Selecting Parameters to Design Auxiliary Ventilation in Underground Mine

Phuong Thao DANG[1)]

[1)] Mining Faculty, Hanoi University of Mining and Geology, Hanoi, Vietnam; 18 Vien Street, Duc Thang Ward, Bac Tu Liem District, Hanoi, Vietnam; email: dangphuongthao@humg.edu.vn

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Abstract

In recent years, Quang Ninh coal mines are continually expanding on size and depth, the total length of the roadway each year amounts about ten thousands meters in order to reach new production zones. The length of new roadways is usually longer, leading to increase to the airflow demand. Ventilation is one of the main factors effecting driving progress of the roadway. The estimation of airflow requirements is usually based on the minimum amount of airflow required at the heading during driving roadways or at the working face, in other words, when the ventilation ductwork is at its maximum length.

Therefore, determination of maximum ventilation length of ductwork has been undertaken. This results allow the selection of a reasonable fan to meet the ventilation requirements when driving the roadway. Also, this value is an important parameter for designing auxiliary ventilation system that operates more efficiently on a lower cost.

Keywords: *air leakage, maximum ventilation length, auxiliary ventilation, duct, working face*

Introduction

Auxiliary ventilation is one of critical importance considerations in coal underground mine. The systems must be supplied a fresh air to ensure a safe and comfortable environment conditions in the working face. Therefore, ventilation system needs to be ensured technical standard and safety regulations, also get optimized both capitals and operating cost.

In fact, in coal mine in Vietnam, when driving roadways, the most common auxiliary ventilation system used is the force system, in which the fresh air is led to the face through the fabric duct. The auxiliary ventilation system is comprised the ductwork and the axial fans. Recently, mines have equipped with auxiliary fans to meet requirements of ventilation. Fan requirements for mechanized roadway depend on the length of the roadways and airflow requirements. The problem is that mines normally select fan based on experience. In practice, one mine use a fan while another mine use two fans with the same conditions (the airflow requirements, the length of the roadways). It can be noticed, if one fan satisfies the air flow, two fans will "redundant" that can increase system operating costs. The another problem is that both cases are aimed at ensuring ventilation by selecting number of fans and not paying much attention to air ducting system to the face. The fan consumes energy to overcome duct resistance to bring fresh air into the face, so duct needs to have special technical characteristics to improve the efficiency of the fan. The cost of fan is no less than the cost of the ducting system. There is a widely-held belief in the mining community that more fan power in a ventilation ducting system will produce more airflow. However, in most cases, this is either not true in any practical sense, or is a very expensive way to achieve an increase, in both capitals and operating costs [1]. Economic fact associated with mine ventilation is well known to the practising engineer as ventilation accounts for 40 to 50% of a mine's total energy consumption [2].

The estimation of air volume requirements is normally based on the minimum amount of airflow required at the heading during the final stages of development or at the stope face during the final stages of production; i.e. when the ventilation ducting is at its maximum length [3]. Therefore, determination of maximum ventilation length with a given ductwork as well as ventilation parameters in auxiliary ventilation system have been investigated in order to optimize parameters to design auxiliary ventilation in underground mine.

1. Optimal fan selection in auxiliary ventilation systems

For each auxiliary ventilation system with a given ductwork, airflow amount of the fan can bring to the working places needs to be determined. One of the important problem of ventilation design when driving roadway is to calculate the maximum length of ductwork that a fan has enough capacity to ensure to bring air to the face.

In case the roadways are not long, solving the above problem is choosing the one appropriate fan for auxiliary ventilation. And ducts must have low resistance, air leakage as well as ensure construction quality when installed in the roadway cross section.

In case the roadways are long. The solution to the problem is to calculate the maximum length of ductwork that a fan can ensure to reach fresh air to prepared face. From that, design a reasonable distance between the fans working in series (the outlet of one fan is the direct inlet to the next fan) in order to prevent pressure drop in the ductwork before the next fan's inlet, causing problems with the fan motor.

