

# Research and Application on the Key Parameters of the Long Compression and Short Pumping Ventilation Dust Removal System

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**Abstract:** For the question of circulation wind emerged in the process of using long compression and short pumping ventilation dust removal system, a new model of air volume matching was proposed, and the empirical formula of the key process parameters such as axial and radial air volume, axial and radial air out distance were derived according to the relevant theories of air jet in the confined space. Then the 20106 return roadway of fully mechanized working face in Wang Jia Ling coal mine was selected to conduct field verification tests. The result showed that the new air volume catching model had good adaptability, and the key process parameters obtained by theoretical calculation and field test were basically identical. Under the condition of optimum technological parameters, the total dust and respiratory dust concentration of the driver's place can be reduced 91.98% and 89.53% respectively.

## 1 Introduction

Long compression and short pumping ventilation dust removal system was one kind of mixing ventilation methods in the driving face, using dust-clearing fan to trap and purify the dust produced when cutting coal in the head working area of the driving face, on the basis of conventional pressure ventilation. Dust removal system was one of the most effective and mature dust control measures, cooperated with the wall attaching chimney and other dust control technology, dust efficiency can reach above 89% under the condition of optimum process parameters[1~3]. It was strict with the matching of air supplying and drawing volume to avoid windless condition in the overlay segment of air supplying and air drawing tubes, namely "circulation wind" phenomenon. According to experience, air drawing volume was about 80% of the air supplying volume, although dust control measures were used, there were still 20% air cannot enter the dust-clearing fan, and carried dust to pollute the rear working areas, especially serious for the tunneling working face with large amount of air supply and high intensity of dust producing. This paper was aimed at this problem, based on the air distribution with wall attaching chimney, a new model of air volume matching was proposed, and the quantitative relations of axial and radial air supplying volume, air drawing volume were found. Then the empirical formulas of the key process parameters such as axial and radial air out distance were derived according to the relevant

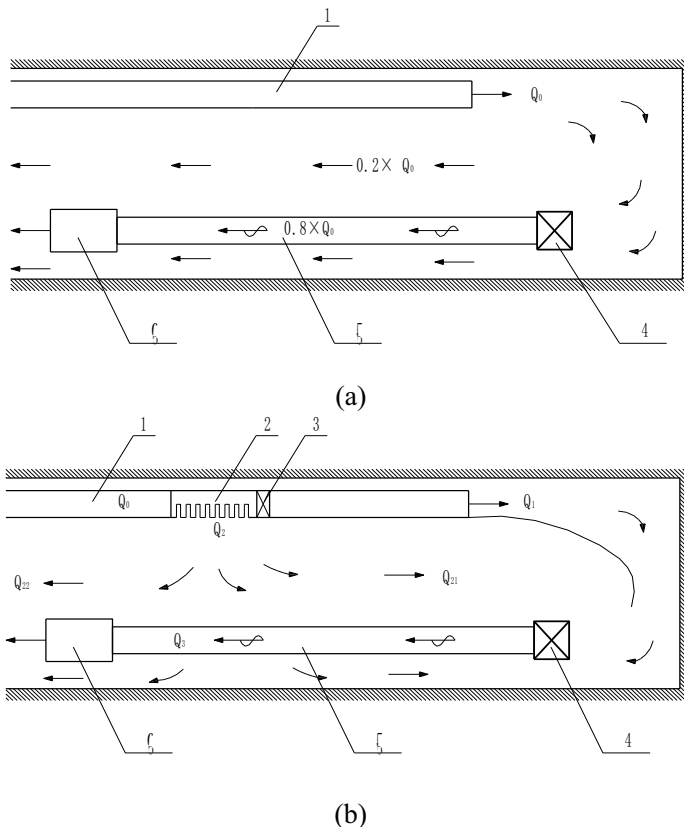
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theories of air jet in the confined space, using the concept of controlling wind speed. In the end the research results of the model were verified by field tests, and good dust control effect was achieved.

