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Operating conditions of a mine fan under conditions of variable resistance

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ABSTRACT
According to the basic fluid principles and ventilation laws combined with the ventilation network computing method, this study proposes the concepts of relative sensitivity and absolute sensitivity, and studies these two sensitivities' variation law under conditions of variable airway resistance. The result showed that when the airway resistance increased, the fan air volume, relative sensitivity, absolute sensitivity and fan pressure's relative and absolute sensitivity tend to decrease. At the same time, fan pressure shows an increasing trend. Conversely, when the airway resistance goes down, the above parameters follow the opposite trend. These results provide a basis and guidance for adjusting the fan operation condition in the mine production process.

KEYWORDS: variable resistance, operating conditions, change rule, sensitivity

1. INTRODUCTION

Mine Ventilation System is one of the basic production systems that ensures the safety of underground work personnel life (Zhou et al., 2005). In recent years, the mining strength, depth, and the production level have all been increasing, which leads to increasingly complex ventilation systems and existing diagonal structures in the mine ventilation system, which make the ventilation management increasingly difficult. The actual production process needs timely adjustment of volume, because the working face to replace, wind resistance of roadways, the network structure and the need to air volume are constantly changing (Mi, 2009. Air conditioning is a dynamic process, and the nonlinear changes not only increase the difficulty of air volume adjustment for complex ventilation networks, but also have a significant impact on production safety. Therefore, mastering the complex network air regulation change rules requires more and more attention. Zhou (1995) put forward and illustrated the simple calculation method of the adjustable resistance value, based on the influence of the network. Zhao et al. (2003) developed measures of increasing and decreasing the resistance to adjust the air volume on the individual ventilation networks. Zhou et al. (2005) analyzed the sensitivity of the branch airflow to the wind resistance and the natural wind pressure, in order to judge the stability of ventilation networks. Jiao et al. (2009) analyzed the partial ventilator regulating ability and introduced the concept of air volume adjustable tunnelling faces. Wu, (2011) used the sensitivity to quantify the selection criteria of the air regulation point. Yan et al. (2011) studied the ventilation system air volume and wind resistance changes between the superpositions. Hu et al. (2014) explored the complexity of mine ventilation network and fan control. There are few reports on air regulation change law for complex ventilation network. The present study examines the fan air volume and air pressure change rules and regulation of sensitivity for the main branches of the complex ventilation network system, in order to provide a basis and guidance for mine air regulation.

2. MODEL OF THE VENTILATION NETWORK SYSTEM

The set of the ventilation network nodes is

$$J = \left(j_1, j_2, \cdots, j_m\right)$$

where m is the number of nodes.

The set of the ventilation network branches is

$$E = \left(e_1, e_2, \cdots, e_n\right),$$

where n is the number of branches.

The ventilation network can be expressed as

$$G = \left(V, E\right)$$

A typical complex ventilation network that included series, parallel, and angle type and containing eight nodes and twelve branches was built, as shown in Figure 1.

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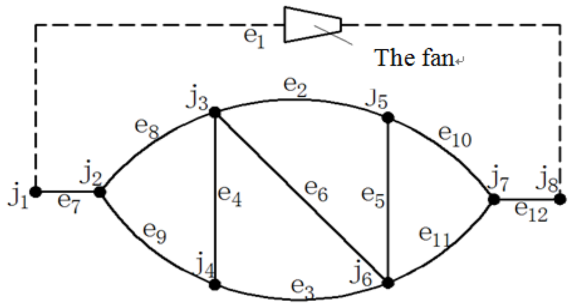

Figure 1: The ventilation network.

