

Comprehensive dust removal technology by ventilation based on the mechanism of cyclone and air splitting in fully mechanized working face

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Abstract. In order to improve the deficiencies of the existing methods removing dust from coal mine fully-mechanized working face, a more effective method is proposed in a fully-mechanized working face of coal mine. Using the cyclone and air splitting effect of the Ventilation duct with Coanda effect (VDCE) in the way of far-pressing-near-absorption ventilation can reduce the disturbance of laneway frontal wind field by the compressed air jet and accumulate high concentration of dust in laneway frontal which will be treated with gas-water spraying. In order to improve the effect of the dust control, CFD is used to establish roadway geometry according to actual conditions under the mine, and simulate the roadway to get the results of dust distribution and escape with different ventilation methods to analysis and make sure the distribution and movement of high concentration of dust in laneway frontal. Based on the above results, the dust comprehensive treatment technology with cyclone and air splitting effect are used to prevent dust. The data from the site measurement shows that dust removal rate of full dust and respirable dust reaches 93%.

Key words. Fully-mechanized working face, dust, cyclone and air splitting effect, ventilation duct with coanda effect (sdce), numerical simulation, far-pressing-near-absorption ventilation.

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1. Introduction

As one of the main hazards of coal mine, coal mine dust will lead to pneumoconiosis and coal dust explosion[1-2]. The current trend of dust control is to take multi-process dust control include "reduce, settling, row, removal" and individual protection in stages to strengthen the control of underground work space dust. However, due to the large amount of wind in the working face, the high-speed airflow of the pressure air blower had too much effect on the disturbance of the dust and the wind flow field, which has affected the effect of the dust reduction measures. Based on the above considerations, the application of the dust control technology in the mining face using cyclone distribution mechanism is based on the long-short-short mixing type ventilation system and Water spray for integrated dust treatment.

2. Working face situation

The digging surface is trapezoidal section, width 4.0m, the center high 2.6m, using pressure ventilation, the end of the outlet air volume 330m³ / min, whice diameter 0.6m, water supply hydrostatic pressure of 2 ~ 3.20MPa. Absolute gas emission is 0.49 ~ 0.75m³ / min, so dust fan and air flow control device can be used in low gas roadway,. Field dust test data show that the unit driver position in the dust-free measures to operate under the conditions of dust concentration reached 967.5mg / m³, respiratory dust concentration of 773.5 mg / m³, respectively, beyond the national regulations 96 times and 221 times.

3. The cyclone mechanism of VDCE

The structure and design of the attached hairdryer can be used to divert the flow through the flow, and the flow of air flowing from the side of the flow along its side changes to radial wind flow or the rotating air flow along the roadway wall, effectively reducing the direct blow to the headwall Air volume, while reducing wind speed and the pressure into the ventilated high-speed air flow on the head of the dust and wind flow disturbance. The air outlet or the hole is usually arranged on the side of the VDCE according to certain rules. The air volume adjustment device is arranged at the outlet to control the axial and radial air volume to suit the different operation. The airflow from the side of the duct is discharged from the side opening of the duct and is affected by the wall effect at the same time. As shown in Fig. 1, the direction of the airflow is changed to a direction at a certain rotational speed surrounded at the same time in the axial direction to the head forward[3-5].

4. Simulation of Dust Distribution and Transport by CFD

4.1. Create model and parameter settings

The excavation work space is simplified as follows: the roadway section is set to $4\text{m} \times 2.6\text{m}$ trapezoidal, the length of 100m; using long- pressure-short-suction ventilation system, the pressure cylinder is located on the right side of the roadway, from the floor height of 1.8m, diameter 0.6m, the outlet from the head of coal wall 8m; dust fan is simplified as a section of the hairdryer, set the air volume $180\text{ m}^3 / \text{min}$, Diameter 0.5m, suction and exhaust from the head of the coal wall were 3m and 22m, respectively. Figure 2 shows the excavation space modeling and meshing.

