Construction and application of gas emission feature outburst early warning system in working face

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Abstract. In order to realize the accurate early warning of coal and gas outburst in Xinyuan Coal Mine, the early warning system of coal and gas outburst based on the dynamic characteristics of gas emission is constructed by using the dynamic characteristics of gas emission. The results show that the outburst early warning system based on the characteristics of gas emission can realize the real-time and dynamic early warning of the outburst danger of the working face of Xinyuan Mine, and the early warning accuracy is up to 79%, which ensures the daily safety production of Xinyuan Mine.

1. Introduction
At present, the method of measuring coal seam gas content is mainly used in the regional prediction and measure effect test of coal face in our country [1-2], and the drilling cuttings gas desorption index K1 and drilling cuttings quantity method are mainly used in local prediction and measure result test [3-6]. The prediction technical method is a static and discontinuous prediction technical means, in theory, it is a sampling inspection method, and it has its own defects in technology. This technology is affected by many factors, such as coal seam occurrence change, drilling hole layout, sampling method, human factors, instruments and equipment and so on. At the same time, with the continuous improvement and improvement of the comprehensive mechanization level of mine mining and the acceleration of advancing speed, the stress state of coal and rock in front of the working face becomes more complicated. And once the disaster of coal and gas outburst occurs in the fully mechanized mining face, it will cause great casualties and property losses. Therefore, it is of great practical significance to study the relationship between gas emission and outburst and establish a gas emission characteristic analysis system to realize non-contact and continuous prediction of outburst danger.

2. Engineering background
Xinyuan Mine, which belongs to Shouyang Coal Management Co., Ltd., Shanxi Yang Coal Group, began construction in 2001 and was put into production in April 2007. the production capacity of the first phase of the mine reached 3.0Mt/a. The conclusion of risk appraisal of coal and gas outburst in No. 3 coal seam of Xinyuan Coal Mine is that the maximum gas pressure in No. 3 coal seam is 2.44MPa, the minimum firmness coefficient of coal is 0.21, and the maximum initial velocity of gas emission is
21.8. Coal seam No. 3 has the danger of coal and gas outburst. The mine has been upgraded to a coal and gas outburst mine. Coal and gas outburst occurred twice in the No. 3 coal seam during mining. Gas disaster has become a bottleneck restricting the high-yield, high-efficiency and sustainable development of Xinyuan Mine.

3. The principle of outburst early warning technology based on the characteristics of gas emission

The study shows that there is a certain relationship between the change of gas emission in working face and coal and gas outburst [7]. The technical principle of outburst early warning system based on gas emission characteristics is to find the coupling relationship between gas emission dynamic characteristics and outburst influencing factors (coal gas content, coal structure, permeability and other outburst influencing factors) [8-9]. The change of outburst influence factors will affect the dynamic characteristic denaturation of gas emission to a certain extent, and the characteristic index reflecting the influence factors of outburst is established. The reason why these indicators can become a continuous outstanding prediction means mainly lies in their continuity in time and space. Therefore, the underground gas monitoring data can obviously reflect the outburst risk of coal in front of the working face, as shown in Figure 1. The gas emission data are obtained through the mine safety monitoring system, and the inherent characteristics of gas concentration time series are analyzed in real time, so as to extract the potential information related to coal and gas outburst, and carry on the identification and early warning of outburst danger [10-13].

![Figure 1. Relationship between gas emission characteristics and outburst risk](image)

4. Construction of early warning system for coal and gas outburst

The mine gas emission dynamic analysis system (referred to as "KJA system") mainly obtains the gas concentration data of the underground working face by installing the gas sensor or the existing mine comprehensive monitoring system, and then automatically calculates the outburst hazard index of the current working face based on the dynamic characteristics of gas emission according to the roadway parameters set by the control terminal, and publishes it in the form of early warning client, short message terminal or web page.

