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Application of trend surface analysis in early warning model of coal mine gas explosion

SUN Yuhang[1], TANG Shoufeng[1], TONG Ziyuan[2], TONG Minming[1], XU Chaoliang[3]

([1]China University of Mining and Technology,School of Information and Control Engineering,Xuzhou 221000,China;[2]University of New South Wales, School of Communication and Electricity,New South Wales 1466,Australia;[3]Xuzhou Hanlin Technology Co, Ltd., Xuzhou 221000,China;)

Abstract: Aiming at the catastrophic problem of common coal mine gas explosion, this paper combines the trend surface analysis method to establish a gas explosion warning model, and validates the model through actual data, and the model has good robustness. Through the data fusion of the comprehensive information of gas explosion, the gas and oxygen concentration are selected as the key indicators of the early warning model, and the trend surface analysis of the finite discrete data is established. The trend surface warning model of gas and oxygen concentration is established, and the distribution of key indicators is obtained. Features that enable predictions and warnings of potential gas hazards.

1. Introduction

China is a big coal country, and the distribution of coal resources in the country accounts for 6% of the country's land area. Coal mining is dangerous, and disasters may occur during the mining process. From the coal mine accidents table counted by the State Administration of Coal Mine Safety over the years, it can be found that 70% of major coal mine accidents causing multiple casualties are caused by gas explosions. It can be seen that coal mine gas explosion is the "first killer" threatening coal mine safety. Therefore, studying coal mine gas explosion warning technology is a major issue involving coal mine safety production in China.

At present, the research on coal mine gas explosion warning is mainly based on monitoring gas concentration. There are few researches on real-time gas explosion warning in a certain area. This paper analyzes and processes the measured discrete point information, analyzes and simulates the gas in the whole area. , this paper detect oxygen concentration distribution and change trend, to achieve the prediction of gas concentration, to achieve the purpose of gas explosion warning for the region. The trend surface analysis method is a method for analyzing the trend gradual characteristics by using the overall difference for a large number of discrete point information.

2. trend surface analysis

2.1 Trend surface analysis mathematical model

Some system element variables can be considered to be distributed on a certain surface G in three-dimensional space. If G is known, the distribution law and local features of these system element variables in the region can be studied according to it. However, in the actual work, an accurate G

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cannot be obtained. Through the existing observation data, an algorithm is used to fit a surface that is close to G, which is called a trend surface.

The relationship between the actual observation data of a system element and the trend value fit value is:

$$z_i(x_i, y_i) = \hat{z}_i(x_i, y_i) + \varepsilon_i \quad (1);$$

Where ε_i -- residual value (residual difference);

z_i - actual observation data;

x_i, y_i --the geographical coordinates of the observation point;

$\hat{Z}_i$ - Trend value fit value.

The mathematicians who fit the trend surface model have Fourier series and polynomial functions, of which polynomial functions are most commonly used. N-degree polynomial trend surface fitting model formula:

$$z = a_0 + a_1 \cdot x + a_2 \cdot y + a_3 \cdot x^2 + \cdots + a_{m-2} \cdot x^2 \cdot y^{n-2} + a_{m-1} \cdot x \cdot y^{n-1} + a_m \cdot y^n \quad (2)$$

Where z--actual observation data;

n--The highest power in thepolynomial (can be determined manually);

x, y - actual observation data;

a_i - the undetermined coefficients of the required trend surface equations (the values of these coefficients need to be determined based on the actual observation data);

m--polynomial coefficient subscript (which is determined by the value of n is: $m = \frac{(n+1)(n+2)}{2} - 1$)。

2.2 Parameter estimation of the trend surface mathematical model

Trend surface parameter estimation is based on observations z_i, x_i, y_i (i=1，2，…，n)，Determine the coefficient of the polynomial a_i (i=1，2，…，p)，The sum of the squares of the residual values is minimized, and n represents the number of items of observation data.If $x_1 = x \quad x_2 = y \quad x_3 = x^2 \quad x_4 = x \cdot y \quad x_5 = y^2$ ... then $\hat{z} = a_0 + a_1 \cdot x_1 + a_2 \cdot x_2 + \cdots a_p \cdot x_p$,The nonlinear regression model was transformed into a linear regression model.

