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Study on Sensitive Index and Critical Value of Gas Content in Mine Area of Complex Geological Area

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Abstract: *In order to study the regional sensitive index and critical value of mine in complex geological area, firstly, the geological and gas occurrence analysis of Sangshuping No.2 well coal mine in Hancheng City, Shaanxi Province, China was carried out. Secondly, the on-site 7000 m dynamic outburst prevention test working face was tracked and investigated, and the three-rate method was used for analysis. The results show that the geology of Sangshuping No.2 well is complex, and the problem of coal and gas outburst is serious. The gas content of more than 7000m and the field construction of 3# coal seam in Sangshuping No.2 coal mine were investigated. Using the three rate method, it is finally obtained that the critical value of the predicted gas content in the 3# coal seam area should be below 11m3/t.*

1. Introduction

China is one of the countries with serious coal and gas outburst disasters in the world[1].At present, coal and gas outbursts have caused huge losses to China's safety production. The geological occurrence law of coal seam gas in the process of mine mining is complex and diverse. Due to the influence of hydrology, geology and rock burst, coal mine mining process may face disasters such as coal and gas outburst and abnormal gas emission, which brings great challenges to coal mine safety production[2-3]. A large number of scholars have done a lot of research on the critical value of coal and gas outburst. Zhu J[4] established a BP neural network adaptive optimization (GA-BP) model based on genetic algorithm back propagation to reasonably identify deep gas outburst in coal mines. Niu H[5] developed a coupled disaster model suitable for deep, complex and heterogeneous strata, using theoretical indicators instead of empirical indicators, and improving these indicators according to specific coal seam characteristics.

In order to comprehensively and systematically grasp the gas parameters and occurrence characteristics of coal seams in complex geological areas, focus on promoting a complete set of technical systems for advanced gas control in large areas of mines, and improve the management and technical level of safe and efficient gas prevention and control in mines, it is necessary to analyze the geology and gas occurrence laws of coal mines [6-9], track the gas content and on-site construction of coal seams, and use the three-rate method to analyze the gas content and corresponding on-site conditions to obtain the gas content in complex geological areas.

2. Geological Analysis

The shallow 3# coal seam of Sangshuping No.2 well is located in the middle and lower part of Shanxi Formation, which can be mined in the whole area. The thickness of the two poles of the coal seam is 3.3 ~ 8.35m, with an average thickness of 5.97m. The formation dip angle is 1° ~ 8°, generally 3° ~ 5°, which belongs to the near horizontal coal seam. The main roof of the coal seam is mainly composed of medium and fine grained sandstone, with a thickness of 3.90 ~ 11.30m, generally 5 ~ 6m, and the uniaxial compressive strength of medium grained sandstone is 38.64 ~ 96.32MPa, with an average of

74.55MPa.

There are two relatively large faults in the shallow well field of Sangshuping No.2 well, DF11 and DF12, respectively, and the rest are small faults. There are two other folds, namely the Majiata anticline and the Majiata syncline. DF11 is a reverse fault with a drop of 0 ~ 8m ; dF12 is a normal fault with a drop of 0 ~ 9m. The thickness of $3^{\#}$ coal seam is generally 5 ~ 6m, and the coal seam is only partially disconnected. The blocking effect of fault on gas flow in coal seam is relatively small, and gas can flow smoothly along the coal seam in the area.

In addition, the $3^{\#}$ coal seam in this area is stable, and a soft layer is developed in the middle and lower part of the coal seam in the test area. The soft layer is gradually thickened from south to north and from east to west.

3. GAS OCCURRENCE ANALYSIS

In 2017, the $3^{\#}$ coal seam of Sangshuping No.2 well was identified as outburst coal seam by Chongqing Coal Research Institute, and the mine was upgraded to outburst mine. The measured $3^{\#}$ coal seam gas pressure P = 0.94MPa, gas emission initial velocity ΔPmax =11.

The gas content of geological prospecting gas in the study area was 3.63 ~ 6.79m^3/t, with an average of 5.52m^3/t. The content of CH_4 ranged from 35.51% to 58.59%, with an average of 43.12%. The geological prospecting gas content in the lean coal area is 0.86 ~ 8.40m^3/t, with an average of 5.99m^3/t; the content of CH_4 ranged from 20.71% to 91.70%, with an average of 57.92%. In general, there is no significant difference in gas content and CH_4 composition between the two coal areas.

The coal quality of $3^{\#}$ coal seam in the study area is basically the same, the complexity of geological structure, the degree of coal seam failure, the thickness of soft layer and so on are similar, the coal seam in the area is basically continuous, and the gas can flow smoothly along the coal seam in the area. It can be considered that the scope of investigation is the same geological unit.

