

Research on the Dust Transport Law in Large Mining Height Fully Mechanized Mining Face

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Abstract

The fully mechanized mining face with high mining height has always been a high-risk area for coal mine dust pollution. In order to further understand the spatiotemporal transport law of dust in the zoning of the high mining height fully mechanized mining face, the 122109 high mining height fully mechanized mining face of Caojiatan Coal Mine was taken as the research object. Numerical simulation method was used to simulate and analyze the dust transport situation of the 122109 fully mechanized mining machine drum single dust source, the hydraulic support moving frame single dust source, and the superposition of all dust sources in forward and backward wind cutting coal. The research results can guide the ventilation layout design in the early stage of the mine and the dust control in the comprehensive mining process, which is of great significance for the construction of safe and green mines.

Keywords

Large Mining Height Fully Mechanized Mining Face; Dust; Transport Law; Numerical Simulation.

1. Introduction

With the continuous expansion of coal mining scale and the widespread application of comprehensive mining technology, dust problems have become increasingly prominent, posing a serious threat to the health of miners and the safety of mine production [1-3]. Therefore, the study of the migration law of flour dust in high mining height fully mechanized mining is of great significance. At present, domestic and foreign scholars have conducted extensive and in-depth numerical simulation research on the transport law of flour dust in high mining height fully mechanized mining. Du Shanzhou et al. [4] took the 12511 fully mechanized mining face of Bulianta Coal Mine as the research object, and used fluid dynamics CFD software to numerically simulate the distribution law of flour dust transport in fully mechanized mining work with a large mining height of 8 meters. Guo Yufeng et al. [5] modeled the diffusion and transport of transfer and crushing dust in the fully mechanized top coal caving face based on the actual situation of the intake roadway and conducted numerical simulation using FLUENT software. Zheng Baoming [6] used Fluent software to simulate the airflow vector and dust field under different cutting positions on the working face, and found that the dust coverage area in the mining area was the largest on the inlet side. When the mining area is located in the middle, the dust concentration near the drum is extremely high, and the dust settles quickly under the influence of wind flow. When the mining area is located on the return air side, the dust transport distance is extremely short, which will seriously pollute the return air roadway. Zhang Suo et al. [7] took the large mining height working face planned in the Xingjie Taige Temple mining area as the research background, and used Solidworks and ANSYS software to establish a geometric

and physical model of the coal mining face. Combined with the gas-solid two-phase flow theory, numerical simulation was conducted on the dust movement during the coal cutting operation of the coal mining machine. Jiao Wanying et al. [8] used Fluent software to simulate and analyze the distribution patterns of diffused dust at various dust source points in fully mechanized mining faces under different wind speed conditions, including single dust source and single double dust source coupling conditions. Through numerical simulation research on dust transport, the movement and distribution patterns of dust in airflow can be simulated, providing a theoretical basis for predicting and controlling dust transport. Therefore, this article takes the 122109 fully mechanized mining face of Caojiatan Coal Mine as the research object to study the migration law of working flour dust.

2. Background of Working Conditions

The 122109 fully mechanized mining face of Caojiatan Coal Mine is located on the west side of the development roadway of the 2⁻² coal seam in the 12-panel area, and the 2⁻² coal seam is being mined. The working face is 260 meters long, with a pushing length of about 6004 meters. The thickness of the 2⁻² coal seam is 11.55-12.03 meters, with an average thickness of 11.8 meters. The inclination angle of the coal seam is 0.4°, and the average burial depth is about 318 meters. The air volume of the working face is 2400 m³/min, with two inlets and two loops. The working face adopts the strike long wall retreat coal mining method, the fully mechanized caving coal mining process, and the total collapse method to manage the roof. The average coal thickness of the working face is 11.8m, with a designed mining height of 5.8m and a coal discharge height of 6m. Adopting a one cut one release method, the coal release step distance is determined to be 0.865m. There are a total of 130 hydraulic supports in the 122109 fully mechanized mining face, including 119 ZFY21000/34/63D basic supports. One intermediate transition bracket ZFYG21000/34/63D (A) head and one ZFYG21000/34/63D (B) tail, totaling two. End transition bracket ZFG22000/30/50D (A) with 3 machine heads and ZFG22000/30/50D (B) with 4 machine tails, a total of 7. There are a total of 2 hydraulic supports ZYT21000/28/50D for the head and end of the machine.

3. Construction of Numerical Simulation Models

This article mainly uses Solidworks software to establish a solid 3D model of the fully mechanized mining face based on the actual situation of the working face, as shown in Figure 1. The model coal cutting methods are mainly divided into upwind coal cutting and downwind coal cutting. The dust sources are set as a single shearer drum, a single support frame, and a double dust source for the shearer drum and support.