The main operation, analysis and setting functions of the KJA prominent early warning system are realized on the KJA client. After the client is installed, click the icon to enter the main interface of the system.
5. Field application analysis

Table 1. Early warning statistical table of Xinyuan Mine

| Publish information | Normal | Threat | Danger |
|---------------------|--------|--------|--------|
| 5172 times          | 4980 times | 128 times | 64 times |

Table 2. Application statistics of Xinyuan Mine early warning system

| Serial number | Working face                                      | Publish information | Early warning section | Threat times | Dangerous times |
|---------------|--------------------------------------------------|----------------------|-----------------------|--------------|-----------------|
| 1             | East second main roadway in the fourth mining area | 360                  | 2                     | 6            | 1               |
| 2             | East second secondary roadway in the fourth mining area | 360                  | 4                     | 14           | 7               |
| 3             | Southern auxiliary transport down the mountain    | 360                  | 1                     | 3            | 0               |
| 4             | East first main roadway in the fourth mining area | 360                  | 0                     | 0            | 0               |
| 5             | East seven middle lane (Inside)                   | 360                  | 9                     | 65           | 29              |
| 6             | Southern belt coal head                           | 360                  | 0                     | 0            | 0               |
| 7             | East Qiliu lane (Inside)                          | 360                  | 5                     | 17           | 16              |
| 8             | South wind goes down the mountain                 | 360                  | 1                     | 6            | 1               |
| 9             | Dongqi main lane                                  | 360                  | 0                     | 0            | 0               |
| 10            | The wind is back to the south-east and down the mountain | 360                  | 1                     | 3            | 0               |
| 11            | East three main roadway in the fourth mining area | 360                  | 0                     | 0            | 0               |
| 12            | Northwest return wind                             | 360                  | 0                     | 0            | 3               |
| 13            | West seven main lane                              | 360                  | 1                     | 2            | 3               |
| 14            | East eight lane                                   | 360                  | 3                     | 9            | 4               |
| 15            | Dongsanliu roadway in the fourth mining area      | 132                  | 1                     | 3            | 0               |

Since it was officially put into operation, the early warning system of Xinyuan Mine has issued information 5172 times, with a cumulative footage of more than 2500m, of which 4980 times have been issued with normal information, accounting for 96.29%, of which 28 sections have been alerted, with a total of 192 times of early warning, including 128 times of threat warning, accounting for 2.47% of the total number of early warning, and 64 times of danger warning, accounting for 1.24%.

The East Seven Intermediate Lane has the highest warning frequency, with an early warning frequency of 26%, which to a certain extent shows the seriousness of the outstanding threat in this working face, as shown in Table 1 and Table 2.

The key to the effect of KJA early warning is the performance of the accuracy of early warning outburst danger. In order to verify the early warning effect of the early warning system in Xinyuan Mine, the mine organized a project team to track and analyze the test during the period from September 26 to November 2. The project team mainly adopted the verification method of actual measurement and observation after early warning, that is, the actual measured K1 value and gas content were compared after the early warning results released by the system to verify the accuracy of the early warning system.

Taking Dongqi Intermediate Lane as the investigation object, the accumulative footage of Dongqi Intermediate roadway from September 26th to October 31th is 87m, with a total of 28 early warning times and 5 section early warning.
According to statistics, it is found that:

1. Dongqi middle lane, October 7th issued early warning message, October 7th gas content is 8.5274 m³/t, increase the pressure relief hole 5, carry on the effect test after the production without outburst danger.

2. Dongqi middle lane, October 12th early warning message, October 12th coal head appeared a large number of soft coal, drilling cuttings, increased pressure relief holes 5, effect test without outburst danger after production, October 14th hole gas 100%, construction 27 drainage holes, stop gas drainage.

3. Dongqi middle roadway, October 18th early warning message, October 18th coal seam bedding disorder, 20-5 cm rock below the roof, 5 additional pressure relief holes, no outburst danger by effect test.