## 2 Air volume matching model

The typical flow field of the Long compression and short pumping ventilation dust removal system was shown in figure 1 (a) below [4~5], fresh wind flow from the air supplying tube reached the tunneling working face and blew the dust away, then part of the dust was trapped and purified by the dust-clearing fan, part of the dust spread to pollute the rear working areas with the reason of dust-clearing fan cannot trap all the dust produced when cutting coal. This paper proposed a new air volume matching model on the basis of previous studies [6~7], as shown in the following figure 1 (b). The principle of this model was with the help of air distribution device to achieve axial and radial air supplying in the tunneling face. Then the gas in the front area of tunneling face can be diluted by the axial air supplying, and a fresh wind moving forward from behind can be formed by the radial air supplying, and the dust produced when cutting coal can be airtight in the area front of the diver and can be efficiently tripped and purified with the use of dust-clearing fan. Specific as follows:



1—Air supplying tube; 2—Air distribution device; 3—Air regulating valve; 4—Dust collection cover; 5—Air drawing tube; 6—Dust-clearing fan

**Figure 1** the flow field for the typical and new air volume matching in fully mechanized tunneling working face with long compression and short pumping ventilation dust removal system

Fresh wind flow from the air supplying tube was changed to axial and radial out air with the using of air distribution device and air regulating valve. Firstly appropriate axial air out distance and velocity (or air outlet type) was selected, and the axial air moving along the top of the roof reached the front area of

tunneling face can dilute the gas and dust, and the air velocity should be reduced as possible to avoid wind disturbance and improve the efficiency of dust-cleaning fan in the region where coal was broken down and collapsed. Secondly appropriate radial air out distance, velocity, outlet type and outlet angle were selected, and the tunnel cross-section can be airtight by the radial air to obstruct the dust from spreading to the rear working areas, and the uniform low velocity air flow moving forward from behind can be ensure formed in the area between air distribution device and dust-cleaning fan's entrance to avoid circulation wind phenomenon and make the work safety. Finally, the axial air and forward moving part of the radial air were discharged into the rear of the tunnel through the dust-cleaning fan, while the dust in the wind was also effectively trapped and purified in this process. In addition, part of the radial air was moving from the air distribution device to the rear tunnel to make sure circulation wind phenomenon cannot be appeared in this area, and there was not any large dust source, also won't cause pollution to the return air.

### 3 Theoretical analyses of the key process parameters

Through the above analysis, the key process parameters in the new model of air volume matching of the Long compression and short pumping ventilation dust removal system in the comprehensive tunneling face included air supplying volume, air drawing volume, axial and radial air volume, axial and radial air out distance and etc. In this model, the axial air and forward moving part of the radial air eventually arrived at the front of the tunneling face, and the former air flow was much in the main section of the latter air flow. So we can assume that there was no interference between the two air flows, and key process parameters of the two flow fields can be calculated respectively.

#### a) Air supplying and drawing volume

The main purpose of the axial air supplying was diluting the gas in the front area of tunneling face, and the main purpose of the radial air supplying was airtight the tunnel cross-section to obstruct the dust from spreading to the rear working areas. Then the parameters of air supplying volume, air drawing volume, axial and radial air volume can be calculated by the following formulas[8].

$$Q_1=100\times q\times k \quad (1)$$

$$Q_2=Q_{21}+Q_{22} \quad Q_{21}=V_{21}\times S \quad Q_{22}=V_{22}\times S \quad (2)$$

$$Q_0=Q_1+Q_2 \quad Q_3=Q_1+Q_{21} \quad (3)$$

In these formulas:

q — Absolute gas gushing volume of the tunneling face, m<sup>3</sup>/s;

k — Irregularity factor of gas gushing;

Q<sub>0</sub>— Air supplying volume, m<sup>3</sup>/s;

Q<sub>1</sub>— Axial air supplying volume, m<sup>3</sup>/s;

Q<sub>2</sub>— radial air supplying volume, m<sup>3</sup>/s;

Q<sub>21</sub>— Forward moving part of the radial air volume, m<sup>3</sup>/s;

Q<sub>22</sub>— Backward moving part of the radial air volume, m<sup>3</sup>/s;

Q<sub>3</sub>— Air drawing volume, m<sup>3</sup>/s;

V<sub>21</sub>— Control velocity of the forward moving part of the radial air, m/s;

V<sub>22</sub>— Control velocity of the backward moving part of the radial air, m/s;

