Research on Error Correction Method of Mine Ventilation Resistance

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Abstract. Aiming at the problems of measurement data deviation during the measurement of coal mine ventilation resistance, the principle of the base point measurement of barometer and the reason of the deviation of measurement data are analyzed. The correlation degree of the data sequence trajectory affecting the influence of the measurement data is compared. The main reasons for the deviation of the measurement data are the changes in the elevation of the measurement point, the sensitivity of the measuring instrument and the complex changes of the atmospheric pressure. Based on this, a correction method based on negative feedback adjustment is proposed. This method uses the difference between the static pressure value of the fan and the static pressure of the fan as a feedback factor by checking whether the accuracy of the calculated ventilation resistance value meets the requirements, then use the least squares method to obtain a new value to replace the original atmospheric pressure value and then solve it, so as to obtain the required ventilation resistance value. A mine ventilation simulation was performed based on the calculated resistance values to verify the availability of the corrected ventilation resistance. The method is currently applied to the Xiaojihan coal mine resistance measurement project. The results show that the method has high practicability in engineering practice, and can quickly and accurately correct the mine ventilation resistance measurement results, which simplifies the operation process and saves time.

1. Introduction
The most important thing in the safe operation of coal mine is the mine safety work, and the foundation of mine safety work is mine ventilation[1]. Mine ventilation can not only dilute and eliminate mine gas and dust, but also create a good working environment for mine staff and improve the air quality under the mine. Mine ventilation design, management and transformation are based on the measurement of mine ventilation resistance[2]. The authenticity and reliability of resistance measurement data can design, manage and reform the ventilation system of production mine scientifically and reasonably[3]. Therefore, the determination of mine ventilation resistance is the key link in the safe operation of coal mine. This paper starts with the principle of measuring ventilation resistance by barometer base point method[4,5], analyses the causes of errors in the process of measuring resistance, and puts forward a method of correcting ventilation resistance based on negative feedback adjustment on the basis of data adjustment model, hoping to improve the accuracy of data in practical engineering application of base point method.
2. Material and Methods Introduction

2.1. Influencing factors of errors
In the process of resistance measurement by barometer base point method, there will be errors to varying degrees in the measured data due to the inadequate accuracy of the instrument, errors in the operation method when correcting the instrument, human errors, and the transient and instability of the ventilation network, the deviation of the measuring point elevation, and the variation of atmospheric pressure with the surrounding environment.

1. Instrumentation error
   The complex ventilation network, unstable air flow, changes of measuring environment such as noise, sensitivity of instruments and fluctuation of data make the measurement results of instruments inevitably error.

2. Errors Caused by Transient Ventilation Network
   Underground roadways in coal mines need not only transportation and pedestrians, but also ventilation. Because of the traffic of transport vehicles, the switching regulation of air doors and the fluctuation of power supply voltage of main ventilators, the air around them is often disturbed, which makes the ventilation air pressure in the mine roadway change, causes the instantaneous change of air pressure and air volume in the surrounding roadway, and has certain influence on the local ventilation system and the stability of air flow in the whole mine, which will inevitably lead to pressure. The measurement error is caused by the change[6].

3. Errors Caused by Change of Measuring Point Elevation
   When new roadways and working faces are mined underground, the shape of the surrounding roadways will change with time. Bottom heave, local accumulation of floated coal, water accumulation in roadways and floor subsidence will make the elevation of the original measuring points deviate from the actual elevation, and make the measurement data have certain errors[6].

4. Errors Caused by Complex Variation of Atmospheric Pressure
   Temperature and humidity at different times and heights in the same mine underground are constantly changing, which makes the measurement results of atmospheric pressure fluctuate in a smaller range. Generally speaking, the regular changes are more complex.

2.2. Analysis of Error Influencing Factors
The basic principle of grey relational analysis is to edit the influencing factors into various correlative sequences, and then draw the series into the curve of geometric shape. According to the shape of the geometric curve and the similarity of its development trajectory, we can judge the degree of correlation and compactness of its factors[7]. Grey correlation analysis needs to consider the similarity of trajectories between two geometric curves on the one hand, and the correlation of trajectories between two data series on the other hand. The correlation degree of these two aspects and the similarity between the two sequences must be taken into account in order to analyze and determine the correlation size and the influence degree of the influencing factors represented by the sequence on its main behavior[7].

