

Influence of the strip-shaped air-out slits' width in the fully mechanized working face under wall-attached swirling ventilation condition

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Abstract. For the purpose of mastering the influence of the strip-shaped air-out slits' width in the fully mechanized working face under wall-attached swirling ventilation condition, By using fluent software, numerical simulation of airflow field and dust diffusion in fully mechanized working face under different strip-shaped air-out slits' width conditions was carried out. The results show that the wall-attached swirling ventilation can effectively control the dust diffusion in the fully mechanized working face, improve the dust collecting effect of the bag precipitator fan, and reduce the particle mass concentration at the driver and the rear of the tunnel; Increasing the air volume of the strip-shaped air-out slits can improve the control effect of the swirling air curtain on the dust, appropriate air volume can make the swirling air curtain control the dusty airflow and push it to the end of the heading surface to control, block and propel the dust; When the width of the strip-shaped air-out slits is 0.06 m, the dust collecting effect of the exhaust air cylinder on the dust and the effect of the wall-attached swirling on the plugging of the dust are best.

1 Introduction

At present, the dust concentration of many coal mines is exceeding the standard, which seriously endangering the health of the workers in the underground work ^[1-3]. So as to reduce the dust concentration in the fully mechanized working face, some mines use the wall circulation wind mode, and use the dust blower to purify the dust-containing airflow to the rear-row roadway, and obtain good dustproof effect. In order to evaluate the working environment and ventilation effect of the fully mechanized face under the operation of the wall-rotating wind, to improve the ventilation efficiency and optimize the ventilation parameters, it is necessary to research the wind speed distribution and the dust

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concentration distribution in the fully mechanized excavation face [4-6]. In this paper, the numerical simulation of fully mechanized digging roadway with CFD is carried out to analyze the characteristics of air current and the movement of dust under the condition of different width of the strip-shaped air-out slits.

2 Physical model and boundary conditions

2.1 Physical model

Under the site investigation, a rectangular roadway with a length of 30 m, a width of 4.5 m and a height of 3.2 m was established, the outlet of the pressure air cylinder is 5 m from the end of the working face, the diameter of the blower is 800 mm, and the central axis of the blower is 2.7m high from the ground. The second half of the press-in hair dryer is an accessory hair dryer. The accessory hair dryer is provided with a radial slit air outlet of length 1.6 m and a width of 0.03 m at a distance of 5 m each, a total of three outlet air outlets. The diameter of the suction tube is 800mm, the center of the front suction outlet is 1.6m from the ground and 3m from the driving head, which is located on the body of the boring machine; the transport belt is located under the suction tube and is the transport belt transfer point at a distance of 15 m from the heading head. The model sets a total of six groups of the strip-shaped air-out slits' width of 0.02 m, 0.03 m, 0.04 m, 0.05 m, 0.06 m, and 0.07 m. In the simulation, the exhaust air volume of the exhaust air cylinder is set to 250 m³/min, the forced air volume of the forced air cylinder is set to 200 m³/min, convert the cross-sectional area of the air cylinder to the wind speed that the FLUENT software can set. Physical model of wall-attached swirling ventilation is shown in **Figure 1**.

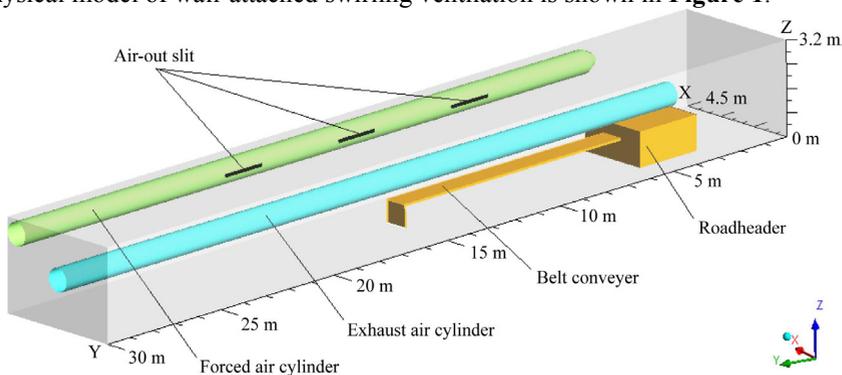


Fig. 1. Physical model of wall-attached swirling ventilation

The model adopts the wall-attached swirling pressure pumping mixed ventilation, and the fresh air enters the roadway from the end outlet and the strip gap through the pressure air tube respectively, after the dust is diluted through the face of the head, one part of the dust-bearing airflow is drawn from the suction tube, and the other part of the dust air from the suction tube and the tunnel between the discharge. Mesh is divided by ICEM-CFD software, physical roadway model of generated grid is shown in **Figure 2**.