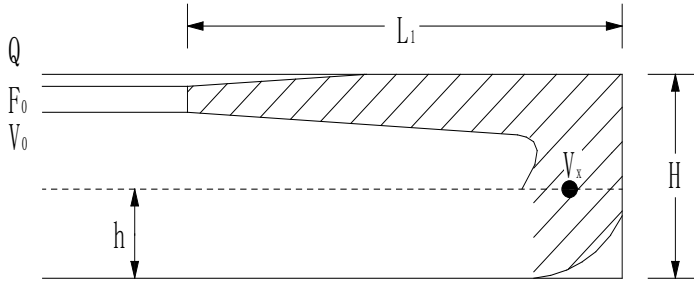
S — Area of the tunnel cross-section, m<sup>2</sup>;

100 — Unit air supply coefficient for the absolute gas gushing volume of the tunneling face , the gas concentration of 1% in the return air was used as the conversion factor.

#### b) Axial air out distance

Axial air flow in the new air volume matching model of Long compression and short pumping ventilation dust removal system belongs to restricted wall-attached jet in the confined space. Then the main segment was selected as the jet segment to reduce the velocity of the wind arrived at the front of

the tunneling face, and the simplified structure of the axial air flow field was shown in the following figure 2.



**Figure 2** the simplified structure of the axial air flow field

According to the theory of air jet, the axial velocity  $V_x$ , which the air flow reached the calculation section of the working area, can be calculated by the following formula[9].

$$\frac{V_x}{V_0} = \frac{Km\sqrt{2F_0}}{x} \quad (4)$$

In this formula:

$V_0$  — Velocity of the axial air outlet, m/s;

$V_x$  — Velocity of the calculation section in the working area, m/s;

$F_0$  — Area of the axial outlet,  $m^2$ ;

$K$  — Correction coefficient for considering the limited air jet;

$m$  — Characteristic parameters related to the outlet type;

$x$  — Total length of the jet stream, which was equal to the calculated cross section from the axial air outlet, , where  $x=L_1+(H-h)$ , m.

$L_1$  — Axial air out distance, m;

$H$  — Height of the tunneling face, m;

$h$  — Height of the broken coal, m.

If the air velocity when the wind reached the front of tunneling face can be limited in a certain range, the axial air can well dilute the gas and greatly improve the efficiency of dust-cleaning fan in the region at the same time. Then the axial air out distance can be calculated by the following formula.

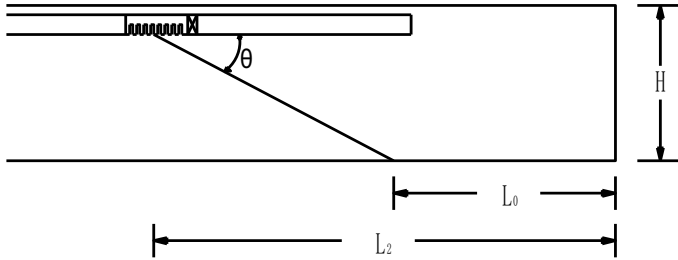
$$L_1 = \frac{KmQ_1}{V_1} \cdot \sqrt{\frac{2}{F_0}} - (H - h) \quad (5)$$

In this formula:

$V_1$  — Controlled air flow velocity in the front area in the tunneling face, m/s.

### c) Radial air out distance

According to the new model of air volume matching for the Long compression and short pumping ventilation dust removal system in the comprehensive tunneling face, the forward moving part of the radial air flow can be also approximately viewed as restricted wall-attached jet in the confined space, and the simplified structure of the radial air flow field was shown in the following figure 3.



**Figure 3** the simplified structure of the radial air flow field

Let us suppose that the distance between the tunnel roof and the radial air outlet can be ignored, and the radius of the air jet should be approximately equal to the height of the tunnel when the restricted wall-attached jet reached the closed cross-section. Then radial air outlet structure characteristics and the size of the tunnel had the following relationship [9]:

$$\operatorname{tg} \theta = 3.4\alpha = \frac{3.4 \times 0.48}{m} = \frac{H}{L_2 - L_0} \quad (6)$$

In this formula:

$\theta$  — Diffusion Angle of the air jet;

$\alpha$  — Turbulence factor,  $\operatorname{tg}\theta=3.4\alpha$ ;

$m$  — Characteristic parameters related to the outlet type,  $m=0.48/\alpha$ ;

$L_2$  — Radial air out distance, m;

$L_0$  — Distance between the front area to the closed cross-section, m.