According to the analysis of grey correlation analysis, it can be seen that the change of measuring point elevation, the sensitivity of measuring instrument and the complex change of atmospheric pressure have a large similarity correlation degree to the geometric curve shape of ventilation resistance error, so it is determined here as the main influencing factor of the error, and other influencing factors are classified as the secondary influencing factor of the error.

3. Results

3.1. Negative Feedback Adjustment Correction Principle
Negative feedback regulation is to suppress and weaken the changing part of the system so as to reach the state when the initial change occurs, so that the system can achieve or maintain equilibrium or steady state[8].
The correction method of ventilation resistance based on negative feedback regulation is to replace the difference between ventilation resistance value and static pressure value of fan as feedback factor when the accuracy test can not meet the accuracy requirement after calculating the ventilation resistance value, and then use the least square method to obtain the new value instead of the original atmospheric pressure to calculate the resistance value. If the calculated drag value does not meet the accuracy requirements, the feedback factor should be used to continuously adjust the atmospheric pressure by negative feedback until it meets the requirements.

In practical problems, especially in the current digital engineering construction, in order to further improve the accuracy of parameter estimation, it is necessary to consider both model error and random parameter error of measurement model, thus forming the following generalized non-linear least squares method[9].

\[
\min_{x \in \mathbb{R}^n, y \in \mathbb{R}^m} F(x, y) = \frac{1}{2}[p_1 f_i(x, y) - L_i]^2 + p_2(y_i - Y_i)^2 = \frac{1}{2}[(x, y)^T P_1 V(x, y) + e(y)^T P_2 e(y)]
\] (1)

Among them, \(p_1 \geq 0, p_2 \geq 0, y_i, L_i (i = 1, 2, \cdots, m)\) are measured values, \(Y_i\) is an estimate of known \(y_i\), \(P_1 = \text{diag}(p_1), P_2 = \text{diag}(p_2)\).

\[
V(x, y) = \left(V_1(x, y_1), V_2(x, y_2), \cdots, V_m(x, y_m)\right)^T = (f_1(x, y_1) - L_1, f_2(x, y_2) - L_2, \cdots, f_m(x, y_m) - L_m)^T
\] (2)

\[
e(y) = (e_1(y), e_2(y), \cdots, e(m))^T = (y_1 - Y_1, y_2 - Y_2, \cdots, y_m - Y_m)^T
\] (3)

3.2. Correction system

The correction method of ventilation resistance based on negative feedback regulation is to distribute the relative error according to the scale of the measured points, so as to correct the resistance. Following are the steps of the amendment method:

1. Detection data

Check the measured data, list the error equation or conditional equation, process the correct original data according to the principle of least square method, and then evaluate the quality of the processing results to obtain the available data.

2. Getting Feedback Factor

Firstly, the mean static pressure of fan in relative time period is calculated, the cumulative value of ventilation resistance of roadway is calculated, and the difference value \(A_i\) is calculated. Negative feedback correction is carried out according to the feedback factor[10].

Secondly, the relative difference of elevation of each roadway (the difference between the max surface of the inlet roadway and the Min minimum of the return air roadway) is calculated, and the ratio of \(B_i\) to the total height (the sum of all the differences) is calculated.

Finally, the feedback value \(C_i (ci= Ai*bi)\) is calculated according to the proportion of each roadway.

3. Calculating new atmospheric pressure values

According to the feedback value of roadway, the atmospheric pressure of each roadway is corrected (the difference \(A\) is positive, the original atmospheric pressure of intake roadway plus relative error \(ci\), the relative error \(C_i\) of original atmospheric pressure reduction of return roadway; the difference \(A\) is negative, the relative error \(C_i\) of original atmospheric pressure reduction of intake roadway and the relative error \(C_i\) of original atmospheric pressure of return roadway) and the new atmospheric pressure obtained is replaced by the feedback adjustment value by the least square method.

4. Solve and test it

The corresponding mine ventilation resistance is calculated from the atmospheric pressure value obtained after correction, and the accuracy is checked. If it does not meet the accuracy requirement, the negative feedback adjustment is made again according to the feedback factor, repeating 2, 3, 4 steps and iterating until it meets the accuracy requirement.
4. Discussion

4.1. Project overview
Xiaojihan Coal Mine is located in Yulin City, Shaanxi Province. It is located in the northeast of Yuheng Mining Area of Jurassic Coalfield in North Shaanxi Province. It is located 20km northwest of Yulin City. Its topography, geomorphology and geological structure are simple, its stratigraphic lithology is simple, its rock mass structure is mostly thick, its rock anisotropy is low gas mine[11, 12]. Mine is a central zonal ventilation, extraction type, three in and two out, the main inclined shaft, auxiliary inclined shaft and central air intake shaft, central air return shaft, Xiaosuji air return shaft. The inclination angle of the main inclined shaft is 14 degrees, the inclined length is 1400m, which goes directly to the bottom of the well; the inclined angle of the auxiliary inclined shaft is 6 degrees, and the inclined length is 3651m. The middle roadway reduces the inclination degree by turning back. All of them are transported by trackless rubber-tyred vehicles[11, 12].

