Delta h_2$ is 220Pa, after carrying out the advance discharge measures of working face, $S$ is 3.2 kg/m, $\Delta h_2$ is 100Pa. The maximum effect test index $S$ is 5.5 kg/m in the area where the index exceeds the critical value, then excavate safely. The sensitive indexes critical value of working face outburst prediction are that under the normal geological conditions, $S$ is 6kg/m, $\Delta h_2$ is180Pa.

When there are roof breaking, stratification disorder, hole-spraying, type V, IV destructed coal, soft layer thickening, rib-fall and so on in the working face, $\Delta h_2$ that excavates safely is 120 Pa. Coal and gas outbursts occur frequently nearby small geological structure in the mine area, so the sensitive indexes critical value of working face outburst prediction are that under the abnormal geological conditions, $S$ is 5kg/m, $\Delta h_2$ is120 Pa.

5. **Conclusion**

According to the characteristics that outburst often occurs in the vicinity of geological structure, different critical values of sensitive indexes are investigated and determined to improve the reliability of outburst risk prediction of working face. The application shows that the sensitive index and its critical value are suitable for the mining and geological conditions in the test area, which provides a basis for the prediction of No.3 coal seam working face in the test area.
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