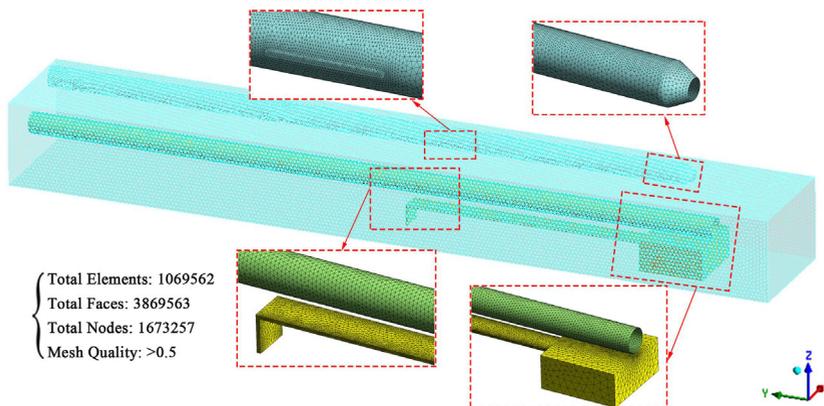


Fig. 2. physical roadway model of generated grid

2.2 Boundary conditions

Import the model mesh file into FLUENT software and set the boundary conditions and particle source parameters. the specific conditions are shown in **Table 1**.

Table 1. Boundary condition and particle source parameter setting

Project	Parameters	
Boundary Conditions	Entrance Boundary	Velocity Inlet
	Export Boundary	Outflow
	Hydraulic Diameter	0.80 m
	Turbulent Intensity	3.22%
	Wall Motion	Stationary Wall
Particle Source	Injection Type	Surface
	Material	Anthracite
	Diameter Distribution	Rosin-Rammler
	Min. Diameter	1 μm
	Mean Diameter	12.5 μm
	Max. Diameter	60 μm
Spread Parameter	1.9	
	Total Flow Rate	0.0015 kg/s

3 Mathematical

A discrete phase model based on Euler-Lagrange method is used to study the airflow characteristics and dust concentration distribution in the roadway, in which the dust particles are discrete phase and the air is continuous phase [7-10]. This paper assumes that the airflow is incompressible and steady fluid and ignores heat transfer, on the basis of this, we adopt two-path model, the gas phase control equation is as follows [11-14]:

Continuity equation:

$$\frac{\partial u_i}{\partial x_i} = 0 \tag{1}$$

Equation of the momentum:

$$\frac{\partial}{\partial x_j}(\rho u_i u_j) = -\frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} + \rho g_i \quad (2)$$

Formula, p is static pressure; $\partial \tau_{ij}$ is stress tensor; g_i is the force of gravity in the direction of i .

Solid phase control equation:

$$\frac{du_p}{dt} = F_D(u - u_p) + \frac{g(\rho_p - \rho)}{\rho_p} + F_S \quad (3)$$

Formula, F_D is Mass drag force of granular unit, following forms:

$$F_D = \frac{18\mu}{\rho_p d_p^2} \frac{C_D Re_p}{24} \quad (4)$$

4 Numerical simulation results and analysis

4.1 Flow field of airflow

Imitation outcomes of airflow flow field under the action of wall-rotating flow wind in fully mechanized excavation face is as shown in **Figure 3** and **Figure 4**.