4.2. Testing process
In the ventilation resistance measurement of Xiaojihan Coal Mine, the barometer base point (point by point) method is used to measure the resistance. Firstly, two resistance measurement routes of 11216 mining face and 11219 reserve mining face are selected. 30 and 21 resistance measurement points are selected on these two routes respectively. In this paper, the resistance measurement routes of 11216 mining face are developed. Then the reference point is set at the wellhead of the auxiliary inclined well as the measuring point 1. Two precise barometers of the same type are simultaneously read and recorded at the measuring point 1. After that, the instrument can be adjusted to measure the relative pressure. One instrument remains at the measuring point 1 and records the pressure value every five minutes. The other barometer measures and records the pressure point by point along the original selected measuring point. At the same time, it is necessary to record the time of pressure measurement. After measuring all the points, it is necessary to proofread the barometer again when returning to point 1. At the same time, the parameters of other measuring points are measured and recorded.

4.3. Result analysis
Table 1 can be obtained after collecting and sorting out the data measured in the process of ventilation resistance measurement in Xiaojihan Coal Mine.

Table 1. Summary of data for measuring roadway resistance.

| Numbe | Name of roadway | Sections shape | Supporting methods | Air density (kg/m³) | Actual wind speed (m/s) | Cross-sectional area (m²) | Perimeter (m) | Air volume (m³/s) | Length of measuring section (m) | Cumulative value (m) | Point elevation (m) |
|-------|----------------|---------------|-------------------|-------------------|------------------------|---------------------------|--------------|------------------|-----------------------------|---------------------|------------------|
| 0     | Auxiliary deviated wellhead | Semi-circular arch | Anchoring and spraying | 1.11 | 0 | 4.91 | 27.2 | 20.54 | 134 | 0 | 0 | 1224.5 |
| 14    | 216 Auxiliary Transport One Measuring Point | rectangle | Anchoring and spraying | 1.11 | 6 | 1.7 | 18.8 | 17.05 | 29 | 6602 | 6602 | 853.7 |
| 23    | Point of No.1 Return Lane Central air return well head | rectangle | Anchoring and spraying | 1.08 | -1.87 | 4.7 | 28.18 | 18.69 | 95 | 9494 | 16106 | 862.5 |
| 30    | Central air | circular | Pit shaft | 1.05 | -6.20 | 4.54 | 33.2 | 88.1 | 151 | 2543.8 | 18579.8 | 1247.3 |
Calculate the ventilation resistance value according to the data in Table 1, and compare the calculated ventilation resistance with the static pressure of the fan 1809.32Pa, the dynamic pressure -29.28Pa and the natural wind pressure 112.78Pa for the accuracy test. It is found that the calculated resistance value has a larger value. Deviation, so the original data needs to be corrected. After the correction of the ventilation resistance correction method based on the negative feedback adjustment, the resistance accuracy is calculated to be 2.13%, which is less than 5%, indicating that the inspection accuracy meets the requirements.

Table 2. Comparison of atmospheric pressure before and after correction.

| Number | Revised atmospheric pressure (Pa) | Atmospheric pressure before correction (Pa) |
|--------|----------------------------------|---------------------------------------------|
| 0      | 89227                            | 89210                                       |
| 14     | 92051                            | 92517                                       |
| 23     | 91688                            | 91783                                       |
| 30     | 87290                            | 88012                                       |

According to the data in Table 1, the frictional resistance of roadway is calculated and compared with the revised ventilation resistance in Table 3. It can be found that the deviation between them is not large. It shows that the revised ventilation resistance value based on negative feedback adjustment is correct and can be used as the basic data for the management and transformation of mine ventilation system.

