**ISSN: 2710-0588**

# Research on Monitoring Method of Critical Path Ventilation Resistance Situation of Mine Ventilation

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## Abstract

**In order to improve the safety and reliability of the ventilation system, the ventilation resistance monitoring and situation analysis methods of the ventilation path are used to diagnose the changes in mine ventilation resistance in real time and determine whether the ventilation system is healthy. Calculate the mine safety monitoring path through the critical path determination algorithm, and install multi parameter sensors (wind pressure, wind speed, temperature, humidity) in the critical path roadway. Real time calculation of mine resistance based on the barometer base point method and saving of historical monitoring parameters. By filtering out data and fitting trend curves in a two-dimensional coordinate system, the subsequent ventilation resistance is predicted using the cubic exponential smoothing method. This provides technical support for real-time control of the impact of changes in mine resistance caused by geological disasters on the mine ventilation system, and provides scientific management tools and advanced technological means for mine ventilation gas safety management and production safety.**

## Keywords

**Mine ventilation; Critical path; Ventilation resistance; Situation monitoring; Time series prediction.**

## 1. Introduction

The mine ventilation system is an important guarantee for coal mine safety production, and its stability and reliability are directly related to the safety production of the mine [1-3]. Ventilation resistance, as an important indicator for measuring the performance of a ventilation system, directly affects the airflow distribution and ventilation effectiveness of the system [4-6]. However, due to the complexity and dynamism of the mining environment, obtaining ventilation resistance parameters is often a discontinuous process, making it difficult to comprehensively and accurately grasp the resistance changes of the entire mine ventilation system [7-8]. Therefore, it is of great significance to comprehensively, accurately, and in real-time monitor and analyze the changes in the resistance of the critical path of mine ventilation in order to improve the safety and stability of the mine ventilation system.

Currently, scholars both domestically and internationally have conducted a series of studies on monitoring mine ventilation systems [9-11]. Early research mainly focused on static parameter measurement and manual inspection of ventilation systems, evaluating their operational status through regular monitoring of various parameters. However, these methods have obvious limitations and cannot reflect the dynamic changes of the ventilation system in real time. With the development of information technology and sensor technology, some scholars have begun to attempt to use real-time monitoring data to dynamically monitor ventilation systems. For example, by installing sensors such as wind speed and pressure in the ventilation system, real-time operation data of the ventilation system can be collected, and data analysis technology can be used to process and analyze the data, achieving real-time monitoring and early warning of the safety of the ventilation system. However, most of these studies focus on the overall monitoring of ventilation systems, lacking targeted monitoring and analysis of critical path ventilation resistance.

Therefore, based on the above analysis, the purpose of this study is to propose a ventilation resistance situation monitoring method for the critical path of mine ventilation. By monitoring and analyzing the resistance changes of the critical path in real time, potential ventilation safety hazards can be discovered in a timely manner, providing strong support for the safe operation of the mine ventilation system.

## 2. Monitoring Method for Ventilation Resistance Situation of Key Path in Mine Ventilation

### 2.1. Mine ventilation system and construction of geometric network topology structure

This article first uses the design drawings and actual operating data of the mine ventilation system to construct a directed graph of the geometric network topology of the mine ventilation system. The directed graph takes the roadway as the edge and the ventilation node as the vertex, and represents the direction of the airflow through the direction of the edge. At the same time, constructing the adjacency matrix and relationship matrix of the mine ventilation system provides a foundation for subsequent critical path calculations and sensor deployment.

### 2.2. Critical path determination algorithm

Based on the constructed geometric network topology directed graph, this paper uses the depth first search algorithm (DFS) to calculate the critical path of the mine ventilation system. The calculation of critical path is divided into two steps:

(1) Calculate the main ventilation path with air volume as the weight: Construct a directed graph of the ventilation network with air volume as the weight, select a branch of the roadway network at a certain air consumption point, use depth first search algorithm to search for the key path from the inlet wellhead to the air consumption point branch and the key path from the air consumption point branch to the return wellhead, and merge the paths to obtain the key path of the air consumption point.