The wind resistance change of branch is defined as the variable resistance branch. When the variable resistance branch of wind resistance changes the air flow and pressure of the fan, this magnitude of the air volume change is defined as the sensitivity of air volume for variable resistance, called γ. The ratio of the air flow (pressure) variation and the wind resistance of variable resistance branch is defined as the absolute sensitivity, called ψ. The formulas are as follows:

$$\gamma_q = \frac{d(\Delta Q)}{d(\Delta R)} = \frac{d(Q_{ij} - Q_{i0})}{d(R_j - R_0)} \quad (1)$$

$$\gamma_q = \frac{d(\Delta Q)}{R_j} = \frac{d(Q_{ij} - Q_{i0})}{R_j} \quad (2)$$

$$\gamma_f = \frac{d(\Delta H)}{d(\Delta R)} = \frac{d(H_{ij} - H_{i0})}{d(R_j - R_0)} \quad (3)$$

$$\gamma_f = \frac{d(\Delta H)}{R_j} = \frac{d(H_{ij} - H_{i0})}{R_j} \quad (4)$$

Where: Q_i is the fan branch air volume after variable resistance of the j time measured in m^3/s; H_i is the fan branch of wind pressure after variable resistance of the j time; Pa; Q_{i0} is the fan branch air volume air volume after variable resistance of the $j-1$ time measured in m^3/s; H_{i0} is the fan branch of wind pressure after variable resistance of the $j-1$ time; Pa; R_j is the resistance value of the variable resistance branch after the j time variable resistance; R_0 is the resistance value of the variable resistance branch after the $j-1$ time variable resistance measured in $N.s^2/m^8$.

The wind resistance information of each branch was as shown in Table 1. The basic information of the fan was as shown in Table 2.

Table 1: The value of the each branch wind resistance.

Branch number	Value of the wind resistance (N. s^2/m^8)
e_1	0. 001
e_2	0. 026
e_3	0. 005
e_4	0. 065
e_5	0. 082
e_6	0. 099
e_7	0. 126
e_8	0. 048
e_9	0. 087
e_{10}	0. 032
e_{11}	0. 029
e_{12}	0. 134

Table 2: The basic information of the fan.

Fan model	FBCDZ-6-№20
Wind pressure(Pa)	661-1917
Air volume (m^3/s)	25. 9-65. 5
Motor model	YBF_2-315S-8
Rated speed (r/min)	900
Rated power (kW)	2×55

3. VENTILATION NETWORK SOLUTION

Network solution is one of the important ways to adjust and analyze the ventilation network. This is theoretically based on the three laws of ventilation, which are the air volume balance law, the mesh air pressure balance law, and the law of resistance (Zhang, 2000).

(1) The balance law of air volume:

The mass flow of each branch that inflows and outflows of a node algebraic addition is zero. The formula is as follows:

$$\sum M_i = 0 \quad (5)$$

(2) The balance law of the mesh air pressure:

In a closed loop without a power source, the ventilation resistance of the branches algebraic addition is zero, while with a power source, the ventilation resistance of the branches algebraic addition is equal to fan air pressure of the loop. The formula is as follows:

$$\sum h_i = 0 \text{ or } \sum h_i = h_f \quad (6)$$

(3) The law of the resistance:

The resistance of the roadway is equal to the product of the wind resistance and air flow square. The formula is as follows:

$$h = RQ^2 \quad (7)$$

By combining (5) to (7), the air volume was calculated using the Scot-Hinsley algorithm. The network solver is written using the VB. net platform.

4. THE DISCUSSION AND ANALYSIS

e_8 and e_9 were selected as a branch of variable resistance, which are parallel branches. e_8 is the increased resistance branch, while e_9 is the reduced resistance branch, resistance changed 20 times in succession, and the network was calculated once the resistance changed. The computed results are as shown in Table 3.