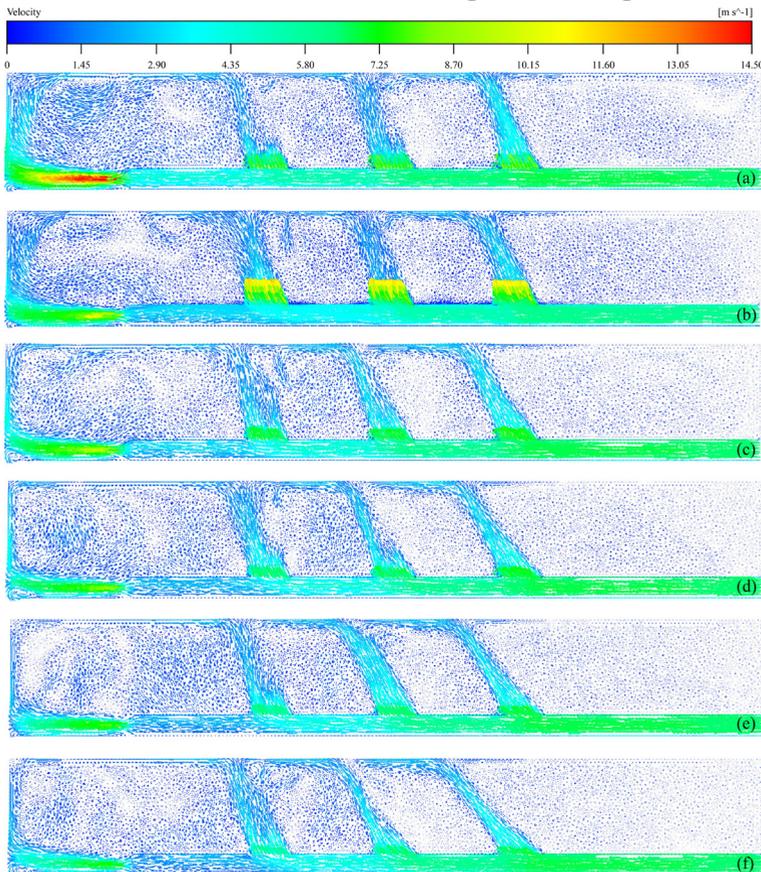


Fig. 3. Z=2.7 m height section wind flow field vector; (a) W=0.02 m; (b) W=0.03 m; (c) W=0.04 m; (d) W=0.05 m; (e) W=0.06 m; (f) W=0.07 m

It can be seen from **Fig. 3** that when the width of the strip-shaped air-out slits is 0.02 m, the air outlet velocity of the air outlet of the wind flow cylinder is the largest, reaching a wind speed of 14 m/s, and the wind speed at the head end is attenuated to 7 m/s. After the heading face, the wind speed is reduced to 4 m/s; as the width of the strip-shaped air-out slits increases, the axial exit wind speed becomes smaller; when the width becomes 0.07 m, the axial exit wind speed becomes 7 m/s. When the heading is reached, the speed is attenuated to 4 m/s, and after passing the head, the speed drops below 2 m/s.

For the strip-shaped air-out slits, the wind speed does not change much with the increase of the width, but the outlet air volume becomes larger as the width becomes larger. For the width of the single strip-shaped air-out slit, the wind speed of the strip-shaped air-out slit is successively decreased, close to the axis. The wind speed of the strip-shaped air-out slit to the air outlet is the smallest; as the width of the strip-shaped air-out slits increases, the axial velocity of the airflow at the outlet of the radial strip-shaped air-out slit becomes smaller. Relatively speaking, the radial velocity is larger, the radial strip-shaped air-out slit outlet the better the swirling air curtain blocking effect produced by the wind flow [15-17]. When the width of strip-shaped air-out slit reaches 0.07 m, the axial velocity becomes larger, the radial velocity becomes smaller, and the sealing effect of the swirling air curtain becomes worse.

