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Determination of Air Leakage of Auxiliary Ventilation Ducting System in VANG DANH Underground Mine

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Abstract: Air leakage of air movement through the ducting system in underground mine is an important factor in ensuring the efficiency of ventilation during mining roadways being driven in mine. This value plays an important role in the reasonable design of auxiliary ventilation as well as in the energy cost in the mine.
Experimental data of the duct air leakage are made on 0.8 m diameter ducts over sections of ducts installing towards the working face in Vang Danh mine. Determination of the air leakage in ducting system have been undertaken.
Keywords: Air leakage; Auxiliary ventilation; Duct; Working face; Ventilation efficiency; Operating costs

Introduction

Ventilation is an important work in the construction of tunnels in underground as well as underground mine. There is high methane content in Vang Danh coal underground mine. The excavation work is carried out by the drilling and blasting method. Therefore, ventilation system used is the force system, in which the fresh air is led to the face through the fabric duct. Fabric ducts and different types of fans are used for the auxiliary ventilation system. The efficiency of ventilation depends on the performance of the fan as well as the quality and aerodynamic characteristics of the duct. In the parameters of the duct, the level of air leakage plays an important role in the efficiency of air ventilation to the face.

1. Determining leakage coefficient of duct used in Vang Danh mine

1.1 Duct air leakage

An overview of methods for studying airflow in the ducting system, it shown that if there is not duct air leakage, then the distribution of airflow through the ductwork can be described by mathematical models quite accurately. However, complete elimination of air leakage from, or to the duct system is impossible due to the duct quality and numerous joints in the duct system [1]. Therefore, the calculation of the flow rate and energy of the airflow becomes complicated.

Air leakage can be described in the following two physical models [2].

- Discrete – air leakage leaks through joints of ductwork
- Continuous – randomly distributed outlets along the ductwork walls.

For estimating level of the air leakage, the researcher proposed the flow of the air leakage leaks in turbulent flow mode; but researcher proposed flow of the air leakage in laminar flow mode. The work shown that the mode of the air leakage is quite complicated and close to exponential function. Therefore, the results of the air leakage coefficient have been shown in the form of tables or graphs for certain types of duct.

1.2 Determining leakage coefficient

Level of air leakage is mainly influenced by the following factors: total length, diameter of the ducting and airflow in the ducting system.

Currently, in Quang Ninh mines, airflow volume Q_{face} supplying to the face changes from 2 to 8 m^3/s for the duct of D = 0.6 ÷ 0.8 m; sometimes 1.0 m for large cross-section roadway.

When the length of the duct is extended from 100 m to 700, 800 m, air leakage will increase quite markedly. Leakage sometimes exceeds 25-30% initial flow volume designed over hundreds m ducting length.

A conceptual prediction model has been proposed based on experimental data. Experimental data of the duct air leakage for the duct of 0.8m diameter measured at Vang Danh Coal mine is shown in table 1.

$p=f(L,Q)$ $p=f(L,Q)$ (1)

Let p, L and Q represent leakage coefficient, duct length and quantity of airflow in the ducting system respectively. It is assumed to express p in the form:

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Table 1. Experimental data of the duct airleakage for the duct of 0.8m diameter measured at Vang Danh Coal mine

L(m) \ Q(m^3/s)	2.1	2.3	2.5	2.8	3.2	3.5	3.8	4.1	4.5
100	1.017	1.017	1.017	1.019	1.020	1.021	1.021	1.024	1.026
200	1.055	1.055	1.056	1.059	1.063	1.065	1.068	1.072	1.078
300	1.116	1.130	1.141	1.153	1.166	1.175	1.188	1.198	1.202
400	1.160	1.171	1.180	1.189	1.211	1.222	1.235	1.246	1.2162
500	1.246	1.255	1.268	1.276	1.288	1.2998	1.311	1.325	1.341
600	1.335	1.348	1.358	1.371	1.388	1.398	1.412	1.423	1.438
700	1.432	1.446	1.458	1.474	1.493	1.508	1.522	1.538	1.556
800	1.534	1.551	1.569	1.589	1.617	1.636	1.655	1.676	1.706
900	1.652	1.676	1.702	1.728	1.756	1.779	1.802	1.823	1.849

1n(p-1)=1nc+b_1ınL+b_2ınQ (2)

1n(p-1)=1nc+$b_1$1nl+$b_2$1nQ Where:

p: Leakage coefficient;

L: Duct length, m;

Q: Quantity of airflow in the ducting system, m^3/s;

lnc, b_1, b_2, constants.

