Application of outburst warning technology based on gas emission characteristics in Xiayukou Coal Mine

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Abstract. Early warning of coal and gas outburst based on gas emission characteristics is a more feasible and effective outburst prediction method. In order to make up for the limitations of the existing traditional contact coal and gas outburst prediction methods, the gas emission dynamic characteristics were used to carry out coal and gas outburst warnings, and the Xiayukou Coal Mine outburst warning system based on gas emission characteristics was constructed. The field application practice shows that the system can evaluate and warn the dangerous state and development trend of the working face stably and reliably. The system has tracked and inspected the tunnel length in the underground mine over 500m, and caught many abnormal gas phenomena in advance, and realized the real-time monitoring, online analysis, and intelligent early warning of coal and gas. It has extremely important practical significance for improving mine gas control and daily safe and efficient production.

1. Introduction
Xiayukou Coal Mine is one of the main production mines of Shanxi Coal Hancheng Mining Co., Ltd. Since it was put into operation in December 1975, with the continuous increase of mining intensity and depth, the gas level of the mine has continued to rise. In the more than 40 years of mine mining, coal and gas outbursts have occurred more than 20 times. The maximum outburst coal volume is 1,100t, and the maximum gas emission volume is 42,000 m³. Coal and gas outbursts have become the main disaster types that restrict the safe and efficient production of Xiayukou Coal Mine [1].

In order to ensure safe production, Xiayukou Coal Mine invests a lot of manpower, material resources and financial resources in outburst prevention and control every year. At present, it has formed two "four-in-one" outburst prevention systems with "regional measures first and local measures supplemented", highlighting prevention and control. The work has achieved remarkable results. However, the outburst prediction method in the local "four-in-one" is a contact point prediction method, which mainly predicts by drilling on the coal wall, measuring the amount of drill cuttings, and cutting gas desorption index. This traditional forecasting method is not only complicated in procedures, but also takes a long time to forecast, which affects the speed of advancement of the working face, especially
under the current situation of tight replacement of mining in the Xiayukou coal mine, it severely restricts the development of mine productivity [2]. Therefore, to study a non-contact, continuous (in time and space does not affect mine production operations) outstanding prediction method, real-time, uninterrupted prediction of outstanding hazards is of great significance for the realization of safe and efficient production of mines.

2. Principle of outstanding early warning technology based on gas gushing characteristics

Gas emission characteristics are controlled by many influencing factors such as coal gas content, coal gas desorption characteristics, coal permeability, mining technology and mining technology. However, not all of the influencing factors of gas emission are prominent influencing factors, and a variety of prominent influencing factors are often implicit in the same gas emission feature, and these influencing factors may cancel each other out [3-6]. For example, the greater the gas emission, the more obvious the characteristics of the gas emission, indicating that the greater the gas content in the coal body ahead, the higher the risk of outburst.

However, the large amount of gas emission may also be the reason for the large amount of gas emission from the coal wall of the roadway. The large amount of gas emission from the coal wall of the roadway indicates that the outburst risk caused by the coal gas content is not high, but the outburst risk is reduced due to the good coal wall permeability. The establishment of prominent predictive indicators must ultimately be the establishment of a relatively complete system or a set of relatively complete systems to directly predict the prominent hazards of the working face, but the implementation process should be different. Therefore, proposing a set of principles for establishing an effective gas emission index system is an important basis for the practical application of the final gas emission dynamic feature prediction of coal and gas outburst. Based on the analysis of the current application of the prominent predictive index system on site, it is believed that the establishment of the gas emission index system should follow the following principles.

1. The establishment of gas emission index should avoid the phenomenon that the same index reflects multiple prominent influencing factors that cause factors to influence each other, and summarize the field application of the combined prediction technology for regional prominent prediction comprehensive index D and K1 value or $\Delta h^2$ and drill cuttings volume S, and establish four types of indicators that can separately reflect changes in content, coal structure, ground stress, and mining environment.

2. Analyze and study the current description method of "suddenly large and small" gas gushing. Due to the backwardness of research technology, it is difficult to study the physical meaning of the prominent omen of gas gushing "suddenly large and small". However, it is possible to explain or explain the shortcomings of the current research methods of "sudden large and small" through the study of the calculation method of the phenomenon of "sudden large and small", and try to propose more effective calculation methods.

3. Establish an index calculation model that is less affected by the underground construction process. The underground construction process and even the construction process have an inevitable impact on the gas emission characteristics. It is almost impossible to completely establish an index system that is not affected by the underground operation. However, indicators that are too sensitive to the impact of operating procedures have serious shortcomings in terms of on-site practicality. Predecessors studied the nearly harsh requirements of the V30 index for the amount of coal falling, which is a typical negative example. Through a certain mathematical method, the establishment of an index calculation model that is less affected by the underground construction process is an inevitable requirement of the gas outburst prediction method.

4. Establish an automatic calculation of gas emission indicator model. Less human participation in the indicator calculation process is the basis of non-contact, continuous prediction technology and a reliable guarantee for field application practice. Therefore, from the establishment of the index model, certain considerations should be made to the automatic calculation factors.
According to the principles of establishing four indicators, four characteristic indicators of gas volume, gas desorption, gas fluctuation, and gas trend are established [7-11], as shown in Figure 1.

