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Study on Gas Outburst Forecast Sensitivity Index for 2[#] Coal Working Face of Xuecun Mine

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Abstract: According to the Xuecun mine field measured data, the gas outburst prediction index is analysed by the qualitative. It is the use of gray relational analysis and the "three rate" calculated quantitatively predict the sensitive indicators of Xuecun mine. The results show that the results of qualitative analysis and quantitative are agreement. It initially came to the prominence predictor of Δh_2 , the sensitivity of which is better. It improves the reliability of sensitivity index for 2[#] coal working face of xuecun mine.

1. Introduction

Xuecun mining area is located in the north-east of Fengfeng coal field. The strike length of mining area is about 6000 metres, and the dip length is about 2838 metres. The acreage is about 17.0 km². The western of mining area is broad, and the western is narrow. The fracture and folding structure develop very much in Xuecun mining area. The partial coal-bed is intruded magmatic rock. 2[#] coal-bed is mined in the coal. The thickness of coal seam is 5.3 metres. The immediate roof is siltstone with poor permeability. The maximum gas content of 2[#] coal-bed is 9 m³/t. 2[#] coal-bed is identified outburst coal seam. The development system is vertical shaft multi-level crossdrift panel. The ventilation mode is central hybrid. The absolute outflow of methane is 51.2m³/min in 2018 year. There have been a number of outburst premonition and gas dynamics during driving construction of Xuecun mining. In order to ensure the safety of mine production and effectively guide the outburst prevention work, the outburst forecast sensitivity index is studied in the paper driving construction of Xuecun mining.

2. Prediction technique and field measurement for working face

Xuecun mine uses the drill cutting gas desorption index Δh_2 and the drill cuttings amount S to predict the outburst danger when conducting the outburst prediction. The measuring instrument adopts the MD-2 desorption instrument and the WTC outburst risk parameter meter. 92802 working face, 92902 working face, 92621 working face, 92607 return wind tunnels were collected, among which the data of drill cuttings index $S_{\max 215}$ group and drill cuttings desorption index Δh_{2232} group data. The outburst prediction adopts the cuttings desorption index method, and the measurement index is the drill cuttings desorption index Δh_2 and the drilling cuttings amount S. The measurement steps are as follows:

(1). Outburst prediction adopts the drill cuttings desorption index method, and the measurement index is the drill cuttings desorption index Δh_2 and the drilling cuttings amount S. In the prediction, three prediction holes with a diameter of $\Phi 42\text{mm}$ and a depth of 10m are arranged horizontally in the layer with relatively soft coal hardness in the section of the working face. If there is no soft stratification, the drilling is arranged in the center of the working face [2-3].

(2). Predicting the drilling arrangement: 1 drilling hole is located in the middle of the working face,



parallel to the tunneling direction; 2 holes are arranged in the lane gang, the opening is 0.5m away from the lane, and the final hole is 4m outside the contour of the roadway, as shown in Fig. 2-1 is shown.

(3). When drilling, measure the drill cuttings index S every 1m drill hole, and measure the drill cuttings gas desorption index Δh_2 every 2m, that is, 2, 4, 6, 8, 10m deep.