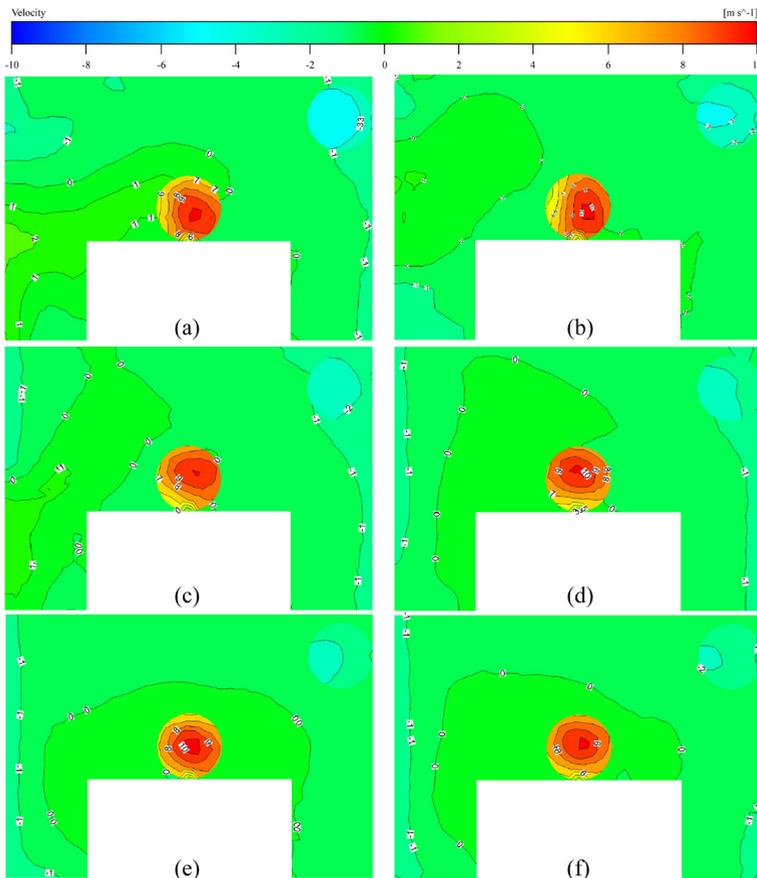


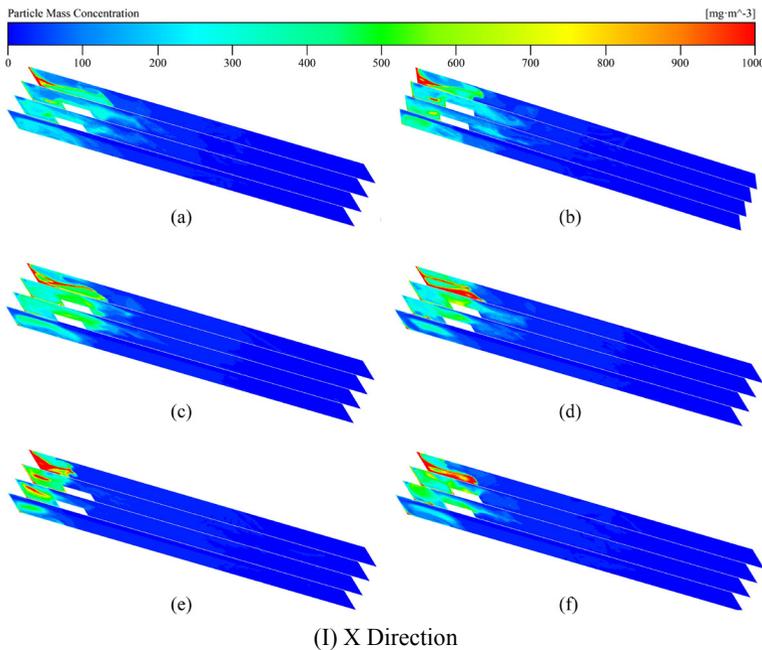
Fig. 4. Y=5 m section axial wind flow velocity counter; (a) W=0.02 m; (b) W=0.03 m; (c) W=0.04 m; (d) W=0.05 m; (e) W=0.06 m; (f) W=0.07 m

As you know from **Figure 4**, in the axial velocity distribution, the velocity is positive to indicate that the wind flow moves from the excavation end to the rear of the roadway, and the velocity is negative, on the contrary, on the 5 m section of the head of the excavation end, the velocity is regular indicates that the movement direction of the dust flow points to the rear of the roadway. The speed is negative to indicate that the airflow at the rear of the roadway flows to the excavation end, which forms a plugging effect on the dust airflow in front of the driver area, which is a relatively favorable area for dust control [18-20]. When the width of the bar outlet is 0.02 m, the axial velocity is the positive area is mainly distributed in the suction side on the left side of the suction tube, the bad area wind speed reaches 1~2/s, the width is 0.03 m, the bad area is mainly distributed in the suction side, some areas reach 1/s, the width is 0.04 m, The bad area is also mainly concentrated in the suction side, the speed reaches 1 m/s area becomes larger, the width is 0.05 m, the bad area increases, the width is 0.06 m,0.07 m, the bad area is mainly concentrated near the air out duct.

Taken together, the better the airflow organization, the easier it is to control the dust, the favorable area of dust control can have a plugging effect on the airflow, when the controlled dust flow is in the favorable area of dust control, it can be blocked in front of the driver area, can efficaciously drop the particle mass concentration of the driver, when the controlled dust flow is in an unfavorable area, This will increase the particle mass concentration in the favorable area of dust control and in the poor area at the same time.

4.2 Flow field of airflow

Figure 5 is the concentration distribution of dust in the roadway under the action of the wall-attached swirling ventilation in the fully mechanized working face. A numerical simulation result section of a dust concentration at a certain distance from the positive direction of X axis and Y axis of the roadway, along the x-axis positive direction is 0.2 m, 1.5 m, 2.8 m, 4.1 m, 1.5 m is the position of the driving driver; along the z-axis positive direction is 15 m, 18 m, 21 m, 23 m, 25 m, 26.5 m, 28 m, 29.5 m, 25m is the position of the driving driver.