**Figure 1.** The relationship between gas emission characteristics and prominent influencing factors

According to the outburst hazard characteristics of the Xiayukou Coal Mine, two early warning methods are selected to reflect local anomalies in gas occurrence, and changes in coal body structure caused by changes in coal bodies and geological structures. And the trend warning indicator A of gas volume and the state warning indicator B that characterizes the coal structure are determined. The specific indicators and critical values are shown in Table 1.

| Coal seam       | Early warning indicators | Warning level | Ranges    |
|-----------------|--------------------------|---------------|-----------|
| 2<sup>nd</sup> Coal seam | A index                  | Danger        | [12, +∞)  |
|                 |                          | Threat        | [9, 12)   |
|                 |                          | Normal        | (-∞, 9)   |
|                 | B index                  | Danger        | [0.9, +∞) |
|                 |                          | Threat        | [0.6, 0.9) |
|                 |                          | Normal        | (-∞, 0.6) |
| 3<sup>rd</sup> Coal seam | A index                  | Danger        | [9, +∞)   |
|                 |                          | Threat        | [6, 9)    |
|                 |                          | Normal        | (-∞, 6)   |
|                 | B index                  | Danger        | [0.9, +∞) |
|                 |                          | Threat        | [0.6, 0.9) |
|                 |                          | Normal        | (-∞, 0.6) |
3. Outstanding early warning construction based on gas emission characteristics

The outburst early warning system based on the characteristics of gas emission ("KJA system" for short) is the realization method of early warning technology, which mainly obtains the gas concentration data of the underground working face through the installation of underground gas sensors or the existing comprehensive monitoring system of the mine. Then, according to the tunnel parameters set by the control terminal, it automatically calculates the salient hazard index of the current working face based on the dynamic characteristics of gas emission, and publishes it in the form of an early warning client, a short message terminal or a web page. KJA highlights the main functions of the early warning system including gas emission dynamic feature analysis, monitoring noise data filtering, gas emission early warning indicators and rule settings, early warning result management and system management, etc.

KJA highlighted that the early warning system operated stably during the inspection period, with the following characteristics: (1) The system runs faster. According to the investigation result, the system starts to normal operation within 5s. (2) The database growth rate is slow. During the normal operation of the system, the system database generally grows by about 5M per month. (3) The system has a low error rate. When the user operates and maintains the system in accordance with the requirements of the "User Manual", the continuous and stable operation time of the system shall not be less than 6 months. At the same time, the early warning system is designed in accordance with the "Detailed Rules for Prevention and Control of Coal and Gas Outbursts" and relevant industry standards. It has sufficient theoretical basis and can accurately and automatically predict and analyze the dangerous information of coal and gas outbursts in front of the work. And it has good reliability.

4. Application effect investigation

During the inspection phase of the early warning system of the Xiayukou Coal Mine, we continuously tracked 21228 Jinshun, 22206 Yunshun, 23202 Jinshun and 21314 Huishun and other tunneling faces. The inspection lasted 3 months and the inspection footage was more than 1,500 meters. Table 2 shows the statistical results of the forecast indicators of the 23202 Jinshun working face from 2020.1.2 to 2020.1.14. It can be seen from Table 2 that the working face prediction index exceeds the limit on 2020.1.8, and the maximum value of the debris and gas desorption index $\Delta h_2$ is 180Pa, indicating that there is a certain degree of danger in front of the working face. Afterwards, the mining face was stopped and local outburst prevention measures were implemented (first drill a row of 12 safety barrier holes, and then drill a row of 15 measure holes for gas pressure relief and discharge), and then the forecast indicators of the working face returned to normal.

| Date       | Maximum drilling cuttings gas desorption index $\Delta h_2$/Pa | Drilling cuttings /kg/m | Coal seam thickness /m |
|------------|-------------------------------------------------------------|--------------------------|------------------------|
| 2020/1/2   | 80                                                          | 4.0                      | 1.2                    |
| 2020/1/4   | 90                                                          | 4.0                      | 1.1                    |
| 2020/1/5   | 80                                                          | 4.2                      | 1.0                    |
| 2020/1/7   | 90                                                          | 3.9                      | 1.1                    |
| **2020/1/8** | **180**                                                      | **4.5**                  | **0.8**                |
| 2020/1/9   | 80                                                          | 3.8                      | 1.1                    |
| 2020/1/10  | 90                                                          | 3.8                      | 1.0                    |
| 2020/1/12  | 80                                                          | 3.9                      | 1.0                    |
| 2020/1/13  | 80                                                          | 3.9                      | 1.2                    |
| 2020/1/14  | 90                                                          | 4.0                      | 1.1                    |

Figure 2 shows the early warning results of the early warning system. It can be seen from Figure 2 that the threat warning information will be issued for three consecutive shifts starting from the four o'clock shift of 2020.1.5, and the danger warning will be issued continuously on the eight o'clock and...
four o'clock shifts of 2020.1.7. And the A index reaches 12.95. The eight o'clock shift of 2020.1.8 issued a threat warning message again, indicating that there is indeed a certain degree of danger at the working face. The early warning system issued a hazard alert one day earlier, and foreseeably issued a threat alert three days ago. The early warning results are advanced and reliable.

![Figure 2. The early warning results of the early warning system](image)

In the 4 tunneling face effect inspection stages of 22206 Yunshun, 23202 Jinshun, 21314 Huishun and 21228 Yunshun, the early warning system sent more than 800 warnings in total. In all the early warning results, there were no such outstanding risks as the daily forecast indicators of the working face exceeding the limit, rapid changes in coal seams, and structural exposure, but the early warning system did not send out early warning signals. The early warning rate was 0.

5. Conclusion
(1) On the basis of the existing Xiayukou Coal Mine monitoring system, a set of early warning system integrating PC client, Web browsing terminal and SMS sending platform has been established. The system realizes multi-channel query of early warning results, and the system can release early warning results in various forms in real time, realizing online gas disaster monitoring, advance warning and trend grasping.

(2) The early warning system is actually operating at the Xiayukou Coal Mine, which can stably and reliably evaluate and warn the dangerous state and development trend of the working face. It has tracked and investigated the length of the roadway in the underground mine over 500m, and caught many abnormal gas phenomena in advance. It has been achieved a good application effect.

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