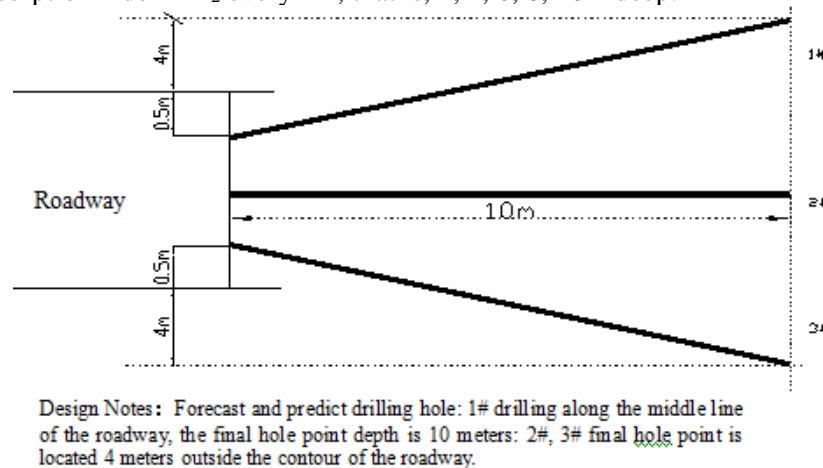


Fig. 1 Predicted drilling layout

3. Qualitative analysis of sensitive indicators

The collected data of 232 sets of drill cuttings analysis index Δh_2 are analyzed (the distribution ratio is shown in Table 1): Δh_2 value range is 40~380Pa, the variation range is larger, the over-standard rate is higher; S_{\max} value distribution is more concentrated, Most of them are concentrated around 3kg/m, the maximum value is 4.0kg/m, and the minimum value is 2.4kg/m, which indicates that the amount of drill cuttings S has little change with the danger of the outburst face of the working face, and the consistency of dangerous risk changes with the working face is poor, indicating that the amount of drill cuttings S is poorly sensitive and cannot truly reflect the outburst danger of the coal seam. There is no over-standard phenomenon in the 215 sets of S_{\max} data (the Δh_2 and S_{\max} value distribution curves are shown in Fig. 2 and Fig. 3).

Table 1 Distribution statistics of drill cuttings desorption index Δh_2

Δh_2 (Pa) value distribution	$\Delta h_2 \geq 190$	$\Delta h_2 \geq 200$	$\Delta h_2 \geq 220$	$\Delta h_2 \geq 240$	$\Delta h_2 \geq 260$	$\Delta h_2 \geq 280$
Predict times	39	34	27	22	16	10
Proportion of total times (%)	16.81	14.67	11.64	9.48	6.89	4.31

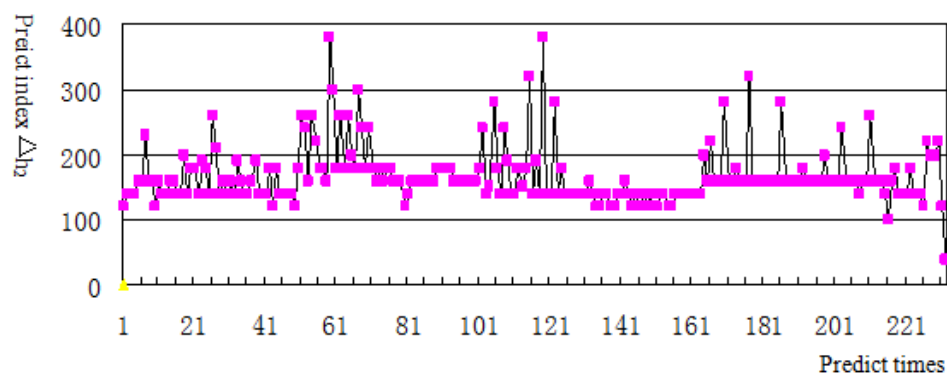


Fig. 2 Distribution line diagram of drill cuttings desorption index Δh_2

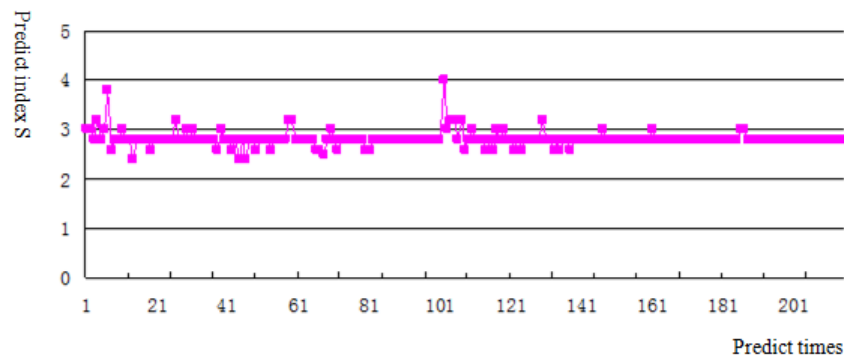


Fig. 3 Distribution line diagram of drill cuttings index S

Based on the above analysis, the outburst occurrence of the combination with the mine is based on the prominent type of gas pressure, and the gas emission is large. In the actual working face prediction, when the Δh_2 value is greater than a certain value, the power phenomenon such as clamp drill, nozzle hole, top drill, and coal cannon is generated during drill cutting; and the larger the Δh_2 value, the more power phenomenon shown; After applying outburst risk eliminating measures, the value of Δh_2 is significantly reduced. Therefore, compared with the amount of drill cuttings S, the sensitivity of Δh_2 is higher.