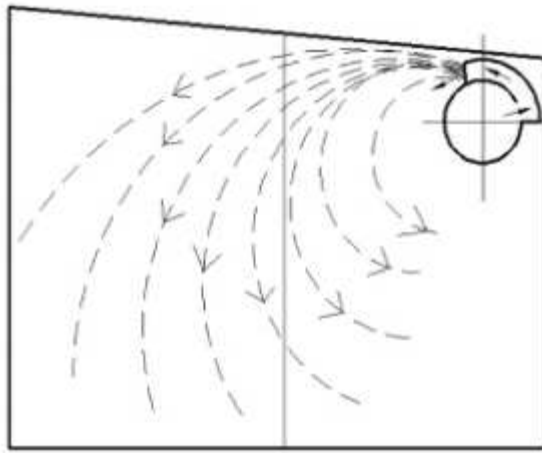


Fig. 1. Out wind state diagram of vdce

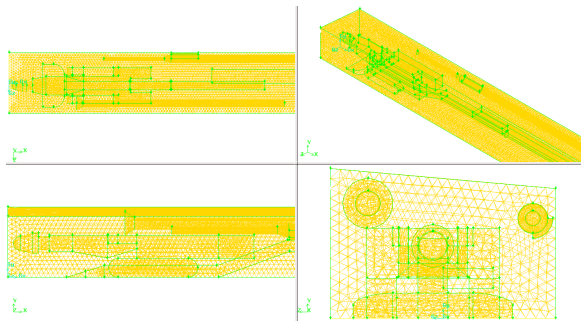


Fig. 2. Grid partition mode of excavation roadway

According to the comprehensive excavation field and measured data, determine the parameters and boundary conditions of CFD simulation [6-11], as shown in Table 1 to Table 4.

Table 1. parameter setting of model and discrete phase model

Model	Solver	Viscous Model	Energy	Discrete Phase Mode
Define	Segregated	k-epsilon	Off	On
Discrete Phase Model	Number of Continuous Phase Iterations per DPM Iteration	Max Number of Steps	Length Scale	Drag Law
Define	40	12000	0.01	Spherical

Table 2. parameter setting of boundary conditions

Boundary Conditions	Inlet Boundary Type	Inlet Velocity Magnitude(m/s)	Hydraulic Diameter/m	Turbulence Intensity/%	Outlet Boundary Type	Wall
						DPM condition
Define	Velocity-inlet	13	0.6	3.01	Outflow	Trap

Table 3. parameter setting of injection

Injection	Injection Type	Material	Diameter Distribution	Min.Diameter/m	Max. Diameter/m	Spread Parameter
Define	surface	limestone	Rosin-Rammler	1.0×10^{-6}	100×10^{-6}	2.83
Injection	Velocity??m/s??	Initial Flow Rate??kg/s??	Turbulent Dispersion	Number of Tries	Time Scale Constant	
Define	9	0.005	Stochastic tracking	20	0.15	

Table 4. parameter setting of solve

Solve	Pressure-Velocity Coupling	Discretization Scheme	Convergence Criterion
Define	SIMPLEC	Second Order Upwind	10-3

4.2. Flow pattern and flow distribution in heading

Flow is the power and carrier of dust, so the speed, direction and flow distribution of the wind must be first understood to analyze the process of the dust transport. Therefore, the CFD is used to calculate the spatial distribution of the wind flow and the flow field at the operating points in the different layouts shown in Fig.3 to Fig.5.

(1)In the case of forced ventilation, the air flow is ejected from the air blower,

