Microseismic Monitoring Data Fusion Algorithm and Coal and Gas Outbursts Prediction

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Abstract – **The prediction study on coal and gas outbursts is carried out by monitoring some indices which are sensitive to the initiation of coal and gas outbursts. The values and changing rules of the indices are the foundations of coal and gas outbursts prediction. But now, only the data of one key monitoring station is used in the coal and gas outbursts prediction practice, and the other data are ignored. In order to overcome the human factor and make full use of the monitoring information, the technique of multi-sensor target tracking is proposed to deal with the microseismic information. With the results of microseismic events, the activities of geological structure, fracture-depth of roof and floor, and the location of gas channel are obtained. These studies indicate that it is considerably possible to predict the coal and gas outbursts using microseismic monitoring with its inherent ability to remotely monitor the progressive failure caused by mining.**

Key words – *coal and gas outbursts*; *microseismic monitoring*; *data fusion*

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1 Introduction

Coal and gas outburst is a dynamic phenomenon in coal exploitation, which causes great casualty and property damage. The damage caused by coal and gas outburst will be more serious in deeper mining. It is very important to predict the occurance of coal and gas outbursts precisely for mine safety. There are many prediction methods for coal and gasoutbursts, among them, method of drilling bits, AE monitoring method and electromagnetic radiation monitoring method are based on in-situ monitoring; and the prediction is conducted through the analysis of data and change rule for indices sensitive to coal and gas outbursts.

To hold the integrate situation about gas and coal mass, multi-stations of seismic monitoring are set in general, and there are several groups of information available about coal mass evolution. But only one key monitoring data of the monitoring station instead of the others can be used to the prediction model at the same time in coal and gas outbursts at present, so we have to select one representative key station to predict the occurance of coal and gas outbursts. In order to overcome the human factor and make full use of the monitoring information, corresponding with the mobility of coal mass microseismic, the technique of multi-sensor target tracking is proposed to deal with the microseismic information. In this paper, the microseismic monitoring data fusion algorithm and the prediction method of coal and gas outbursts are studied.

2 Principle of microseismic monitoring location

The principle of microseismic monitoring location is that[1]: the sensors array is set up in the monitoring area; while microseismic event occurs in coal mass or rock mass, the signal can be pickup by the sensor and the signal is switched to voltage or electric charge; determine the arrival moment of signal, substitute the sensor coordinate and wave velocity into eqution groups; solve the equation and get the space-time parameters of hypocenter.

Least squares method is a classic location algorithm, in which the equation group (1) is established according to the signal arrival moment and the hypocenter location is determined[2].

$$(X_i - X_0)^2 + (Y_i - Y_0)^2 + (Z_i - Z_0)^2 = V_i^2 \times (T_i - T_0)^2. \quad (1)$$

Where X_i, Y_i, Z_i is the number i sensor position; V_i is the wave velocity at number i sensor; T_i is the signal arrival moment; X_0, Y_0, Z_0 is the position of hypocenter; T_i is the crack moment.

If there are five sensors receive effective signal, then

$$\begin{cases}(x_1 - x)^2 + (y_1 - y)^2 + (z_1 - z)^2 = v^2 \times (t_i - t)^2, \\ (x_2 - x)^2 + (y_2 - y)^2 + (z_1 - z)^2 = v^2 \times (t_i - t)^2, \\ (x_3 - x)^2 + (y_3 - y)^2 + (z_1 - z)^2 = v^2 \times (t_i - t)^2, \\ (x_4 - x)^2 + (y_4 - y)^2 + (z_1 - z)^2 = v^2 \times (t_i - t)^2, \\ (x_5 - x)^2 + (y_t - y)^2 + (z_1 - z)^2 = v^2 \times (t_i - t)^2.\end{cases} \quad (2)$$

Eliminate the x^2, y^2, z^2, t^2, then we can get the linear transcendental equation

$$a_j x + b_j y + c_j z + d_j t = e_j. \quad (3)$$

Where a_j, b_j, c_j, d_j, e_j are the coefficients. Let

$$\boldsymbol{A} = \begin{bmatrix} a_1 & b_1 & c_1 & d_1 \\ a_2 & b_2 & c_2 & d_2 \\ a_3 & b_3 & c_3 & d_3 \\ a_4 & b_4 & c_4 & d_4 \end{bmatrix}, \boldsymbol{X} = \begin{bmatrix} x \\ y \\ z \\ t \end{bmatrix}, \boldsymbol{B} = \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \end{bmatrix}.$$