Finally, radial air out distance for the Long compression and short pumping ventilation dust removal system in the comprehensive tunneling face can be calculated by the following formed formula.

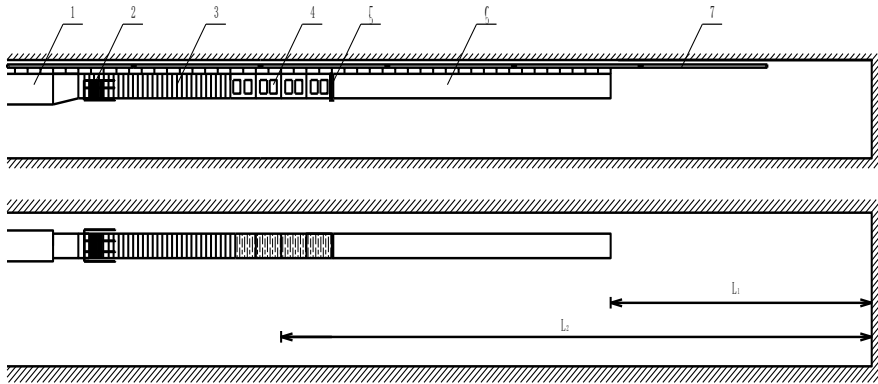
$$L_2 = \frac{H \times m}{1.632} + L_0 \quad (7)$$

## 4 Field verification tests

In order to verify the applicability of the formulas derived from the theory, the 20106 return roadway of fully mechanized working face in Wang Jia Ling coal mine was selected to conduct field verification tests, and the width of the tunneling face was 5.4 m, height was 3.2 m, net area was 17.28 m<sup>2</sup>, absolute gas gushing volume was 4.5 x 10<sup>-3</sup>m<sup>3</sup>/s, the total air supply volume was 9.625m<sup>3</sup>/s and the diameter of the air supplying tube was 0.8m.

To ensure the smooth development of field tests, one type of split dust collection covers were deigned according to the comprehensive tunneling machine structure combined with the flow field distribution in the tunneling face firstly, and total area the dust collection covers was 0.38 m<sup>2</sup>, arranged in the machine arm roots and its sides respectively. Then one type of air controlling system was also designed according to the situation of the tunneling face, as shown in the following figure 4.

The new system was mainly composed of light weight lifting rail; air formed tube, air regulating valve, air distribution device, negative pressure tube, and tube storage device, etc. It had the characteristics of easy moving and simple adjustment, and can easily adjust the axial and radial air volume, axial and radial air out distance in the stretching process of the tunneling face [10~11].

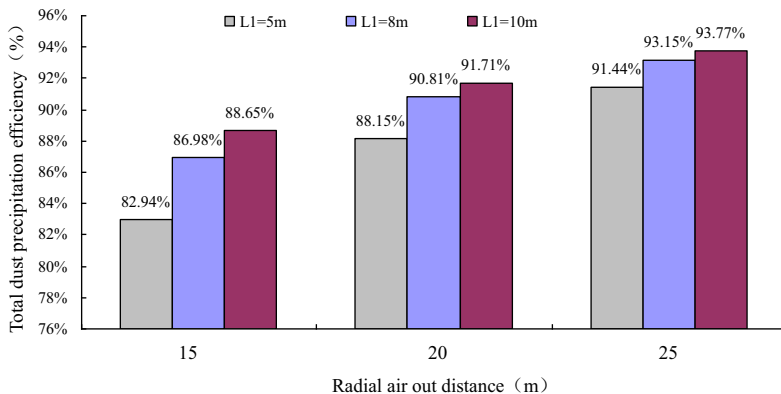


1—Air supplying tube; 2—Tube storage device; 3—Negative pressure tube; 4—Air distribution device;  
5—Air regulating valve; 6—Air formed tube; 7—Light weight lifting rail