Table 3. Summary of calculation of ventilation resistance and frictional resistance in mine roadways.

| Segment labeling | Length of roadway (m) | Wind resistance of roadway (Ns²/m⁸) | Reference friction coefficient/a*10000 (Ns²/m⁴) | Friction wind resistance/R* 10000 (Ns²/m³) | Friction resistance (Pa) | 100-meter wind resistance/ R*10000 (Ns²/m³) | Computation of friction coefficient/a* 10000 (Ns²/m⁴) |
|------------------|-----------------------|------------------------------------|-----------------------------------------------|---------------------------------------------|--------------------------|-----------------------------------------------|---------------------------------------------------|
| 0-14             | 6602                  | 1249.8                             | 788.11                                        | 89.00                                       | 701.52                   | 1118.096                                      | 201.7986                                          |
| 14-23            | 9434                  | 257.56                             | 448.31                                        | 399.18                                      | 520.8828                 | 127.4307                                      | 91.66                                             |
| 23-30            | 2543.8                | 425.67                             | 58.396                                        | 80                                          | 28.555                   | 6.2286                                        | 8.684613                                          |

4.4. Natural Distribution Simulation of Mine Ventilation System

According to the need of ventilation system analysis in Xiaojihan Coal Mine, it is necessary to establish a network analysis model of mine ventilation system to simulate the distribution of air volume in the ventilation system. Therefore, based on the second development of AutoCAD, the auxiliary design system of mine ventilation is developed. The system can calculate the air demand of each mine air point, calculate and input the value of mine air resistance, select reasonable fan type, and calculate ventilation network, etc. It can be used to simulate and analyze the actual ventilation system, to predict the air distribution of underground roadways, to analyze the structure of mine ventilation system, and to optimize the ventilation system scheme with safety, reliability and low power consumption.

According to the ventilation system diagram of Xiaojihan Coal Mine, the ventilation network diagram (Fig. 2) is drawn and modeled in the auxiliary ventilation design system of coal mine. The revised ventilation resistance value and the related parameters measured are input into the model of the ventilation aided design system. The parameters of the fan are input to set the fan roadway for network calculation. The results are shown in Table 4.
Figure 2. Ventilation network diagram of Xiaojihan Coal Mine.

Table 4. Table of simulation results.

| Roadway Number | Name                          | Supportin g methods                  | Start Node Number | End Node Number | Wind resistance of roadway | Laneway air volume | Roadway negative pressure | Roadway wind speed |
|----------------|-------------------------------|-------------------------------------|--------------------|-----------------|---------------------------|--------------------|--------------------------|------------------|
| 24             | 11216 working face            | anchor-plate retaining              | 19                 | 20              | 0.0393                    | 40                 | 62.8                     | 3.3              |
| 34             | Central air return shaft      | anchor-plate retaining anchor-plate retaining | 28                 | 29              | 0.0061                    | 148.8              | 134.9                    | 12.4             |
| 93             | 11219 Preparatory Mining Face | anchor-plate retaining anchor-plate retaining | 45                 | 46              | 0.0034                    | 23.4               | 1.9                      | 2                |
| 144            | 11217 Mining Face and Return Air Channel | anchor-plate retaining anchor-plate retaining | 43                 | 71              | 0.0273                    | 39.7               | 43.2                     | 3.3              |
| 172            | Xiaosuji return air shaft     | anchor-plate retaining anchor-plate retaining | 30                 | 107             | 0.0047                    | 173.7              | 141.8                    | 14.5             |

The actual working measurement data of ventilation system in Xiaojihan Coal Mine are 39.93 m³/s in 11216 working face, 40.30 m³/s in 11217 working face, 23.77 m³/s in 11219 reserve working face, 150.01 m³/s in central air return shaft and 177.60 m³/s in Xiaosu meter air return shaft. Comparing with the results of the mine ventilation aided design system, it can be concluded that the simulation results are basically consistent with the operation of the mine ventilation system in Xiaojihan Coal Mine.

5. Conclusions

1. There are many reasons for the measurement error of the ventilation resistance in the barometric point measurement of the barometer. Among them, the change of the elevation of the measuring point, the sensitivity of the measuring instrument and the complex change of the atmospheric pressure are the main reasons for the error here.

2. This paper analyzes the basic principle of negative feedback regulation, introduces the least squares method and proposes a correction method based on negative feedback adjustment, and applies it to the Xiaojihan coal mine resistance measurement project. The results show that the method is suitable for mine ventilation resistance. The measurement results can be quickly and accurately corrected.

3. The ventilation network diagram is drawn according to the mine ventilation system diagram, and then modeled in the coal mine ventilation auxiliary design system, the corrected mine ventilation resistance is set, and the natural ventilation simulation of the mine ventilation system is carried out. The simulation results are basically consistent with the operation of the actual coal mine ventilation system in the coal mine.

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