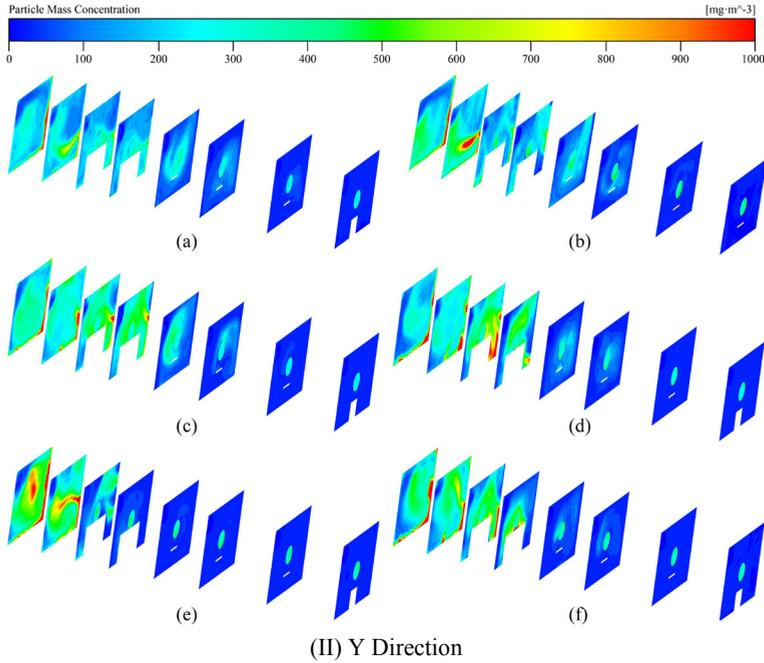


Fig. 5. Overall change trend of dust concentration in different directions along roadway; (a) $W=0.02$ m; (b) $W=0.03$ m; (c) $W=0.04$ m; (d) $W=0.05$ m; (e) $W=0.06$ m; (f) $W=0.07$ m

It is known from **Figure 5** (I) that the suction side is a highly concentrated area of dust, and the control of the dust on the suction side and the plugging and propelling action are of great significance for reducing the dust concentration at the driver of the roadheader [21]. When the width of the strip-shaped air-out slit is 0.06 m, the diffusion range of dust is the smallest, and it is mainly concentrated within 5 m from the head of the excavation. When the width of the strip-shaped air-out slit is 0.04 m, the diffusion range of dust is the largest and not concentrated. The dust concentration is higher in the entire roadway 7 m from the head end, and the dust concentration in most areas is between 200 mg/m³ and 600 mg/m³.

It can be seen from **Figure 5** (II) that the average dust concentration at the 2 m section from the head end reaches the maximum and minimum values at widths of 0.06 m and 0.04 m, respectively, because this section is in the suction of the suction cylinder. Within the range, the higher the dust concentration here, the higher the dust collection efficiency of the suction cylinder. Compared with the other widths, the dust concentration of this section shows that as the width of the strip-shaped air-out slit increases, the dust collection efficiency of the suction cylinder becomes wave. The formula changes to a maximum at a width of 0.06 m.

Based on the above simulation results and analysis, it can be seen that increasing the width of the strip-shaped air-out slit can reduce the axial exit wind speed of the blower cylinder, and increase the radial air volume of the radial strip-shaped air-out slit; reduce the axial exit wind speed, and can change the dust collection of the suction duct capacity, suitable axial exit wind speed can improve the dust collecting capacity of the suction cylinder; increasing the radial air outlet volume can improve the control effect of the swirling air curtain on the dust, and the proper air volume can make the swirling air curtain control. The dusty airflow is continuously pushed to the end of the heading surface to control, block and propel the dust; when the width of the strip-shaped air-out slit is 0.06 m, the dust collecting effect of the suction cylinder on the dust, the side wall swirling to the dust The plugging advancement is best.

5 Conclusion

- 1) In the roadway of the fully mechanized working face, the wall-attached swirling curtain is formed and the dust-bearing airflow in the working face is blocked to prevent the dust from spreading outward.
- 2) The better the airflow organization, the easier the dust is controlled, and the dust control favorable area can block the airflow. When the controlled dusty airflow is in the dust control favorable area, it can be blocked in front of the driver area, which can be effective. Reduce the particle mass concentration at the driver's office.
- 3) Increasing the radial air outlet volume can improve the control effect of the air swirling curtain on the dust, and the proper air volume can make the swirling air curtain control. The dusty air movement is continuously pushed to the end of the heading surface to control, block and propel the dust; when the width of the strip-shaped air-out slit is 0.06 m, the dust collecting effect of the suction cylinder on the dust, the side wall swirling to the dust, the plugging advancement is best.

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