(2) Calculate the maximum resistance path with wind resistance value as the weight: Construct a ventilation network directed graph with wind resistance value as the weight, and also use depth first search algorithm to search for the critical path from the inlet to the outlet to obtain the maximum resistance path.

Determine the critical path of the mine ventilation system by comparing two paths.

### 2.3. Sensor layout and data collection

On the determined critical path, this article deploys multi parameter sensors, including wind pressure sensors, wind speed sensors, temperature sensors, and humidity sensors. The placement of sensors is determined based on the actual situation of the tunnel and monitoring requirements. The specific placement method is as follows:

(1) Pressure sensor deployment: Pressure sensors are installed at the inlet and outlet of the roadway to measure pressure changes in the roadway.

(2) Wind speed sensor deployment: Install wind speed sensors in critical path branch tunnels, located at the average wind speed line of the tunnel, to measure changes in wind speed in the tunnel.

(3) Temperature and humidity sensor deployment: Install temperature and humidity sensors simultaneously in critical path branch tunnels to monitor temperature and humidity changes in the tunnels.

Set up a unified controller module to synchronously collect the values of all deployed sensors, ensuring the accuracy and consistency of the data.

## 2.4. Ventilation resistance calculation and data analysis

Synchronize the collection of all sensor values and calculate the ventilation resistance value of the tunnel. The method is to set up a unified controller module to read all sensor values installed on the critical path at the same time. The resistance calculation formula is: wellhead pressure sensor elevation ($H_B$), roadway pressure sensor elevation ($H_f$).

①When $H_B$-$H_f$≤600m, the gas flowing in the tunnel is assumed to be an incompressible fluid, and the formula for calculating resistance is:

$$h_{i-j} = K(p_{Bj} - p_{Bi}) + k(p_i - p_j) + \rho(z_i - z_j)g + (\rho_i v_i^2 - \rho_j v_j^2)/2 \tag{1}$$

In the formula, K- Unit conversion factor for base point barometer. k- Unit conversion factor for branch barometer.$p_{Bj}$,$p_{Bi}$-Measure the atmospheric pressure values at the starting and ending points, $p_a$.$p_i$,$p_j$- Measure the air pressure values at the starting and ending points, $p_a$. $z_i, z_j$- Measure the elevation of the starting and ending points, m. $\rho_i$,$\rho_j$- Measure the air density at the starting and ending points, $kg/m^3$. $v_i$,$v_j$- Measure the wind speed at the starting and ending points, $m/s$. $g$- Gravitational acceleration, $m/s^2$. $\rho_{i-j}$- Measure the average air density at the starting and ending points, $\rho_{i-j} = \frac{\rho_i - \rho_j}{2}$, $kg/m^3$.

②When $H_B$-$H_f$>600m, the gas flowing in the channel is assumed to be a compressible fluid, and the formula for calculating resistance is:

$$h_{i-j} = K(p_{Bj} - p_{Bi}) + k(p_i - p_j) + \rho_m(z_i - z_j)g + \rho_m(v_i^2 - v_j^2)/2 \tag{2}$$

In the formula, $\rho_m$ is calculated according to the multivariate process:

$$\rho_m = \frac{\dfrac{p_1 - p_2}{ln({}^{p_1}/_{p_2})}}{\dfrac{({}^{p_1}/_{\rho_1} - {}^{p_2}/_{\rho_2})}{ln\dfrac{{}^{p_1}/_{\rho_1}}{{}^{p_2}/_{\rho_2}}}}$$

## 2.5. Time series prediction and analysis methods

In order to predict the long-term trend of wind resistance at monitoring points, this paper adopts a time series prediction analysis method. The specific steps are as follows:

(1) Data preprocessing: Filter the collected ventilation resistance data to eliminate the influence of random errors and outliers.

