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Stability of mine ventilation system based on multiple regression analysis

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Abstract: In order to overcome the disadvantages of diagonal connection structures that are complex and for which it is difficult to derive the discriminant of the airflow directions of airways, we have applied a multiple regression method to analyze the effect, of changing the rules of mine airflows, on the stability of a mine ventilation system. The amount of air (Q_j) is determined for the major airway and an optimum regression equation was derived for Q_j as a function of the independent variable (R_i), i.e., the ventilation resistance between different airways. Therefore, corresponding countermeasures are proposed according to the changes in airflows. The calculated results agree very well with our practical situation, indicating that multiple regression analysis is simple, quick and practical and is therefore an effective method to analyze the stability of mine ventilation systems.

Keywords: ventilation network; stability; diagonal connection; multiple regression analysis

1 Introduction

At present, the most commonly used method to study airflow stability of a mine ventilation system involves the application of diagonally connected structures. The main processes include the determination of diagonal connecting airways, the discriminating directions of the airflow and the effect on the diagonally connected airways during times of mine disasters. Therefore, investigations into the problem of airflow stability largely involve the determination of the diagonally connected airways and to confirm the specific conditions of airflow directions[1–5].

However, as far as mine ventilation systems are concerned, there are the stability problems not only in the diagonally connected airways, but also in other airways of entire ventilation networks. Under the exacting conditions of a mine, it is very important to ensure the stability of airflows at work stations and to maintain the stability of airflows of the main ventilator.

The problem of stability of airflows not only exists in the diagonal road layouts, but also in other roads throughout the entire ventilation network. For safe production in mines, the stability of the airflow at all points is very important, as is the stability of the flow fan. What is more, mine ventilation networks are very extensive, and flow identification in unstable roads varies considerably and may be even very complex. To distinguish among the variable wind directions, may pose enormous problems. The real problem with the diagonal structure of the ventilation system in a productive mine is that, this diagonal structure, which is simply used to determine the stability of the airflow, has serious limitations.

Hence, we have used a multiple regression approach to explore and analyze the stability of the ventilation system of a mine. There are two aspects to be considered. The first one is “quality”, the other “quantity”. Both aspects are required in order to determine the main ventilation roads which impact on the stability of the airflow in the ventilation network of any mine. In our investigation of this problem we found an optimum regression equation relating the amount of airflow Q_j and the flow resistance of each ventilation road. According to the estimated parameters in the regression equation, the impact level on and direction of ventilation from each flow resistance can be determined directly[6–9].

2 Mathematical model

In mine ventilation systems, the amount of air in one ventilation circuit will change when its natural relationship and aerodynamic characteristic changes. This implies that if the wind resistance in one ventilation circuit changes, this relationship can be expressed as Eq.(1)[5–6].

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$$Q_j = Q_{j0} + A_i(9.8R_i - 10)\exp(-4.307R_i^{0.14}) \quad (1)$$

where Q_{j0} is wind resistance in the i^{th} ventilation circuit relative to the air volume in the j^{th} ventilation circuit; Q_j is the change in wind resistance in the i ventilation circuit relative to volume of air in the j^{th} ventilation circuit; A_i is the vector of parameters to be estimated:

If $B = Q_{j0}$,

then $X_i = (9.8R_i - 10)\exp(-4.307R_i^{0.14})$,

and $$Q_j = B + A_i \cdot X_i \quad (2)$$

Given m experimental results where every experiment contains a data vector of size n, we obtain the following matrices $(Q_{kj}, R_{k1}, R_{k2}, \cdots, R_{k(n-1)})$ and Eq.(3) holds.

$$Q_j = B + \sum_{i=1}^{n-1} A_i \cdot X_i + \varepsilon \quad (3)$$

Where ε is a random variable, implying that the sum of other random factors have an effect on Q_j.

3 Analysis of main ventilation circuit

The mine ventilation network can be defined as: $G = (v, e)$, $|v| = m$, $|e| = n$ (see Fig. 1).

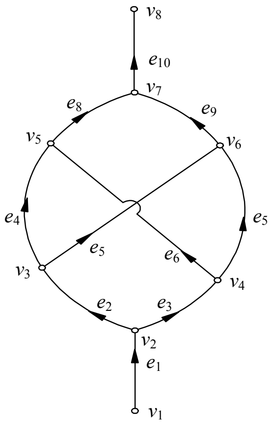
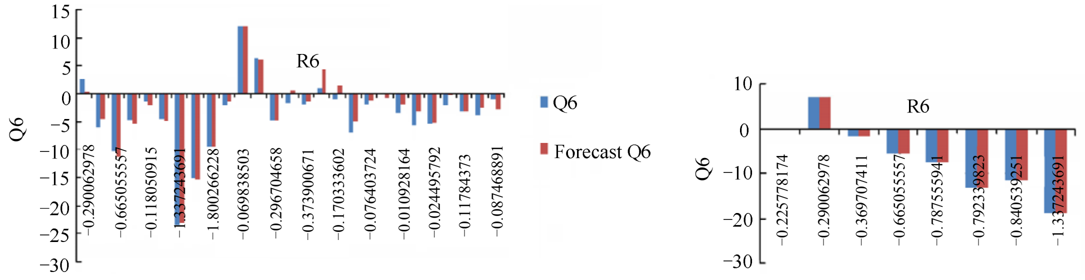


Fig. 1 Mine ventilation network

Assume that e_6 is the main ventilation circuit and e_{10} the ventilation circuit of the fan blower. Under the condition of different wind resistance, i.e., $R_{ki}(i = 1, 2, \cdots, 10;\ k = 1, 2, \cdots, 2n+8)$ and the characteristic curve of the main fan blower in a coal main estimated as $h = -0.1833Q^2 + 1.1426Q + 1433.2$, a ventilation network optimization is carried out and the air volume is obtained as $Q_{kj}(j = 1, 2, \cdots, 10;\ k = 1, 2, \cdots, 2n+8)$ for each ventilation circuit after a natural air distribution. The experimental data is composed of k dimensional vectors, $Q_{k,10} = \{Q_{1,1}, Q_{2,2}, \cdots, Q_{k,10}\}^{\mathrm{T}}$ with the test values $X_i = \{X_1, X_2, \cdots, X_{10}\}$ stored in a $k \times 10$ order matrix. According to three different kinds of valuation methods, a solution to the problem of the air volume of e_6 and the regression coefficients of the wind resistance of each ventilation circuit in the mine ventilation network under different conditions, can be obtained (see Table 1). Calculating air provides a contrast to forecasting air (see Figs. 2 and 3).

As shown in Table 1, the differences in the valuation methods of wind resistance in each ventilation circuit will result immediately in a different regression equation. In test 1, the wind resistance of each ventilation circuit is generated randomly and the regression equation has a great impact on the ventilation circuit. In tests 2 and 3, the wind resistance of both ventilation circuits are endowed values with a certain rate of change $R_{ki} - R_{(k-1)i} / R_{ki} = C_i$. From the regression coefficients, the level of effect of each ventilation circuit on the Ventilation circuit of the wind-force and the equivalent ventilation network is clear. Such as e_1 and e_{10}, e_4 and e_7, e_5 and e_6. Especially for test #3, because of its particular valuation of wind resistance of each ventilation circuit, this phenomenon is clearly very special. It is consistent with the equivalent branch of a diagonal structure, but it avoids the recognition of the diagonal structure and the complexity of decisions on wind direction.



(a) Random

(b) Equidifferent

Fig. 2 Unequal initial value to wind resistance of each ventilation and combination of test series, R6 line fit plot

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