Research and Application of Regional Outburst Risk Prediction Based on Gas Content Method

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Abstract. The prediction of regional outburst risk is an important guarantee to strengthen the pertinence and effectiveness of the outburst prevention measures and improve the economic benefits of the mine. Based on the analysis of the law of gas occurrence in working face, this paper puts forward the method of predicting regional outburst risk with gas content as the prediction index, determines the critical value of the index, and using this method to predict outburst risk in working face. The field practice shows that the gas content method based on the results of regional prediction and pertinence of outburst prevention measures, reduce the outburst prevention drilling engineering quantity, the regional gas control to reduce costs, the production time is shortened, precision achieved mine outburst prevention, good results have been achieved, the method is applied in the coal mine.

1. Introduction
As the mining depth of coal mine increases, the complex geological conditions, gas pressure and content no longer show a significant linear relationship with the increase of the buried depth, and the deep mine safety problem caused by outburst is more complicated[1-3]. "Low index outstanding phenomenon", brings to the mine safety production hidden danger[5 ~ 9], the main reason is the sensitivity of the predictor and the critical value is not in conformity with the mine reality, especially for the large depth of the nearly horizontal coal seam, gas occurrence difference is bigger, most of the mine area outburst danger prediction using the prevention and control of coal and gas outburst regulations provided by the gas pressure, gas content, the critical value of 0.74MPa, 8m³/t index[4], the division of hazardous area is determined according to elevation, which is very unreasonable [9~10]. Therefore, it is of great significance to study and determine the risk index and critical value of regional outburst prediction in line with the actual coal mine for gas prevention and control.

11-2 based on the research of mines on the basis of coal seam gas occurrence regularity, to determine the gas content highlight the critical value, by the method of gas content in the area of mining face outburst danger prediction, and formulated the corresponding outburst prevention measures to reduce the outburst prevention of quantities, the gas control to reduce costs, improve the economic benefit of mine, realized safety mining of working face, for the similar condition of coal seam occurrence outburst danger zone division provides reference.
2. Engineering Background
11-2 coal seam buried depth of 963~1083m, average thickness of coal seam 1.57m, the average Angle of 5°, coal seam occurrence stability; The top and bottom strata are mainly mudstone and sandstone, and the maximum gas pressure measured is 0.25~1.2MPa, and the gas content is 3.64~8.39m$^3$/t. Roof sandstone has strong impact tendency and coal seam has weak impact tendency. This coal seam is the coal and gas outburst coal seam dominated by ground stress.

3. Analysis of Gas Occurrence Regular

3.1. Analysis of Geological Gas Parameters
By statistical analysis of the gas content and gas composition of mine geological survey, the variation trend of coal seam buried depth is shown in figure 1, figure 2. Geological exploration of gas components of CH$_4$:CO$_2$:N$_2$ = 1.93%~94.13%: 1.29%~68.58%: 2.08%~85.86%, and most CH$_4$ component is 40%~85%. According to the law of gas zoning, the 11-2 coal seam is located in the complex zone between the N$_2$-CH$_4$ belt and the CH$_4$ belt. The gas content of geological survey is 1.87~14.11m$^3$/t, and the trend of increase with the increase of coal seam buried depth is not obvious, but fluctuates within a certain range. The correlation coefficients in the fitting formula are 0.2895 and 0.2296 respectively, which are of poor correlation, indicating that the gas content in this region is not uniform and the regular is not obvious.

![Figure 1. Variation relation of natural gas composition with buried depth](image1.png)

![Figure 2. Relation of gas content in geological survey with buried depth](image2.png)
3.2. Analysis of measured gas content underground.

The measured gas content was 3.73~8.39m$^3$/t during coal roadway driving in the 11-2 coal seam. The relation between the gas content and the elevation is shown in figure 3. It can be seen from the figure that the trend of increasing gas content with the increase of elevation is not obvious, but fluctuates within a certain range, and the dispersion gradually increases, which further indicates that the gas content in this region is not uniform and the law is not obvious. At the same time, gas components CH$_4$:CO$_2$:N$_2$ = 40.79%:26.20%:30.15%, 59.94%:23.23%:16.30%. 11-2 coal seam is located in the mixed zone of gas zone and gas weathering zone. The relation between the gas content and the buried depth is not obvious. The regularity of gas occurrence is poor, and the gas content is relatively low compared with the typical outburst coal seam.

4. Study on Forecast Index of Outburst Risk by Gas Content Method and Determination of Critical Value

4.1. The Reasonableness of Outburst Risk Prediction was Analyzed by Gas Content Method

During the coal roadway excavation in the working face of the 11-2 coal seam, there are obvious warning signs of dynamic hazards such as clamping, boring, shotcrete and blasting, etc. Near the structures such as faults, folds or changes in coal thickness. When the hole was sprayed, the drill chips were obviously heated up and burned, and the particle size became coarse, while the gas concentration on the working face was basically unchanged. Indicating that the prediction indexes of coal and gas power danger areas on the working face were sensitive to reflecting the ground stress. The gas desorption characteristic curve of hard coal and soft coal is $K_{hard} = 0.1397P^{0.5504}$ and $K_{soft} = 0.3677P^{0.6405}$. Compared with domestic typical coal seams, coal gas desorption characteristics of the poor. During working face advancing predictor of $K_1$ and $\Delta h_2$ determine values range from 0~0.15ml/g $\cdot$ min$^{1/2}$, and predictor of $\Delta h_2$ determine values range from 0 ~ 60pa. It also indicates that the sensitivity of gas desorption index is poor. It is difficult to predict in-situ stress of coal and gas outburst danger.

