

# Application of Natural Ventilation in Metal Mine Ventilation System

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**Abstract:** With the increase of mining depth, heat harm is becoming more and more serious, paper established series of fan operating parameters model, designed energy-saving system of use natural ventilation to solve mine thermal harm, combined ventilation remote monitoring and natural ventilation, and innovated the mechanical-natural ventilation system. Evaluated fan operating parameters and the ventilation system results of the experimental area, this method can achieve good ventilation cooling effect and can save a lot of power energy.

## 1 Introduction

With the continuous development of mineral resources, the reserves for superficial mines and the ore deposits with relatively simple technical mining condition in our country has been used up constantly, which forced most mines to move on to exploiting deep deposits or duplicating mines. The technological difficulties for exploitation of deep deposit mainly focus on three aspects: deep ground pressure forecast and control technique, underground heat damage control technique and intensified mining technology integration. In the respect of underground heat damage control technique, the study has currently focused on the field of research primarily cooling by means of ventilation, deep underground cooling does not only increase the difficulty of ventilation system, but also with great energy consumption. Many scholars at home and abroad have carried out a great number of in-depth studies on how to deal with mine deep ventilation and maximize the use of natural resources to lower the energy consumption in the ventilation<sup>1-6</sup>. Taking Jinqingding Mine as an example, this article designs surface monitoring control system consisting of indirect airflow volume measurement, automatic adjustment of airflow volume and fan performance monitoring, and combines this system with natural wind pressure in the ventilation system.

## 2 Study of Base Station Remote Monitoring System

### 2.1 Design Thought of Remote Monitoring System

The system adopts main control computer and touch screen display and monitoring pattern. The main control computer communicates via fieldbus communication network and PLC control module installed in the underground fan electrical cabinet, the control module completes the start, stop, forward, backward, adjust revolutions of the fan through the commands of main control computer, monitor the input and out of switching value, and convert to collect the airflow volume, wind pressure, bearing temperature, current, voltage and other analog quantity, then return to main control computer. The main control computer analyzes and processes the data received, and then displays the operating condition and various performance parameters of the fan on the monitor and touch screen through words or graphics. Then, the main control computer will determine whether the fan is overload according to the working current and time of duration of the fan, and send out overload shutdown command timely. Meanwhile, it may also adjust the airflow volume based on the field work requirement, issue an order to PLC controller via upper computer monitor software, and then control the inverter to adjust the fan speed, so as to adjust the airflow volume. Furthermore, the main control computer will also save and summarize the historical data and printout the report.

## 2.2 Electrical Connection Control Circuit and Basic Monitoring Network

The control circuit mainly comprises breaker, fuse, motor protector and AC contactor. The control circuit consists of button switch, inverter and PLC controller.

The breaker QF acts as the master switch, the contactor KM1 and KM2 have different phase sequence of main contact, which will control the positive and negative rotation of motor. In order to prevent from short circuit between power supplies caused by arc striking, PLC is used to control the AC contactor KM1 and KM2.

When the fan is in speed regulating operation, KM3 closes, the inverter is used to supply power; when the fan is in full-speed operation, KM1 closes, the power frequency is used to supply power directly. Add some time delay between forward and backward handover process. In order to prevent from misoperation, interlock circuit shall also be added.

## 3 Analysis on Measurement of Total Pressure of Fan in the Base Station

The static pressure for the fan in the base station refers to the difference of the static pressures in the air inlet and outlet of the fan; total pressure for the fan in the base station refers to the difference of the static pressures in the air inlet and outlet of the fan plus the differences of the dynamic pressures. The fan installed on the earth's surface which conducts forced and exhaust ventilation will have different expressions with those fans installed underground.