Each set of data: ln (p_i), ln (L_i) and ln (Q_i) under given data – duct diameter, with i=1, 2…n.

With ducting length L_i, the quantity of airflow in the ducting system Q_i is measured; the air leakage coefficient p_i is calculated as:

$$p_i = \frac{Q_0}{Q_i}$$

Where: Q_0 the quantity of airflow beyond the fan, m^3/s; Q_i quantity of airflow reaching the end of the ducting length - L_i.

Linear regression analysis to fit these experimental data that can determinate the air leakage coefficient.

Let y_i, x_{i1}, x_{i2} and b_0 represent ln (p_i -1), lnL_i, lnQ_i and lnC respectively. Equation above can be rewritten for the i^{th} observation from the model:

$$y_i = b_0 + b_1 x_{i1} + b_2 x_{i2} \quad (3)$$

The model is represented as a system of n equations as follows:

$$Y_1 = b_0 + b_1 x_{11} + b_2 x_{12} + e_1 \quad (4)$$

$$Y_2 = b_0 + b_1 x_{21} + b_2 x_{22} + e_2 \quad (5)$$

. . …………………….

$$Y_n = b_0 + b_1 x_{n1} + b_2 x_{n2} + e_n \quad (6)$$

These n equations can be written in matrix form as:

$$\begin{vmatrix} y_1 \\ \vdots \\ y_n \end{vmatrix} = \begin{vmatrix} 1 & x_{11} & x_{12} \\ \vdots & \vdots & \vdots \\ 1 & x_{n1} & x_{n2} \end{vmatrix} \begin{vmatrix} b_0 \\ b_1 \\ b_2 \end{vmatrix} + \begin{vmatrix} e_1 \\ \vdots \\ e_n \end{vmatrix} \quad (7)$$

$$Y = X.b + e \quad (8)$$

Where: Y is a vector of n observation on study variable;

X is a matrix of n observations on each of the 3 explanatory variables;

b is a vector of regression coefficients;

e is a vector of random error components or disturbance term.

It is assumed that: $E(e) = 0,\ Var(e) = I.\sigma^2$

To estimate the parameters b_0, b_1 and b_2 using the principle of least squares. Least-squares regression is to fit these experimental data that minimizes the sum of squared residuals in matrix form.

$$\acute{e}e = (Y - Xb)(Y - Xb) = \acute{Y}Y - 2\acute{b}\acute{X}Y + \acute{b}\acute{X}Xb \quad (9)$$

Then parameters are:

$$\hat{b} = (\acute{X}X)^{-1}\acute{X}Y \quad (10)$$

Therefore, the air leakage coefficient for the duct of 0.8m diameter can be obtained based on data at Vang Danh mine:

$p = 1 + 2.8597.10^{-6}.L^{1.6245}Q^{0.4468}$ (11)

Use the F-test can evaluate Pro (F) = 0.0000 with significance level is 0.5. This low a value would imply that the regression parameters are nonzero and the regression equation does have some validity in fitting the data.

2. Conclusion

In Vietnam, for the design of ventilation, the air leakage coefficients of the ducts are mainly referenced from foreign handbook. This often leads to inaccurate ventilation calculations.

The coefficient of air leakage can be determined based on a general assessment of the influence of many factors, in which the length and diameter of the duct, and the flow rate are very important.

The air leakage coefficient in Vang Danh has been determined based on survey data in Vang Danh coal mine by using the linear regression method.

In addition, the research results have been used to optimize the ventilation system. Optimizing the auxiliary ventilation system can save money and energy.

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