3. Selection of feature data

The study found that when the oxygen concentration is greater than 12%, and the gas explosion concentration ranges from 5% to 16%, the gas is ignited when the ignition energy reaches 0.28 MJ.

However, for example, the concentration change of carbon monoxide mainly occurs after the explosion, and the remaining combustible gas also needs to be combined with oxygen to affect the explosion. The most important and easy to monitor for underground gas warning is gas and oxygen concentration, so the gas warning mentioned in this paper. The main choice is to monitor downhole gas and oxygen concentrations. The control of gas concentration and oxygen concentration in the influencing factors of coal mine gas explosion is still difficult in the current technology. Other influencing factors such as fire source and coal dust can be controlled by timing inspection and development measures, so the gas concentration and The prediction of oxygen concentration can play a certain early warning role on gas explosion.

4. gas explosion warning model

4.1 Data collection

This paper selects the goaf of the mining face of a coal mine in Shanxi as the test area, which belongs to the high gas mine. The working face has a width of 250m, a radial length of 300m, a coal seam inclination of 6~11°, an absolute gas emission of the working surface of 10.3m~3/min, and a relative gas emission of 24.7m~3/ton. The schematic diagram is shown in Figure 1. The working face of the mine is mainly based on the Y-type ventilation system, and the gas drainage of the floor gas drainage

road is the main body, with the coal seam gas drainage in the coal seam, the upper adjacent gas drainage and the buried wall isolation wall. Gas extraction and other methods for integrated gas control. The coal seam dip angle of the working face adopts the room-column mining method, and the size of the retained coal pillar is 5*5m. The six rectangular areas in the goaf in the figure are the retained coal pillars. In order to facilitate the calculation of the geographical coordinates, the width direction of the mining face is selected as the X-axis direction, the radial direction is the Y-axis direction, and the lateral position of the inlet wind lane is taken as the coordinate zero point.

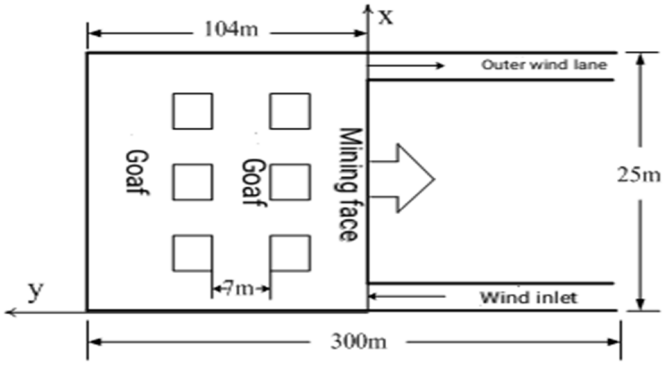

Figure 1 Schematic diagram of the goaf in the mining face

After testing, the oxygen concentration in the area 60m away from the working surface is less than 12%, and there is no danger of explosion. Therefore, 12 sets of measurement data ranging from 0 to 60m from the working surface are randomly selected as observation values for trend surface analysis. The observation point data is shown in Table 1.

Table 1 Observation point data

Numbering	Abscissa x/m	Y-axis y/m	data observation z	
			Gas concentration /%	Oxygen concentration/%
1	1	1	0.5	21.0
2	15	7	0.9	20.8
3	8	12	1.0	20.4
4	22	19	1.0	20.5
5	3	19	1.1	20.7
6	15	26	9.0	19.6
7	11	26	7.2	19.4
8	17	30	16.3	18.6
9	5	40	23.8	16.0
10	23	48	25.2	14.4
11	9	54	30.5	13.9
12	14	60	30.2	14.0

4.2 Trend surface mathematical model for gas explosion warning

The high-order trend surface has a good fitting effect near the observation value, but its effect is poor when interpolating and extrapolating, and the calculation amount is too large to realize real-time warning. Therefore, this paper makes a second or third trend. Face fitting. Using the observation point data obtained in Table 1, the trend surface fitting is performed by using the quadratic and cubic polynomials respectively for the gas concentration and the oxygen concentration distribution, and then the fitting equations are obtained by the least squares method.