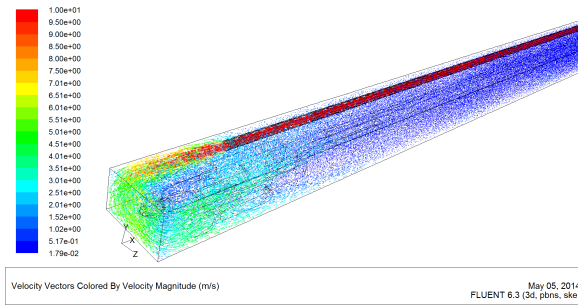


Fig. 3. pressure-ventilating

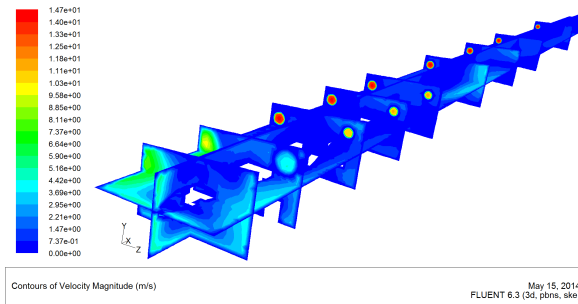


Fig. 4. dust collector

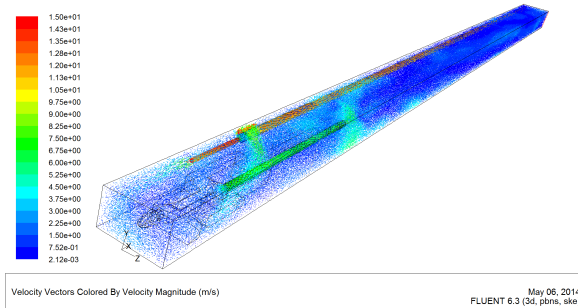


Fig. 5. dust collector and wall attaching chimney

and when it is sprayed to the head coal wall, some of the air flow remains at a high speed, and the high speed air flow is obstructed by the surrounding coal wall and the boring machine, and only can flow through the space in left side. Part of the wind flow along the return side of the wind, and another part of the wind flowed from the return air side to the right and front by the pressure jet suction effect, formed a wide range of spiral vortex area from the head of the coal wall within the range of 3-10m. There are some small range of unstable swirling flow in the range of 20m from the head, and the stability of the wind flow is poor. After the wind flow gradually diffuses on the air return side, the wind speed decreases and is evenly distributed in the whole section of the roadway. The wind speed is basically maintained at

0.3-0.4m / s, and the wind flow field tends to be stable after the wind speed exceeds 20m.

(2)After adding the dust removal fan, the kinetic energy of the pressure air flow from the pressure air blower is reduced and the wind speed is reduced. Under the action of the suction port, the pressure airflow outlet jet action and the suction range of the effect is reduced and the spiral vortex region is reduced to the range of 2-7 m in the head, and the whole wind speed of the whirlpool is reduced ,with the number of unstable swirl decreases. In the vicinity of the suction port, a small negative pressure wind field is formed, and some of the airflow is sucked by the dust suction fan. The wind speed is higher at the dust fan outlet .

(3)It is evident that most of the pressure air flow flows out of the side outlet after adding VDCE, and only a small part of the air flow is ejected from the front of the air blower and the speed is drastically reduced , while the flow speed from the side of the duct higher;After the outflow of the duct, the flow is blocked by the wall .With the wall effect , the wind speed is rapidly reduced, the wind direction changes from the original axial to the spiral, and the overall wind speed of the roadway is reduced. At the same time, the dust blower will draw the wind in the front area, which formed a large range of negative pressure area;

A small range of forward flow of the curtain formed in the head of the front 3-8m range with the helix forward air and negative pressure zone working together .As a result, the formation of vortex in the region of the wind is avoid, the disturbance of dust is reduced, the distribution of wind flow in the headway area is more uniform, the return air side of the poor ventilation situation is improved.

4.3. Dust movement and spatial distribution

Based on the existing flow field calculation, the discrete phase model is opened, and the dust source is set in the unit cutting head and the shovel plate on both sides. The results are shown in Fig. 6 to Fig.8.

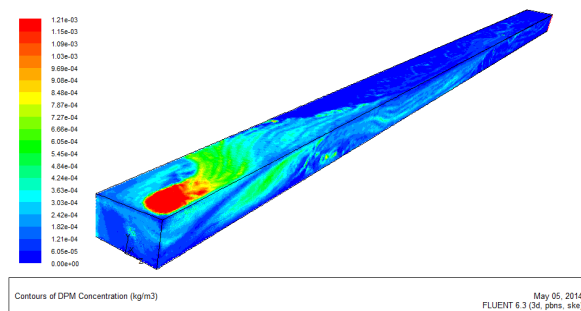


Fig. 6. Pressure-ventilating

(1) In the case of forced ventilation, the high concentration dust accumulates in the vicinity of the cutting head, and then moves back to the air return side and flows away from the whole roadway. The dust concentration is the highest in the first 5m, the dust concentration 5-10m is high and high Concentration of dust