Then equation (3) is equal as $\boldsymbol{AX} = \boldsymbol{B}$, solve the equation using least squares method and then:

$$x^* = (\boldsymbol{A}^{\mathrm{T}}\boldsymbol{A})^{-1}\boldsymbol{A}^{\mathrm{T}}\boldsymbol{B}. \quad (4)$$

So if we have 5 sensors, we have 5 locations, and if

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we have 6 sensors, we have 6 locations. Select the geometric center of the all hypocenters coordinate and we get the location result.

3 Error analysis of microseismic monitoring algorithm

The location process of microseismic event is to make the time difference as minmum, and the simplest method is to make the absolute value of time difference of arrival moment-between the wave detected by sensor and the calculated result-as minmum. To that aim, we should compare the calculated moment and detected moment and we get an error; the error is used to judge whether the location is meet the demand[3-4]. The compare methods include: absolute value deviation estimate (5) and least squares estimate (6):

$$E = \left[\frac{1}{N}\sum_{i=1}^{N} \| T_{0i} - T_{ci} \| \right], \quad (5)$$

$$E = \left[\frac{1}{N}\sum_{i=1}^{N} (T_{0i} - T_{ci})^2 \right]^{\frac{1}{2}}, \quad (6)$$

which method is selected based on the minmum time different error. The second method emphsizes that the biger error should be eliminate and the first method diminish the effect of biger error so its application is wider. After the errors of every mesh point are calculated, the errors are mapped in a 3D space which is called error space. The smallest error space is thought as the optimum result for real events location theoretically.

4 Analysis of events location

The microseismic monitoring technology could be used in coal mine. The three dimensional images of roadway surrounding rock failure could be shown visually through the surrounding rock failure monitoring. Through the monitoring of fracture development we can get the gas migration law and we can analyse the potential room of gas accumulate and store, so as to predict the occurance of coal and gas outbursts.

The procedure of microseismic application is microseismic signal extraction and analysis; microseismic location; coal(rock) failure analysis and energy analysis; 3-dimension coal (rock)mass failure field determination; regional prevention of coal and gas outbursts. The primary demand of microseismic monitoring is the good accuracy of events location. As of May 5,2010, the monitoring system had received 400 events, some are shown in Tab.1.

Through the events records, we can get the hypocenter parameter such as space location, static stress drop, dynamic stress drop, seismicity scale and the error range.

Tab.1 Microseismic location events

X	Y	Z	Static sterss drop(Pa)	Dynamic sterss drop(Pa)	Maximum of displacement(m)	Seismicity
14 704.6	6678.8	−529.4	457 928.7	7703.6	0.000 304 316	−1.536 687 0
14 839.5	6 717.5	−541.3	85 699.8	4 905.3	0.000 205 73	−2.069 757 9
14 834.3	6 839.9	−694.4	233 605.4	2 276.7	0.000 045 638 2	−2.723 850 7
14 702.3	6 676.7	−524.4	425 431.2	6 710.2	0.000 264 229	−1.605 543 37
14 834.9	6 722.9	−501.3	79 637.9	3 199.5	0.000 089 824	−2.046 620 7
14 784.4	6 687.4	−504.7	77 650.8	3 180.5	0.000 077 221 6	−2.252 420 9
14 826.4	6 753.4	−551.8	651 930.2	25 538.5	0.000 488 307	−1.183 436 8
15 219.5	6 207.1	−580.2	292 193.6	8 237.8	0.000 257 614	−1.743 076 4
14 703.9	6 700.5	−518.4	67 952.4	3 179.1	0.000 083 143 5	−2.212 010 7
14 798.8	6 892.8	−564.3	2 457 633.6	25 154.1	0.000 484 84	−1.234 777 4
15 359.9	6 501.3	−552.6	227 562.1	5 085.9	0.000 075 927 3	−2.284 056 8

5 Conclusions

1) Using global optimize location technology, and take the inner field and outer field location effect factors into account, it is significantly possible to realize the high precision microseismic hypocenter location.

2) It is the effective technology means for the real time monitoring and series monitoring to discribe the process of gestation, development and failure for gas channels.

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