In order to make the gas explosion warning more intuitive and convenient, the trend concentration distribution of gas and oxygen is drawn by using the surfer software. As shown in Fig. 2, the medium concentration trend line value of 0 to 1 indicates that the gas concentration is 0 to 100%. According to the analysis, the goaf of the mining face is within 0-20m from the recovery face, and the gas concentration is less than 5%. Within the range of 20-40m from the recovery face, the gas concentration is within the explosion limit, and the oxygen concentration is greater than 12%. Gas explosion occurred; within the range of 40 ~ 60m from the mining face, it belongs to the high gas combustion zone; the oxygen concentration is less than 12% from the recovery face 60m, which belongs to the safety zone.

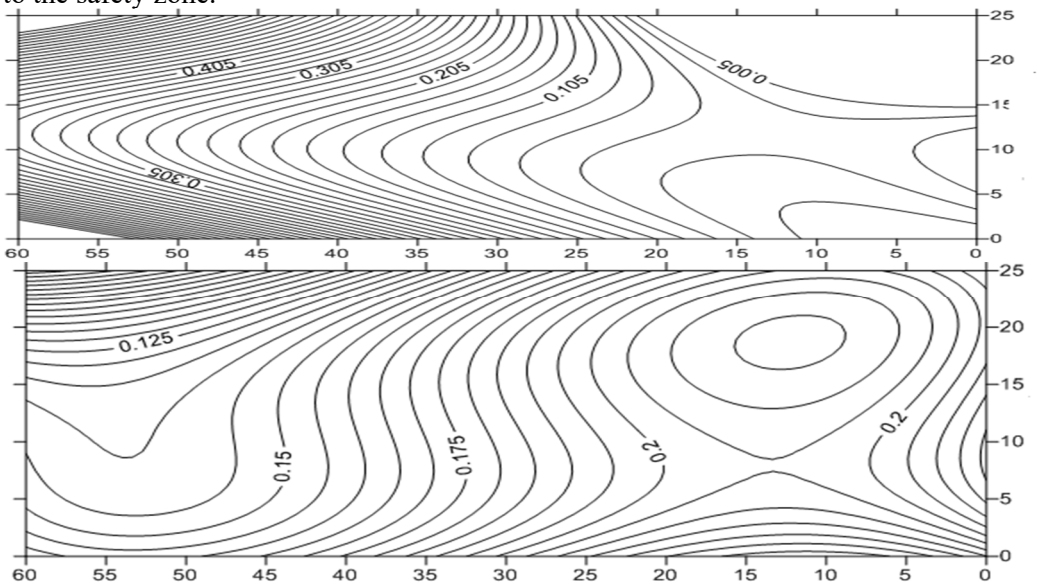

Figure 2 Gas and oxygen trend surface fitting concentration distribution map

5. Conclusion

This paper studies the application of the trend surface analysis method in the gas explosion warning model. The article analyzes the conditions and influencing factors of coal mine gas explosion, and selects gas concentration and oxygen concentration as the research factors of trend surface analysis. The trend surface analysis method is introduced. Then the algorithm is applied to the gas explosion warning model to establish a prediction model of gas and oxygen concentration. The calibration of the two gas concentration distributions can be realized, and the gas explosion of the area can be predicted in real time. And through the example application to analyze and verify. The preliminary example analysis shows that the gas explosion warning model established in the paper can make accurate and objective predictions of real-time gas explosion in a certain area, and has strong operability, which can provide reference for coal mine gas explosion warning.

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