### 3.1 Measurement of Underground Fan Total Pressure (Static Pressure)

Under normal conditions, when the fan is installed underground, there is little difference between the sectional area of roadway in the front and rear of the fan, it can be deemed as equal, i.e.  $v_1 \approx v_2$ , furthermore, when the air density in the front and rear of the underground fan is approximately equal ( $\rho_2 \approx \rho_1$ ), the differential pressure caused before and after is approximately equal to the total pressure, i.e.:

$$H_t (P_2 - P_1) + \left( \frac{\rho_2}{2} v_2^2 - \frac{\rho_1}{2} v_1^2 \right) \approx (P_1 - P_2) H_s \quad (1)$$

Through analysis, we can know that, when the fan is installed underground, the static pressure for the fan in the base station stands for the total pressure. Upon measurement of static pressure, install the static tube in the front and rear of the fan to measure the change of the static pressure (or total pressure) online. When the piezometer tubes in the inlet and outlet are connected to both ends of the differential pressure transducer, the static pressure (or total pressure) value of the fan can be got. Then, transport the output signal (electrical signal etc.) of differential pressure transducer to monitoring system remotely, and we will get the static pressure display value of the fan after conversion and processing. In view of the test principle, upon measurement of static pressure (or total pressure) for the underground fan, the static pressure difference in the inlet and outlet of the fan shall be measured only.

### 3.2 Indirect Measurement Theory and Method Relating to The Fan Delivery in The Fan Stations

Generally three methods are used for the measurement of underground blowing rate, namely the direct measurement, dynamic pressure measurement and static pressure difference measurement<sup>6</sup>.

For dynamic pressure measurement method, the pitot tube and differential gauge are applied to measure the multipoint dynamic pressure on a roadway section, which is averaged and then the average blowing rate is computed with the dynamic pressure formula, multiplied by the cross-sectional area. Due to the irregular distribution and direction of the blowing rate resulting from the irregular section of the underground roadway, the total pressure hole of the pitot tube is difficult to be aligned with the direction of air current, resulting in

inaccurate measurement data.

Static pressure difference measurement method is based on the Bernoulli equation of fluid mechanics, namely the conversion relationship between the static pressure, dynamic pressure and the resistance of fluid motion, using the static pressure difference between the different sections to indirectly measure the blowing volume, since static pressure is easily measured, this method is the relatively widely used for measurement of the blowing volume of the fan blower.

### 3.2.1 Theoretical Analysis of the Static Pressure Difference Method for Indirect Measurement of Blowing Volume

The static pressure difference method for measurement of the blowing volume, based on the principle of applying Bernoulli equation of fluid mechanics for the two different cross-sectional areas of the fan and the tunnel, that is, the energy relation equation to derive the functional relation between the air blowing volume and the two sections, which is obtained through correction in the experiment.

According to the fluid mechanics theory, the energy conversion equation for the two different sections of the drift should be:

$$P_1 + \frac{\rho}{2} v_1^2 = P_2 + \frac{\rho}{2} v_2^2 + \xi \frac{\rho}{2} v_1^2 \quad (2)$$

Where:  $P_1, P_2$  —1, 2, the static pressure of the section, Pa;  $v_1, v_2$ —1, 2 the blowing rate of the section, m / s;  $\rho$ —1, 2, the aircurrent density of the section, kg/m<sup>3</sup>;  $\xi$ - the local resistance coefficient obtained by way of look-up table or experiments.

As the blowing volumes flowing through the two sections of the roadway are equal, it can be deduced with the hydrodynamic continuity equation:

$$Q = v_1 \cdot S_1 = v_2 \cdot S_2 \quad (3)$$

Where:  $S_1, S_2$ —1, 2 the cross-sectional area of the sections, m<sup>2</sup>.

Equation (3) is substituted into equation (2) to obtain the following:

$$Q = \frac{\sqrt{2} \cdot S_1 \cdot S_2}{\sqrt{\rho[S_1^2 + (\xi - 1)S_2^2]}} \times \sqrt{(P_1 - P_2)} = K \sqrt{\Delta P} \quad (4)$$

Where:  $K = \frac{\sqrt{2} \cdot S_1 \cdot S_2}{\sqrt{\rho[S_1^2 + (\xi - 1)S_2^2]}}$ , the geometric factor can be calculated;  $\Delta P = P_1 - P_2$ , the differential pressure value

between the two sections.