4. Dongqi middle roadway, October 20th early warning message, October 21th gas content is 9.23 m³/t, increase 5 pressure relief holes, carry out effect test after production without outburst danger. October 22th hole gas reaches 100%, immediately stop, October 22th geophysical exploration in front of 13 m abnormal, immediately stop 35 pre-extraction holes.

5. Dongqi middle lane, October 30th early warning message, October 30th gas content 10.7541 m³/t, orifice gas 90%, immediately stop the first 38 pre-extraction holes.

6. Conclusion

1. On the basis of the existing gas disaster comprehensive early warning system platform, combined with the actual situation of Xinyuan Mine, the KJA outburst early warning system, KJA short message release platform and KJA outburst early warning website are adaptively developed, and the coal and gas outburst early warning system suitable for Xinyuan Mine is formed.

2. Through the verification of the early warning effect of Dongqi intermediate roadway in Xinyuan Coal Mine, the early warning accuracy reaches 79%, which achieves the goal of providing basis for regional comprehensive outburst prevention measures and auxiliary decision-making for advance early warning of local outburst prevention and control. The functions of real-time monitoring, online analysis, intelligent early warning and timely release of coal and gas outburst disasters are realized, which greatly improves the technical level of mine outburst prevention and promotes mine safety production.

3. The early warning system of coal and gas outburst based on the characteristics of gas emission can provide reference for similar coal mines.

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References
[1] Cheng Bo, Qiao Wei, Yan Wen, Xiang Yanbin. Research Progress on determination methods of Gas content in Underground Coal seam [J]. Safety and Environmental Protection of Mining Industry, 2019, 46 (04): 98-103.

[2] Huo Yanzhao. Analysis of determination process and influencing factors of gas content in coal seam [J]. Petrochemical Technology, 2019, 26 (12): 160-168.

[3] Lei Hongyan. Experimental study on rapid determination of critical value of drilling cuttings gas desorption index K1 [J]. Coal Science and Technology, 2019, 47 (8): 129-134.

[4] Liu Zhiwei. Study and application of critical value of gas desorption index for drilling cuttings of wet coal samples [J]. China Coal, 2018, 44 (11): 105-107+118.

[5] Xing Changyong, Yang Han, Huang Guangping, Zhang Dongming, Jiang Zhigang. Determination of sensitive index and critical value of coal seam outburst prediction in Xuyong No. 1 Coal Mine [J]. Coal Technology, 2020, 39 (11): 83-86.

[6] Wang Zhiming, Feng Haipeng, Chen Bing. Study on reasonable sealing depth of bedding boreholes based on drilling cuttings method [J]. Coal Technology, 2015, 34 (5): 164-165.

[7] Tan Guowen. Construction and application of multi-parameter early warning system for coal and gas outburst disaster in complex mining area [J]. Coal Engineering, 2020, 52 (3): 17-20.
[8] Xu Xuezhan. Research and application of cooperative prediction technology of coal and gas outburst [J]. Industrial and Mining Automation, 2020, 46 (4): 10-16.

[9] Zhang Nianwei. Research status and development trend of coal and gas outburst early warning technology [J]. Inner Mongolia Coal Economy, 2020 (3): 106-108.

[10] Liu Yanwei, Liu Mingju, Wu Gangsheng. Selection and Application of Gas Emission characteristics and Prediction Indexes before outburst in No.10 Coal Mine of Hemei[J]. Coal Mine Safety, 2005 and 36 (11): 18-21.

[11] Zou Yunlong, Zhao Xusheng, Sun Dongling, et al. The gas emission time series of blasting face is used to predict the outburst risk of working face [J]. Mining Safety and Environmental Protection, 2010, 37 (3): 7-10.

[12] Wang Jianmin, Ma Guolong. Application of outburst early warning technology based on gas emission characteristics in Dashucun Coal Mine [J]. Mining Safety and Environmental Protection, 2013, 40 (6): 39-42.

[13] Chen Qinghua, Zhang Guoshu. Development of coal and gas outburst prediction software based on gas emission anomaly [J]. Coalfield Geology and Exploration, 2007, 35 (3): 18-21.