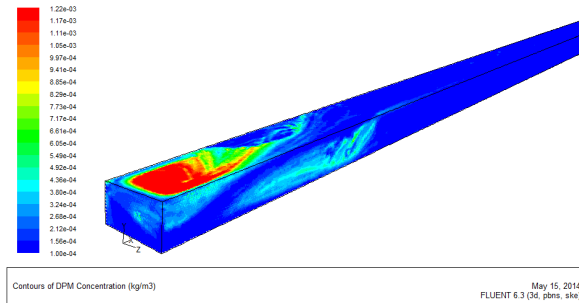


Fig. 7. Dust collector

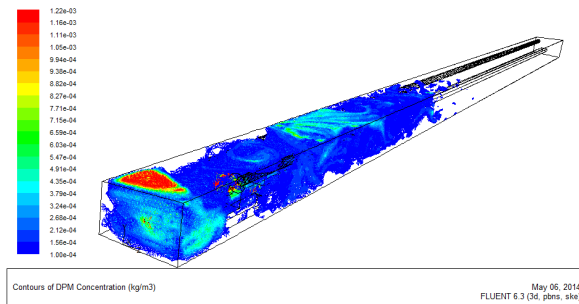


Fig. 8. Dust collector and wall attaching chimney

distribution tends to the return side of the wind, the dust has been filled to the full roadway after 10m, dust concentration is still high after the range of 10-20m, the dust concentration is basically reduced to 100mg / m³ after 20m;

(2) Adding to the dust fan, the high concentration of dust gathered 5m in front of the head, the radial range doubled, the dust concentration of the regional area reduced to 5-8m range, the dust concentration reduced to 100mg / m³ after 10m; the higher dust concentration range of the air return side increases to 20m;

(3) After adding the VDCE, the high concentration of dust is basically gathered in the head 3m range, the radial width range extends to the full section, the higher dust concentration area reduced to 3-5m range, and dust concentration dropped sharply below 100mg/m³ after the 5m range;

5. Application

According to the site conditions and the procedures requirements, in the digging surface application of long-press-short-pump ventilation system, as shown in Figure 9. In order to strengthen the tunneling machine external sprayer, the new gas spray is used and the nozzle structure and layout has been improved combining with the working scene[12]. 1-suction port; 2-out hairdryer; 3-dust fan; 4-belt; 5-driving machine; 6-VDCE;7- forced ventilation

Use the AKFC-92A sampler to measure the dust concentration and plot the

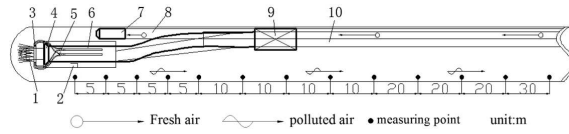


Fig. 9. Dust removal equipment layout

distribution curve, in which Q is 20L/min t is 2min see Figure 10 The dust concen-

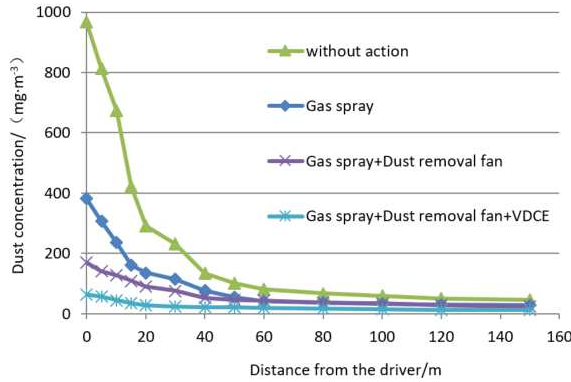


Fig. 10. Distribution map of dust concentration along the way

tration of the driver is used as the standard for comparison: When using gas spray, the dust concentration was more than 60%, and most of the dust is reduced. After adding dust fan, the dust concentration was more than 80%.After adding VDCE, the dust concentration was more than93%.

6. Conclusion

(1) CFD simulation results and field practice observations show that the airflow at the outlet of the forcing duct is high and the momentum is high, which will cause a large range of strong disturbance to the head flow field, which will bring difficulties to the dust control. The dust volume of the dust fan is limited by the stipulation, so the suction range of the suction hood and the negative pressure range is small with the influence of the wind disturbance.

(2) The wind speed distribution can be significantly reduced, the distribution of the flow field is more uniform and stable, and no vortex airflow formed, and the air curtain can be formed in front of the driver, and the high concentration dust will be stoped in the head of the area within 5m, blocking its outward diffusion, which can improve the efficiency of suction of dust removal fan and spray on the dust particles of the wet and capture; Field application shows that the dust removal rate of the ventilation and dust removal system can reach 93%.

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