**Figure 4** Component diagram of the new type of air controlling system for the long compression and short pumping ventilation dust removal system in the comprehensive tunneling face

In the process of determining the key parameters, firstly determine the controlled air flow velocity in the front area in the tunneling face  $V_1=1.0\text{m/s}$  according to the coal mine safety regulation, and selected the Irregularity factor of gas gushing  $k=3$ , and used the formula (1) and (5) to calculate  $Q_1=1.35\text{ m}^3/\text{s}$  and  $L_1=11.5\text{m}$ ; Secondly selected  $V_{21}=0.32\text{m/s}$  and  $V_{22}=0.16\text{m/s}$  according to the coal mine safety regulation, and used the formula (2) to calculate  $Q_{21}=5.525\text{ m}^3/\text{s}$ ,  $Q_{22}=2.75\text{ m}^3/\text{s}$ ,  $Q_2=8.275\text{ m}^3/\text{s}$ , and used the formula (3) to calculate  $Q_0=9.625\text{ m}^3/\text{s}$  and  $Q_3=6.875\text{ m}^3/\text{s}$ ; Thirdly selected  $L_0=15\text{m}$  according to the location of the excavator, and used the formula (7) to calculate  $L_2=20.3\text{m}$ . Finally, the preliminary long compression and short pumping ventilation dust removal system was build and optimized for the field verification tests.

In the process of the field test, axial and radial air volume were adjusted to the calculate value with the using of air distribution device and air regulating valve, axial air out distance was respectively selected to 5 m, 8 m and 10 m, radial air out distance was respectively selected to 15 m, 20 m and 25 m. The optimum technological parameters of the system were determined by continuous testing of the total dust precipitation efficiency of the driver's place in different air out distances, and the test results was shown in the following figure 5.



**Figure 5** Total dust precipitation efficiency in the position of the driver in different air out distances

Can be seen from the diagram above, under the condition of the same radial air out distance, the total dust precipitation efficiency of the driver's place was increased with the increase of axial air out distance, which can prove that the farther of axial air out distance, the lower flow velocity when air attaching to front area in the tunneling face, the less dust produced when cutting coal can be blown

into the flow, and the more dust can be efficiently tripped and purified with the use of dust-clearing fan. Under the condition of the same axial air out distance, the total dust precipitation efficiency of the driver's place was increased with the increase of radial air out distance, which can prove that the farther of radial air out distance, the more favorable to form a "air barrier" moving forward from behind, and the dust precipitation efficiency was also higher.

By comparison, the best dust controlling effect appeared under the process parameters with  $L_1=10\text{m}$  and  $L_2=25$ . But considering the machine moved back and forth in the production process, the radial air out distance was finally selected 20m to avoid the air distributing device beyond the outlet of dust-clearing fan, and the dust controlling effect was not very relevant with the  $L_2=25$ . Then the best process parameters of this system obtained by field test were  $L_1=10\text{m}$  and  $L_2=20\text{m}$ , which was basically identical with the result obtained by theoretical calculation, and under the condition of optimum technological parameters, the total dust and respiratory dust concentration of the driver's place can be reduced 91.98% and 89.53% respectively.

## 5 Results

(1) The new air volume catching model for the long compression and short pumping ventilation dust removal system had good adaptability. The gas in the front area of tunneling face can be diluted, and the dust can be airtight in the front area of tunneling face with the fresh air flow moving forward from behind, and can be efficiently tripped and purified with the use of dust-clearing fan. In addition, in order to avoid the pollution caused by the fresh radial air flow moving forward, spray and Local sealing measures should be used to control the dust produced at the transfer point.

(2) The best process parameters of this system obtained by field test were basically identical with the result obtained by theoretical calculation, and under the condition of optimum technological parameters, the total dust and respiratory dust concentration of the driver's place can be reduced 91.98% and 89.53% respectively, and can be used to provide reference for the design of long compression and short pumping ventilation dust removal system.

(3) In consideration of the differences of production conditions and air supply conditions in the comprehensive tunneling face, the field test was only for a particular tunneling face, and the empirical formula obtained by theoretical derivation for calculating key process parameters of the long compression and short pumping ventilation dust removal system should be verified by a large number of field experimental data.

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