4. Quantitative analysis of sensitive indicators

4.1 Grey correlation analysis

4.1.1 Determination of grey correlational model

In view of the fact that the drill cuttings desorption index Δh_2 and the cuttings amount S are equivalent in the prediction of the outburst, only when the coal seam occurrence, gas geological conditions and mining technical conditions are different, the sensitivity of the index will be different. Therefore, it is necessary to establish a system reflection function that reflects the degree of danger [4-5]

$$E_I(i) = f(X)$$

$$f(X) = \prod_{j=1}^m X_j(i)$$

In the formula: X —Order matrix consisting of $X_j(i)$;

$f(X)$ —reflection quantity function;

$X_j(i)$ —same predictive indicator Δh_{2i} , S_i respectively;

i —Measure the data group number, $i = 1, 2, \dots, n$;

j —indicator data serial number, $j = 1, 2, \dots, m$, where $m=2$

n —the number of indicator data sets;

4.1.2 Normalization of data

Since the dimension of the gas desorption index Δh_2 and the cuttings amount S of the drill cuttings are different, and the measured values of the indexes differ greatly in quantity, in order to eliminate the adverse effects of the unit and the magnitude difference of each index on the analysis results, it is necessary to standardize the predicted data. Here, the mean value operator is used to convert the values of each indicator as follows:

$$X'_j(i) = \frac{X_j(i)}{\bar{X}_j}$$

In the formula: $X'_j(i)$ —Index dimensionless transformation, $i=1, 2 \dots n, j=1, 2 \dots m$, where $m=2$;

\bar{X}_j —Sample average of forecast indicators, $j=1, 2 \dots m$, where $m=2$,

The value is determined by following formula:

$$\bar{X}_j = \frac{1}{n} \sum_{i=1}^n X_j(i)$$

Then the amount of system reflection after the dimension transformation is: $E_2(i) = f(X')$

Among them, $E_1(i)$ and $E_2(i)$ indicate the degree of danger. The mathematical relationship between the degree of danger and the indicators is established, which is the reflection function that reflects the inherent law of coal and gas protruding.

4.1.3 Calculation of Grey Correlation Degree

Coal and gas protruding systems are gray information systems that contain both known internal characteristics and unknown and non-determined internal characteristics. The relation analysis reference sequence $X_0, k(i)$ is the system reflection amount $E_1(i)$, $E_2(i)$, ie: $X_0(i) = \{E_1(i), E_2(i)\}$, and the comparison sequence $X_j(i)$ is Each forecast indicator drill cuttings gas desorption index Δh_2 and cuttings S .

$$X_j(i) = \{\Delta h_2, S\}$$

Grey correlation function $\xi_j(i)$ calculation model:

$$\xi_{j,k}(i) = \frac{\Delta_j(\min) + K \cdot \Delta_j(\max)}{\Delta_j(i) + K \cdot \Delta_j(\max)}$$

$$\Delta_j(\min) = \min_j \min_i |X_0(i) - X_j(i)|$$

$$\Delta_j(\max) = \max_j \max_i |X_0(i) - X_j(i)|$$

$$\Delta_j = |X_0(i) - X_j(i)|$$

$$(j=1, 2, \dots, m; i=1, 2, 3, \dots, n)$$

Where, $\xi_{k,j}(i)$ —The relative difference between the behavior sequence $X_j(i)$ and the reference sequence $X_k(i)$ at the i -th moment, that is, the correlation coefficient of $X_j(i)$ to $X_0,k(i)$ at time i ;

K —resolving coefficient, taking into account the equality of indicators, take $K=0.5$;

m —compare the number of series, that is, the number of predictive indicators for predictive measurement, $m=2$;

n —analysis of the number of data sets;

$X_0,k(i)$ —reference series, that is, the amount of system reflection established; other symbols are the same as before.

The degree of correlation between indicators and protruding hazards can be expressed as:

$$\text{Correlation: } r_{k,j} = \frac{1}{n} \sum_{i=1}^n \xi_{k,j}(i)$$

According to the above formula, the correlation degree calculation result can be obtained, that is, the sensitive relationship between each prediction index and the coal seam outburst risk is obtained.