(2) Time series construction: Compile the ventilation resistance data into a time series based on the measured time, and plot a statistical graph according to the time series.

(3) Weighted moving average method: Set a set interval time (such as 5 days, 10 days, 15 days) to calculate the moving average. The weight of the data decreases every 10 numerical terms from recent observations to long-term observations.

(4) Triple exponential smoothing method: Use the triple exponential smoothing method to analyze the long-term trend and rate of flow field resistance changes at monitoring points.

## 3. Experimental Verification and Result Analysis

### 3.1. Experimental setup

To verify the effectiveness and practicality of the proposed method, this paper selects a coal mine as the experimental object and conducts experiments using the actual operating data of the underground ventilation system of the coal mine. The experimental period is three months, with sensor data collected synchronously once a day.

### 3.2. Experimental results

Through experimental verification, the proposed method can accurately monitor the resistance changes in the critical path of mine ventilation, and accurately predict the trend of resistance changes at monitoring points. The specific experimental results are as follows:

(1) Accuracy of critical path determination: The critical path calculated by the depth first search algorithm is consistent with the actual operation of the mine ventilation system, verifying the accuracy of the critical path determination algorithm.

(2) Reliability of sensor data collection: The sensor is arranged in a reasonable position, the data collection is accurate and reliable, and it can reflect the real-time changes in ventilation resistance of critical paths.

(3) Accuracy of ventilation resistance calculation: The ventilation resistance calculated using the barometer base point method is consistent with the actual operation of the mine ventilation system, verifying the accuracy of the ventilation resistance calculation method.

(4) Time series prediction effect: Using the cubic exponential smoothing method to predict the long-term trend of wind resistance at monitoring points, the prediction results are basically consistent with the actual operating conditions, verifying the effectiveness of the prediction model.

### 3.3. Result analysis

By comparing and analyzing the experimental results, it was found that the proposed method has significant advantages in the following aspects:

(1) Strong targeting: Monitoring and analyzing the critical path of the mine ventilation system can promptly identify potential ventilation safety hazards.

(2) Good real-time performance: Utilizing multi parameter sensors to collect real-time ventilation resistance data, ensuring the timeliness of monitoring results.

(3) Accurate prediction: Using time series prediction analysis methods to predict the trend of resistance changes at monitoring points, the prediction results are accurate and reliable.

(4) Strong practicality: The proposed method is easy to implement and apply, and can provide strong support for the safe operation of mine ventilation systems.

## 4. Conclusion

This article proposes a ventilation resistance situation monitoring method for the critical path of mine ventilation. By constructing the geometric network topology of the mine ventilation system, the critical path is determined, and multi parameter sensors are deployed on the critical path to collect real-time ventilation resistance data. Using time series prediction analysis methods, predict the trend of resistance changes at monitoring points and promptly identify potential ventilation safety hazards. This method can accurately monitor the resistance changes in the critical path of mine ventilation, providing strong support for the safe operation of the mine ventilation system.

Future research can be further conducted from the following aspects: Based on the actual situation and monitoring requirements of the mine ventilation system, further optimize the sensor deployment plan to improve the accuracy and reliability of monitoring results. Explore more advanced prediction algorithms to improve the accuracy and timeliness of predicting long-term trends in ventilation resistance. Apply the proposed method to the monitoring and analysis of other similar complex systems to verify its generality and practicality. By combining intelligent technologies such as artificial intelligence and big data, deep mining and analysis of monitoring data are carried out to achieve intelligent management and optimization of mine ventilation systems.

## Acknowledgments

The study was supported by the Key Project of Science and Technology Innovation and Entrepreneurship Fund of Tiandi Technology Co., Ltd. (2022-2-TD-ZD010), and Key Research and Development Project of National Key Laboratory for Coal Mine Disaster Prevention and Control (2025ZDYF12).

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