As can be seen in Figure 1, distance between the fans installed in series can be as [4]:

a. The distance between the fans is calculated in theory.
b. The distance between the fans is far causing a ducting pressure loss at the inlet of the next fan in series. This can cause problems with the fan motor.
c. The distance between the fans is recommended for installing fans based on the maximum ventilation length

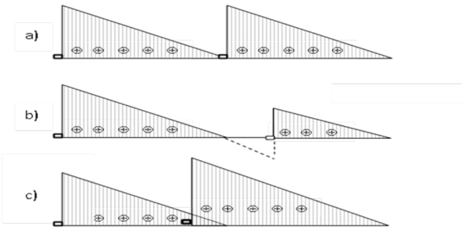

Fig. 1. Schematic of fans installation in series whilst in a series operation system

Fig. 10. Relationship between shrinkage and ratio of fly ash

Q (m^3/s) / L(m)	2	2.3	2.5	2.8	3	3.2	3.4	3.5	3.8	4.0
100	1.024	1.026	1.027	1.028	1.030	1.030	1.032	1.033	1.035	1.035
200	1.091	1.097	1.102	1.111	1.118	1.120	1.124	1.125	1.131	1.135
300	1.203	1.214	1.221	1.230	1.238	1.242	1.249	1.252	1.261	1.272
400	1.323	1.345	1.368	1.378	1.394	1.415	1.435	1.450	1.476	1.488
500	1.542	1.568	1.590	1.618	1.642	1.666	1.688	1.678	1.798	1.716
600	1.749	1.776	1.798	1.838	1.889	1.908	1.930	1.946	1.977	1.995
700	1.976	2.032	2.078	2.133	2.169	2.193	2.218	2.233	2.268	2.296

Tab. 2. Values of aerodynamic characteristic of the fan YBT-22

Flow rate, m^3/s	3.9	4	4.15	4.27	4.5	4.66	4.83	5
Pressure, mmH_2O	316	316	316	314	302	291	277	261
Flow rate, m^3/s	5.16	5.33	5.5	5.67	5.83	6	6.18	
Pressure, mmH_2O	245	228	206	179	149	113	70	

estimated, it is estimated the reasonable distance between the fans working in a series operation system.

Netherless, it is necessary that the use of fans and their operation in optimal conditions lead to savings in energy consumption.

2. Model of conceptual analysis for calculating maximum ventilation length

For example, determining the relationship between the maximum length of duct which the fan can bring the required airflow to the face, is difficult to solve by graph method if not combined with analytical methods.

Underground mine ventilation network analysis has not been much changed since 1935 when McElroy conducted the study of the engineering factors in the underground mine ventilation [5–6]. In the general case, the concept mathematical model of the auxiliary ventilation system is described by the following expression [7]:

$$R_o.p.Q^2=n.f(Q) \quad (1)$$

Where: R_0: Theoretical friction resistance of ductwork (no air leakage in ductwork), kμ;
f (Q): Analytic expression of the fan aerodynamic characteristic curve;
p: Duct leakage coefficient;
Q: Quantity of airflow, m^3/s;
n: Numbers of fans in series;

Resistance Ro is determined by the formula [8]:

$$R_0 = 6.48 * 0.00048 * L/D^5 \ (k\mu) \quad (2)$$

Where: α: Friction factor for the duct, α= 0.00048 $KgF.s^2/m^4$;
L: Distance between two cross sections of duct, m;
D: Diameter of the duct, m.

Equation (1) can be represented as follows:

$$6,48.\alpha.L/D^5 .p.Q^2=n.f(Q) \quad (3)$$

Estimating duct leakage coefficient – p and fan characteristic curve – H=f(Q) in order to calculate the maximum ventilation length, which the fan can generate the required air flow.

2.1 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. The experimental data are made on 0.7 m diameter ducts over sections of ducts installing towards the working face in actual field conditions in Vang Danh Coal mine in Quang Ninh province as shown in Tab.1. A conceptual prediction model has been proposed based on experimental data at Vang Danh Coal mine [9–10].

$$p=f(L,Q) \quad (4)$$

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:

$$ln(p-1)=lnc+b_1 \ lnL+b_2 \ lnQ \quad (5)$$

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 $p_i=Q_0/Q_i$;
Where: Q_0 the quantity of airflow beyond the fan, m^3/s;

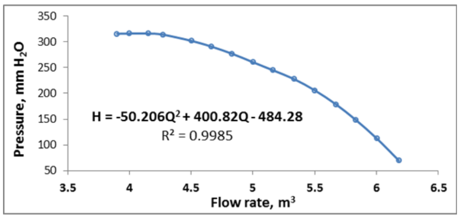

Fig. 2. Pressure-volume characteristic curve for fan YBT-22

Tab. 3. Values of aerodynamic characteristic of the fan SDF(A)-II-5.3/ 2x7.5

Flow rate, m^3/s	3.3	3.5	3.7	3.8	4	4.3	4.5
Pressure, mmH_2O	405	407	407	406	403	393	375
Flow rate, m^3/s	4.8	5	5.3	5.5	5.8	6	6.2
Pressure, mmH_2O	347	311	269	224	174	123	88