4. INVESTIGATION PLAN

At present, single index methods such as coal seam gas pressure or content, coal metamorphic degree and multi-index comprehensive regional prediction are commonly used in China, such as coal failure type, initial velocity of gas emission (ΔP), coal firmness coefficient (*f*) and coal seam gas pressure (P). 'Four-index method', gas geology method and geophysical prospecting combined with in-situ gas content measurement technology of borehole coal seam, these methods and indicators have high reliability for gas-dominated outburst prediction, while the prediction accuracy and reliability of in-situ stress-dominated coal and gas dynamic disasters are low.

In the aspect of regional risk prediction of outburst coal seam, the method of coal seam gas parameters combined with gas geological analysis is mainly used to predict. The critical value of regional outburst risk prediction of coal seam in China should be determined according to the experimental investigation. The critical values of gas pressure and content are 0.74MPa and 8m^3/t respectively. Chongqing Coal Research Institute and other units have developed a deep hole rapid sampling device, which provides a new technical equipment for the regional prediction of coal seam outburst danger by gas content method, improves the accuracy of coal seam gas content test, and increases the control range of coal roadway regional measure effect test. The combination of geophysical exploration and drilling is used to accurately detect the geological structure and the comprehensive analysis of the gas anomaly area to determine the outburst risk. The production practice shows that there are some limitations in using 8m^3/t as the critical value of outburst danger in coal seams in China.In some cases, when the gas content of coal seams is lower than 8m^3/t, outburst may also occur.

Because the development roadways in the shallow area of Sangshuping No.2 well are all coal roadways, and the original gas pressure measured by bedding boreholes has unfavorable conditions such as difficulty in sealing holes, long test time, high cost, inaccurate pressure measurement, and the measurement technology of gas content is relatively mature and accurate. Therefore, the gas content is selected as the prediction index of the outburst risk area of the long borehole section in the shallow area of the mine.

In the test area of nearly horizontal $3^{\#}$ coal seam in shallow mining of Sangshuping No.2 well, the

occurrence of coal seam is relatively stable, the main structure of coal seam is I and II, the cracks are relatively developed, and there are III and IV soft layers in local areas, and the law of soft layer thickening from south to north and from east to west is obvious. The thickness and gas content of the soft layer in the coal seam structure are the main indicators reflecting the regional outburst risk. The original gas content is high, and the coal seam is hard. The gas geological conditions of the coal seam are relatively hard. The buried depth of the mining $3^{\#}$ coal seam is small, and the critical value of the outburst gas content is uniformly set to $8.0m^3/t$. There is a certain blindness in the regional outburst prevention work. In order to ensure the safe and efficient production of Sangshuping No.2 well, it is necessary to analyze the coal and gas outburst law of the roadway in the north area of Sangshuping No.2 well to determine the critical value of the gas content index.

Under the premise of taking strict safety protection measures and ensuring safety, combined with a certain roadway project, the original gas content determination of coal seam and the residual gas content test engineering investigation, the critical index of gas content prediction in $3^{\#}$ coal seam outburst area is determined.

5. INVESTIGATION METHODS

During the test period, the gas content of $3^{\#}$ coal seam heading face in Sangshuping No.2 well was tracked and investigated. The main contents of follow-up investigation include: the measured value of gas content in coal roadway excavation face; coal and gas dynamic phenomena and signs in the process of operation, geological structure of working face, etc. The critical value of gas content is determined by statistical analysis of ' three rate ' method.

Sangshuping No.2 well uses the ' three rate ' analysis method to determine the critical value of gas content in $3^{\#}$ coal seam. The ' three rate ' analysis method is briefly described as follows. The so-called ' three rate ' refers to the prediction of outburst rate, prediction of outburst accuracy and prediction of non-outburst accuracy. The calculation formula is as follows:

(1) Predicted outburst rate

$$\eta_1 = n/N \tag{1}$$

Among them: η_1-predicted prominence rate, %;

n- Predicts the number of times there is a significant risk, times;

N- Total number of predictions, times.

(2) Prediction accuracy

$$\eta_2 = n_1/n \tag{2}$$

Among them: η_2-predicted outburst accuracy, %;

n_1 - Predict the number of times there is a risk of outburst in the number of times there is a risk of outburst, including : 1 the actual occurrence of outburst ; 2 In the prediction, there are serious outburst signs such as nozzle hole, sticking, top drilling and frequent coal gun. 3 In the vicinity of faults, small folds and other geological structural belts, the prediction indexes are obviously increased.

(3) Prediction does not highlight the accuracy rate

$$\eta_3 = n_2/n_3 \tag{3}$$

Among them: η_3-prediction does not highlight the accuracy, %;

n_2-the number of times that there is no outburst danger in the number of predicted non-outburst times;

n_3 - Predict the number of non-outburst times, times.