Table 3: The computed results

Adjustment times	Value of the increased resistance ($N.s^2/m^8$)	Pressure of the fan（ Pa ）	The air volume of the fan（ m^3/s ）	Adjustment times	Value of the reduced resistance（ $N.s^2/m^8$ ）	Pressure of the fan（ Pa ）	Air volume of fan（ m^3/s ）
1	0.088	1183.079	64.242	1	0.077	1180.815	64.274
2	0.128	1199.206	64.011	2	0.067	1178.297	64.310
3	0.168	1210.512	63.849	3	0.057	1175.465	64.350
4	0.208	1219.151	63.725	4	0.047	1172.222	64.396
5	0.248	1226.125	63.624	5	0.037	1168.427	64.450
6	0.288	1231.953	63.540	6	0.035	1167.583	64.462
7	0.328	1236.946	63.468	7	0.033	1166.704	64.475
8	0.368	1241.300	63.405	8	0.031	1165.787	64.488
9	0.408	1245.152	63.349	9	0.028	1164.335	64.509
10	0.448	1248.597	63.299	10	0.026	1163.310	64.523
11	0.488	1251.708	63.254	11	0.024	1162.235	64.538
12	0.528	1254.539	63.213	12	0.022	1161.106	64.554
13	0.568	1257.133	63.175	13	0.020	1159.915	64.571
14	0.668	1259.522	63.140	14	0.018	1158.657	64.589
15	0.868	1264.768	63.064	15	0.016	1157.324	64.608
16	1.068	1273.026	62.943	16	0.014	1155.904	64.628
17	1.668	1279.335	62.851	17	0.012	1154.387	64.650
18	2.668	1292.079	62.664	18	0.008	1150.991	64.698
19	4.668	1304.128	62.487	19	0.004	1146.940	64.755
20	6.668	1316.509	62.304	20	0.001	1143.241	64.807

4.1 The change rule of the fan air volume and air pressure

When the airway resistance changed, the fan air volume and air pressure changed, as shown in Figures 2 and 3. The figure shows that, when the airway resistance increases, the fan pressure will increase and the fan air volume will decrease; On the contrary, when the airway resistance decreases, those parameters' change follows the opposite trend. This is due to the changes of total wind resistance in the ventilation network system caused by the airway resistance.

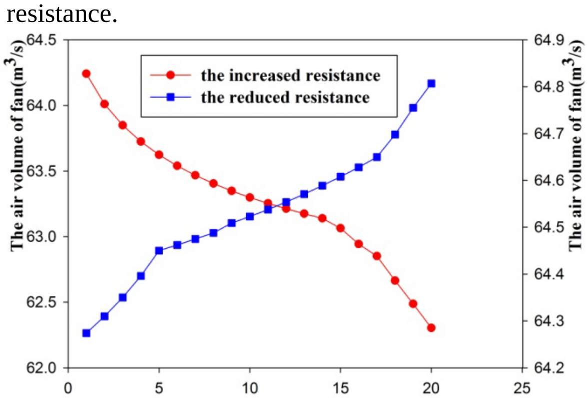

Figure 2: The changed curve of the fan air volume when variable resistance.

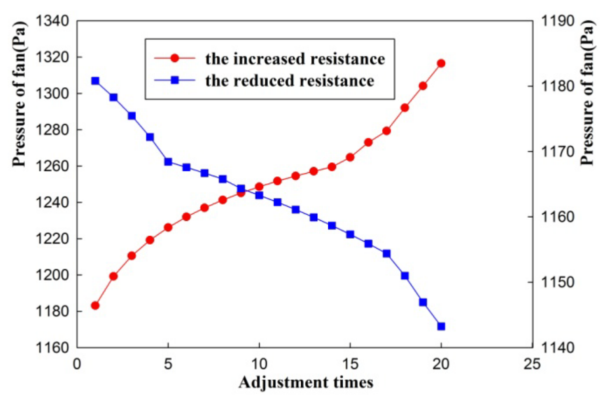

Figure 3: The changed curve of the fan pressure when variable resistance.

4.2 The sensitivity of the fan air volume and air pressure

The computed results were substituted into formulas (1) to (4). The relative and absolute sensitivity of the fan air volume and air pressure were computed when varying the resistance, as shown in Figures 4 to 7. The figures show that, when the airway resistance increases, the relative and absolute sensitivity of the fan air volume and air pressure showed a decreasing trend. The curve is initially steep before gradually slowing. When the airway resistance goes down, the relative and absolute sensitivity of the fan air volume and air pressure showed an increasing trend, with the relative sensitivity stability increased gradually. The early stage of the absolute sensitivity changes smoothly, while the late stage increases suddenly. This suggests that the influence of the fan air volume and air pressure is obvious when the airway resistance increases in the early stage and the airway resistance goes down in the later stage.