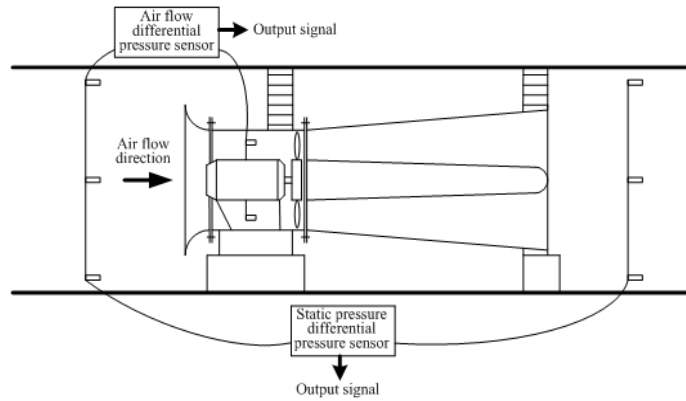
Then by substituting  $K' = \lambda \cdot K$  into equation (4) to get the following:

$$Q = K' \sqrt{\Delta P} = \lambda \cdot K \sqrt{\Delta P} \quad (5)$$

Where:  $\lambda$ —the correction factors taking into account the factors of the irregular sections, etc, which is obtained through field measurement with equation (5).

### 3.2.2 Combined Measurement of Ventilating Current Parameters (Static Pressure, Blowing Volume)

In the system detection, the measurement of the static pressure and the blowing volume can be combined for simultaneous determination, the measurement method as shown in Fig. 1.



**Fig.1 Combined measurements of static pressure and blowing volume**

#### 4 Natural Wind Pressure Combined with Fan Blower Remote Monitoring System Energy-saving Analysis

A long-term detailed actual measurement was conducted on the combined effect of the ventilation system and the natural wind pressure in energy saving and consumption reduction in Jinqingding underground mine of Jinzhou Mining Group in the research process, which showed a considerable energy-saving effect.

The electric energy saved in this system compared with the conventional system:

$$\Delta Y = Y'' - Y' = 152 - 75.1 = 769000kW \quad (6)$$

The electricity cost saved in this system:

$$\Delta I = I'' - I' = 91.4 - 45.1 = RMB463000 \quad (7)$$

Through the above comparison and further analysis of the following calculation, for the ventilation system with the blowing volume remote control as required and the rational use of natural wind pressure as well as the mechanical ventilation based and supplemented with the natural ventilation, the energy-saving rate of fans in Grade I , IV grade main stations reached:

$$z = \frac{Y'' - Y'}{Y''} \times \% = \frac{\Delta Y}{Y''} \times \% = \frac{152 - 75.1}{152} \times \% = 50.6 \%$$

Energy-saving effect is very obvious, which also creates the greater economic benefit and considerable social benefit.

#### 5 Conclusions

(1) Considering the specific circumstances of Jinqingding underground mine, several advanced energy-efficient ventilation technologies such as remote fan frequency control to adjust the underground blowing volume, the remote monitoring of fan operation security and full use of ventilation by natural wind pressure have been studied in the process of the ventilation system research, which has achieved a significant energy saving effect.

(2) The remote control of the fan blowing volume of the main stations is achieved through the application of the inverter technology, and the method of static and dynamic pressure conversion is applied to solve the issues including the difficulty in accurate measurement of the station aircurrent, the measuring element prone to damage and the influence on the fan blower maintenance.

(3) The remote monitoring system combined with the mechanical and natural wind alternate ventilation in full use of natural energy has opened up a new way for the energy reduction in underground mine ventilation, which is of practical significance to the underground mine in full use of the natural green energy for saving energy and reducing consumption as well as the emission reduction.

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