The predicted outburst rate η_1 in the ' three rates ' represents the proportion of the predicted outburst

dangerous section to the total predicted section. The smaller the η_1, the smaller the range of outburst prevention technical measures to be taken. Therefore, under the premise of ensuring accurate prediction, the smaller the η_1, the better. According to the tracking investigation results of the former Soviet Union on the roadway excavation face, the section with actual outburst danger in the outburst danger zone accounts for 10% -15% of the total area of the coal seam, so the ideal value for predicting the outburst rate should also be 10% -15%. However, under the current technical level, the prediction prominence rate is generally not high. According to experience, it is generally believed that η_1 does not exceed 30%.

The prediction outburst accuracy η_2 reflects the accuracy of the prediction outburst, and the higher the better. However, due to the fact that the mechanism of gas outburst is still unclear, the prediction methods and prediction methods lack strict theoretical basis, and the accuracy of prediction is generally not high. According to the current technical level, the general requirement is not less than 40%.

The prediction accuracy of non-outburst η_3 reflects the safety and accuracy of outburst risk prediction with this index. The higher the accuracy rate of non-prominent prediction, the lower the rate of outstanding omission, and the better the safety. Because of the great harm of gas outburst, and when the prediction is no outburst dangerous working face, usually do not take measures to eliminate the outburst of direct tunneling, prediction accuracy η_3 should reach 100%.

Therefore, when the prediction index is used to predict the outburst risk of the working face, the predicted outburst rate η_1 is as small as possible and does not exceed 30%; the prediction accuracy η_2 is as large as possible and not less than 40%. The prediction accuracy η_3 reaches 100%. Therefore, according to the change of the 'three rates' when the prediction index takes different critical values, the critical interval of the prominent prediction index can be found and the reasonable critical value can be determined. According to the 'three rate' requirements, the steps to determine the critical value of gas content are as follows:

1. According to the tracking investigation of the predictive index, when the critical value of the predictive index is analyzed, the expression of the 'three rates' is calculated as follows :

$$\eta_1 = f_1(x_l) \tag{4}$$

$$\eta_2 = f_2(x_l) \tag{5}$$

$$\eta_3 = f_3(x_l) \tag{6}$$

2. According to the change of 'three rates', the critical value range of gas content XL must meet the requirements of 'three rates' at the same time.

$$X_L = X_1 \cap X_2 \cap X_3 \tag{7}$$

$$X_1 = \{x_l \mid f_1(x_l) \le 30\%, \quad 即 \eta_1 \le 30\%\}$$

$$X_2 = \{x_l \mid f_2(x_l) \ge 40\%, \quad 即 \eta_2 \ge 40\%\}$$

$$X_3 = \{x_l \mid f_3(x_l) = 100\%, \quad 即 \eta_3 = 100\%\}$$

Among them: X_L-the range of the critical value of the index that meets the requirements of 'three rates' at the same time;

the critical value range of X_1-η_1 satisfying the requirement of 'not more than 30%';

the critical value range of X_2-η_2 meets the requirement of 'not less than 40%';

the critical value range of X_3-η_3 meets the requirement of 'reaching 100%'.

6. INVESTIGATION RESULTS

From June 2015 to June 2017, the project researchers tracked and investigated more than 7000m dynamic outburst prevention test working face of Sangshuping No.2 well. The statistics of the correlation between gas content test and outburst occurrence during the investigation are shown in Table 1.

Table1: ***Statistical table of correlation between gas content and outburst danger in heading face***

Gas content range（m^3/t）	Gas content test (times)	Prominent foreboding (times)	Prominent foreboding occurs
W＜8	17	0	There is no obvious prominent omen
8≤W＜9	15	0	There is no obvious prominent omen
9≤W＜10	21	0	There is no obvious prominent omen
10≤W＜11	23	0	There is no obvious prominent omen
11≤W＜12	29	2	Occasionally prominent omens occur
W≥12	17	4	Occasionally prominent omens occur

It can be seen that there is the following regularity between coal seam gas content and outburst risk :

1) When the gas content is less than 11m^3/t, there is no obvious outburst omen ;
2) When the gas content is greater than or equal to 11m3/t and less than 12m3/t, obvious outburst omens such as drilling holes and jacking drills occasionally occur, with a frequency of about 6.9% ;
3) When the gas content is greater than or equal to 12m3/t, obvious outburst omens such as drilling holes and jacking drills occasionally occur, with a frequency of about 23.5%. According to the correlation between gas content and outburst risk, the critical value of gas content in 3# coal seam area should be less than 11m3/t.

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