4.1.4 Gray correlation analysis results

Table 2 Correlation analysis results

Location	Reflection value	Correlation	
		Δh_2	S_{\max}
92802 lane	System reflection E_{11}	0.878724	0.912714
	System reflection E_{21}	0.91269	0.878689
92621 slippery road	System reflection E_{11}	0.815445	0.935521
	System reflection E_{21}	0.938688	0.837822
92621 working face	System reflection E_{11}	0.913817	0.997619
	System reflection E_{21}	0.976304	0.913979
92902 working face	System reflection E_{11}	0.910366	0.951702
	System reflection E_{21}	0.95128	0.910446
92607 return air course	System reflection E_{11}	0.854362	0.897523
	System reflection E_{21}	0.935461	0.836987

The amount of reflection E_{1i} focuses on the accuracy of the response prediction, and the amount of reflection E_{2i} focuses on the accuracy of the response prediction. From the analysis of the correlation analysis results in the table, it can be seen that the correlation degree of the drill cuttings desorption index Δh_2 system mapping amount E_{2i} is the largest among the two indexes, compared with the drill cuttings desorption index Δh_2 , the cuttings amount S system reflection amount. E_{2i} is less relevant. The degree of closeness to the coal seam protruding is obviously much smaller, and it is considered to be insensitive and consistent with the results of the three-rate analysis. Therefore, the drill cuttings desorption index Δh_2 is a sensitive indicator for predicting the risk of working face.

4.2 "Three-rate" method for analyzing sensitive indicators

4.2.1 Principle of "three rate" method

The so-called "three rates" refers to the prediction of the outstanding rate, the prediction of the outstanding accuracy rate and the prediction of the non-prominent accuracy rate, and its calculation formula is as follows [6-7]:

(1) Predicted prominence

$$\eta_1 = n/N$$

Where: η_1 —prediction protruding rate, %;

n —Predicting the number of protruding number, times;

N —the total number of predictions, times.

(2) Predicting protruding accuracy

$$\eta_2 = n_1/n$$

Where: η_2 —Predicting protruding accuracy, %;

n_1 —The number of times that there are protruding dangers in predicting the number of protruding dangers, including: 1 Actual occurrence of protrusion; 2 Predicted serious signs such as nozzle holes, stuck drills, top drills, and frequent guns; 3 In faults, the prediction indicators near the geological tectonic belt such as small folds are significantly increased.

(3) Predicting non-protruding accuracy

$$\eta_3 = n_2/n_3$$

Where: η_3 —predicting non-protruding accuracy, %;

n_2 —the number of times in which the number of unobtrusive times is predicted to be non-insurgent, times;

n_3 —predicting non-protruding times, times;

The predicted protruding rate η_1 in the "three rates" represents the ratio of the predicted protruding dangerous segment to the total predicted segment. Under the premise of ensuring accurate prediction, the smaller the η_1 is, the smaller the range of anti-sudden technical measures is needed. Therefore, for η_1 , the smaller the better. Under the current technical level, the prediction rate is generally not high. According to experience, η_1 is generally considered to be no more than 30%. The prediction salient accuracy η_2 reflects the accuracy of the prediction prominence, the higher the better. However, because people do not know the mechanism of gas protruding, the prediction methods and prediction methods lack strict theoretical basis, and the accuracy of prediction is generally not high. Generally, the requirement is not less than 40%. The prediction non-protruding accuracy rate η_3 reflects the safety and accuracy of using this indicator for protruding risk prediction. The higher the prediction accuracy is the lower the protruding false negative rate and the better the security.

4.2.2 Comprehensive analysis of predictive sensitivity indicators by the "three rates" method

Table 3 "Three rate" method analysis results

Investigation	Unite	Predict individual indicator	
		Δh_2	S_{\max}

Total number of predicted results	times	232	215
Actual number of protruding	times	31	
Predictive effectiveness has a significant number of dangerous times	times	42	0
Predictive rate	%	18.1	0
Predicting the number of dangerous times in dangerous times	times	31	/
Predictive accuracy	%	73.8	/
Predict non- protruding dangers	times	190	206
Predicting the number of times without significant dangers	times	190	176
Predict non- protruding accuracy	%	100	85.4

It can be seen from the table that the prediction accuracy of the prediction index S_{\max} is as high as 100%, and there is a serious underreporting phenomenon; while the prediction index Δh_2 has a prediction probability of 18.1%, the prediction protruding accuracy rate is 73.8%, and the prediction non-protruding accuracy rate. Δh_2 is more suitable as a sensitive indicator.

5. Conclusion

(1) Based on the measured data of Xuecun Mine, qualitative analysis highlights the predict indicators. The analysis shows that the amount of drill cuttings S is less sensitive and the sensitivity of Δh_2 is higher.

(2) Using the grey correlation analysis and the “three-rate” method to quantitatively calculate the predictive sensitivity index, the quantitative calculation is consistent with the qualitative analysis, and the preliminary prediction of the sensitive indicator Δh_2 sensitivity is obtained, which provides a scientific basis for the prediction of the working face of Xuecun Mine.

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