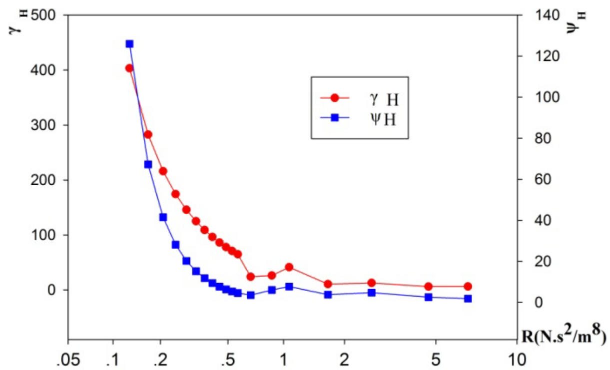

Figure 4: The sensitivity curve of the fan pressure when increased resistance.

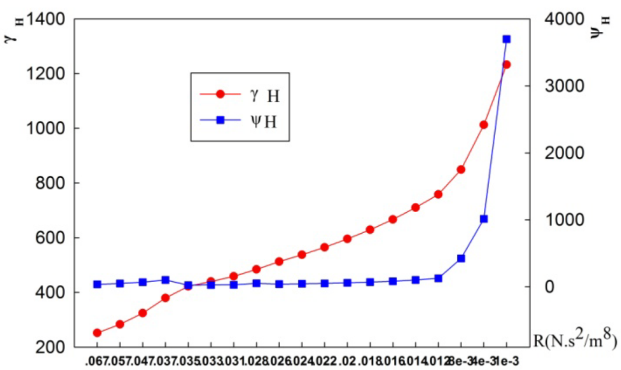

Figure 5: The sensitivity curve of the fan pressure when reduced resistance.

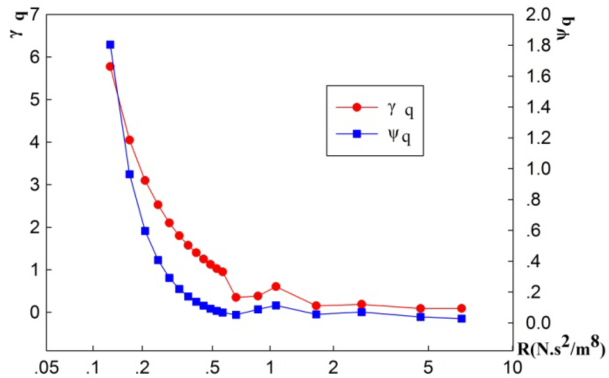

Figure 6: The sensitivity curve of the fan air volume when increased resistance.

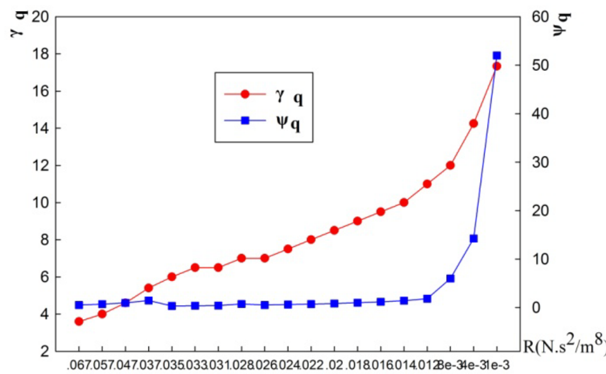

Figure 7: The sensitivity curve of the fan air volume when reduced resistance.

5. CONCLUSIONS

The following conclusions can be drawn:

First, when the airway resistance increases, the fan air volume, its relative and absolute sensitivity, and fan pressure's relative and absolute sensitivity, tend to decrease. At the same time, fan pressure showed an increasing trend. Conversely, when the airway resistance goes down, the above parameters change in the opposite direction.

Second, the influences of the fan air volume and air pressure is obvious when the airway resistance increases early on, and then gradually weakens. Conversely, when the airway resistance goes down, the influence of the fan air volume and air pressure follow the opposite trend. These results provide a basis and guidance for adjusting the fan air volume in mines.

Finally, when increasing the resistance, even the appearance of the fan air pressure being too high should be avoided, as it could cause unstable running of the fan, and ultimately impact safe production.

6. ACKNOWLEDGEMENT

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