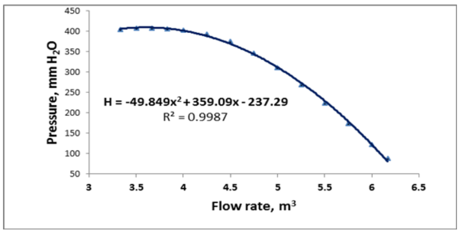

Fig. 3. Pressure-volume characteristic curve for fan SDF (A)-II-5.3/ 2x7.5

Q_i the quantity of airflow reaching the end of the ducting length – L_i.

Linear regression analysis by using Stata software to fit these experimental data can derive the relationship between the air leakage coefficient, the quantity of the air in the ductwork and the ducting length. Therefore, the air leakage coefficient for the ductwork of 0.7 m diameter can be estimated based on the experimental data at Vang Danh Coal mine by the regression method.

As a result obtained from Stata software, the air leakage coefficient for the duct of 0.7 m diameter can be found based on data at Vang Danh Coal mine:

$$p= 1 + 3.06397.10^{-6}.L^{1.88078}Q^{0.47215} \quad (6)$$

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 [11].

2.2 Analysis of the fan characteristic curve H=f(Q)

Drawing figure representing the relationship between fan flow rate and pressure of fan to find fan characteristic curve. The figures of the fan characteristic curves of the fan YBT-22 and the fan SDF (A)-II-5.3/ 2x7.5 are determined by data describing the fan characteristic as shown in table 2 and table 3.

The fan curve H=f(Q) for fan YBT-22 in the form of an inverse curve figure 2. Quadratic polynomial fit to these data is as follows:

$$H=-50.206.Q^2 + 400.82.Q - 484.28 \text{ for fan YBT-22} \quad (7)$$

The value of the correlation coefficient r^2= 0.9985, showing that the function H = f(Q) describes quite accurately the characteristic curve of the fan.

The fan curve H= f(Q) for fan $SDF_{(A)}$-II-5.3/ 2x7.5 can be obtained by using the same procedure, as shown in figure 3:

$$H = -49.849.Q^2 + 359.09.Q - 237.29 \text{ for fan } SDF_{(A)}\text{-II - 5.3/ 2x7.5} \quad (8)$$

Correlation coefficient r^2= 0.9987 is shown that a regression line to be considered reliable.

2.3 Calculating maximum ventilation length

Combining equation (3) and equation (7), gives:

$$6,48.\alpha.L/D^5 .p.Q^2=-50.206.Q^2+400.82-484.28 \quad (9)$$

For fan YBT-22

Currently, in Quang Ninth mines, airflow volume Q 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.

Under the conditions of this study: using the fan YBT-22, the ductwork of 0.7 m diameter and amount of airflow required at the face Q= 4m^3/s,

Substituting values $p= 1 + 3.06397.10^{-6}.L^{1.88078}Q^{0.47215}$ (10)

into (Eq. 9) then obtains maximum ventilation length L_{max} = 566.25 m.

By using the same analytical procedure as above, under the conditions of this study: using the fan SDF(A)-II-5.3/2x7.5 , the ductwork of 0.7 m diameter and amount of airflow required at the face Q= 4m^3/s, maximum ventilation length L_{max} for SDF(A)-II-5.3/2x7.5 is 860.22 m.

Conclusion

Analysis of fan characteristics and ductwork parameters in order to assess the reliability of the ventilation level when driving roadways. From the analytic equations it is possible to determine the maximum ventilation length that the auxiliary fan has enough capacity to ensure to bring the required airflow to the face. The equations to solve the problem of selecting the number of fans need to be used for the ducting system.These data can help designers and operators to select the appropriate fan in auxiliary ventilation systems.

A conceptual prediction model has been proposed based on the experimental data at Vang Danh Coal mine.

In addition, this is the basis for making a plan to equip ducts and fans to meet production requirements for each stage in underground coal mines. The research results were used to optimize the auxiliary ventilation system that can save costs and energy.

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