In the process of excavating in coal roadway, especially near the geological tectonic belt, in-situ stress leading sign more apparent. It can not be simply specified outstanding dangerous zone according to the relevant standards by the gas pressure of 0.74MPa or the gas content of 8m$^3$/t. Therefore, the prediction of regional outburst risk in the 11-2 coal seam mainly takes into account the main energy index reflecting the dynamic phenomenon and the factors causing the disaster, so as to facilitate the adoption of targeted regional prevention and control measures.

The dynamic prediction of coal roadway driving in working face is mainly due to ground stress. However, when the gas content in coal seam reaches a certain value, the gas harm after dynamic
phenomenon will be highlighted. The gas permeability of deep coal seam is poor, the original fracture of coal seam is not developed, the gas in free state is less, and the deep surrounding rock has partition rupture phenomenon, which has certain influence on the accuracy of gas pressure test of coal seam. Therefore, the gas content can better reflect the gas hazards of dynamic disasters. Based on this, the outburst risk prediction should be made according to the coal seam gas occurrence law and the geological structure, using the gas content as the index.

4.2. The index critical value is determined

According to the domestic and foreign research shows that the minimum outburst of coal seam gas pressure value and the consistence coefficient of coal volatile, a certain functional relation \( P_{\text{min}} = (f, V_{\text{daf}}) \), and the volatile coal metamorphic degree of coal seam, is often volatile score for the same coal seam is stable, is along with the coal volatile score, established the coal seam outburst risk minimum and the consistence coefficient of coal gas pressure values [9 ~ 11]:

\[
P_{\text{min}} = 0.5 + 0.0085 V_{\text{daf}} \cdot f_{\text{min}}
\]  

\( V_{\text{daf}} \) - volatile content of coal seam, %;
\( F_{\text{min}} \) - minimum firmness coefficient of coal seam.

Based on the above formula, the minimum gas pressure value of outburst in the 11-2 coal seam can be calculated as 0.71MPa. By using Langmuir equation, the minimum gas content value of outburst in the 11-2 coal seam is 7.28m³/t. Therefore, the critical value of outburst gas content in the 11-2 coal seam is respectively 7.23m³/t. In order to simplify field management and improve the safety factor of regional prediction, the critical value of regional prediction of the working face was preliminarily determined as 7.23m³/t.

5. The Engineering Application

5.1. Forecast Results of Coal Seam Outburst Risk

According to the above research and analysis and combined with the requirements of "regulations on prevention and control of coal and gas outburst", the prediction methods and indicators of coal and gas outburst risk areas are as follows: The critical value of gas content of 11-2 is 7.23m³/t, and its adjacent 50m range is divided into outburst danger area. The influence range of 50m on both sides and folding flanks of the faulted faults is divided into outburst danger area. The prediction results of the outburst risk area of the first mining face are as follows:

Region 1: area 190~356m of rail distance orbital gateway, area 150~290m of operation distance transport gateway. This area is affected by FD35 fault, and the coal seam and roof strata are broken, and the maximum measured gas content in this area is 8.39m³/t, which is easy to induce coal and gas outburst due to the influence of mining.

Region 2: the area of track alignment kerning is 435~535m, and the area of track alignment kerning is 367~468m. The gas content in this area is 7.24~7.92m³/t, and there is synclinal structure leading to stress concentration, which is easy to induce coal and gas outburst.

Region 3: rectangular region with orbit and transportation trough distance from the cutting hole of 860~1040 m, the gas content in this region is 7.34~7.63m³/t.

Region 4: rectangular region of track and transport trough away from stop-mining line 174~252m, with gas content of 7.56~8.12m³/t.
The remaining areas of the first mining face are all without coal and gas outburst danger areas. The prediction results of outburst risk in the first mining face are shown in figure 4.

5.2. Engineering Application Effect
The working face is predicted to be in the dangerous area of coal and gas outburst, and the regional prevention and treatment measures of drainage and mining holes along the construction layer, with holes of 108mm and spacing of 10m. In the area after pre-pumping, there was no dynamic phenomenon such as clamping drill and drilling suction during the drilling hole construction. The measured maximum residual gas content was 6.09m³/t, indicating that the regional measures were effective. During the stoping of working face, air drainage, buried pipe in goaf and surface drilling are combined to treat the gas of working face of 11-2 coal seam. The gas concentration in the return airflow is 0.26%~0.46%. The gas emission of this coal seam is 7.01~11.18m³/min.

![Figure 4. Prediction results of coal and gas outburst risk areas on working face](image_url)

6. Conclusion
Through the analysis of the geological survey and the measured gas data in the well, the correlation between the gas content in the 11-2 coal seam and the elevation (buried depth) is not obvious, and the whole is in the complex zone between the N₂–CH₄ belt and the CH₄ belt, with uneven gas occurrence and poor regularity.

According to the gas occurrence characteristics of the 11-2 coal seam, a method was proposed to predict the outburst risk area of the mining face using the gas content as the index. According to the correlation of coal seam gas parameters and the actual production requirements of the mine, the critical value of the gas content index was determined to be 7.23m³/t. In addition, the study results were used to predict the outburst risk area, which was divided into 4 outburst risk areas, and the rest were all non-outburst risk areas.

In the region of the gas content method is used to predict the result on the basis of adopting the outburst prevention measures, reduce the outburst prevention drilling engineering quantity, the regional gas control to reduce costs, the production time is shortened, precision achieved mine outburst prevention, realized safety mining of working face, the method is used widely in zhu-jixi coal, for the similar conditions of coal seam outburst danger prediction provides reference.

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