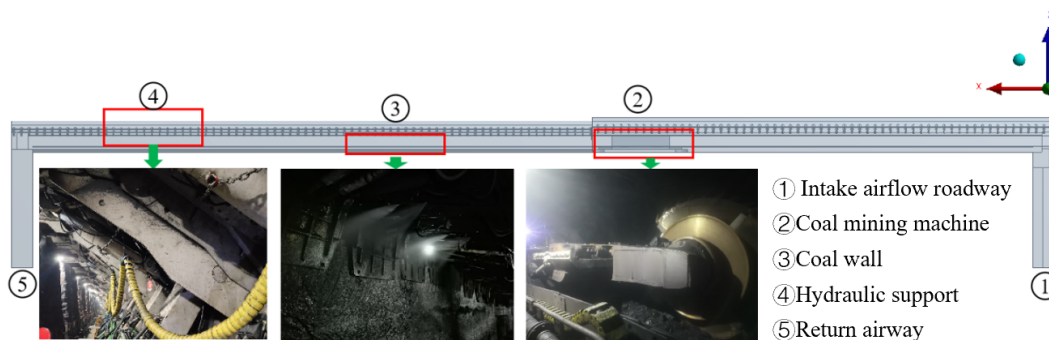


Figure 1. 3D model of 122109 working face

The simulation parameters are set according to the actual situation on site. When solving the ventilation dust field, the solver adopts steady-state and absolute velocity. Due to the influence

of gravity on dust particles in the tunnel, the gravity acceleration is set during simulation calculation. The specific parameters are shown in Table 1.

Table 1. Simulation parameter settings

Boundary condition	Parameter settings	Boundary condition	Parameter settings
Inlet Boundary Type	velocity-inlet	Injection Type	Surface
Velocity Magnitude(m/s)	1.2	Diameter Distribution	Rosin-Rammler
Turbulent Intensity(%)	5	Min. Diameter(m)	1e-06
Turbulent Viscosity Ratio	10	Max. Diameter(m)	1e-04
Outlet Boundary Type	Outflow	Mid. Diameter(m)	2e-05
Wall Shear Condition	No Slip	Number of Diameters	150
Interaction with Continuous Phase	On	Spread Parameter	3.5
Number of Continuous Interaction per DPM Iteration	200	Total Flow Rate(kg/s)	0.025
Material	Coal-hv	Turbulent Dispersion	Discrete Random Walk Model

4. Analysis of Simulation Results

(1) Dust transport law of a single dust source in a coal mining machine

Figures 2 and 3 respectively represent the distribution of dust concentration in the three-dimensional space of the working face and the YOZ section. From the figure, it can be seen that a portion of the dust generated by the windward side drum of the shearer when cutting coal diffuses along the gap between the shearer and the coal wall to the downwind side drum, while another portion moves along the windward side of the shearer body. At a position about 45m above the windward side drum of the mechanism shearer, the dust generated by the drum cutting coal begins to diffuse towards the pedestrian side inside the support. The main reason for the diffusion of dust in this part may be that the airflow is obstructed at the body of the shearer, diffusing towards the pedestrian side, causing dust diffusion. And it was found that the movement of dust diffusion first diffuses towards the inner top plate of the support, then towards the pedestrian side bottom plate, and finally the dust diffuses throughout the entire mining space. The high concentration dust generated by drum coal cutting is mainly concentrated in the front and rear drums of the shearer. Under the influence of the airflow, the high concentration dust particles on the downwind side of the shearer gradually settle slowly due to their own gravity and accumulate near the bottom plate of the downwind side, which is 25m away from the shearer, with a dust concentration exceeding 1000mg/m³.

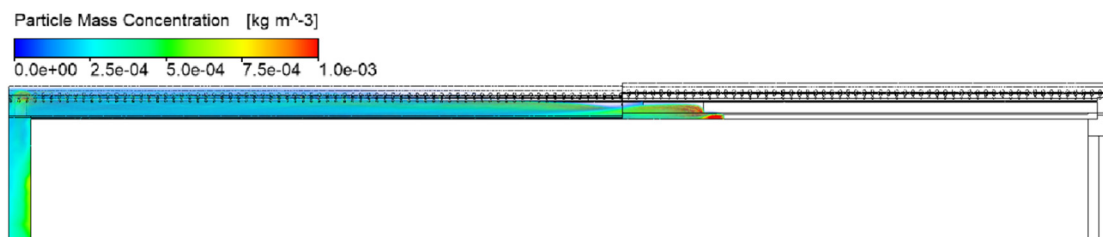


Figure 2. Three dimensional spatial distribution of dust concentration in the working face

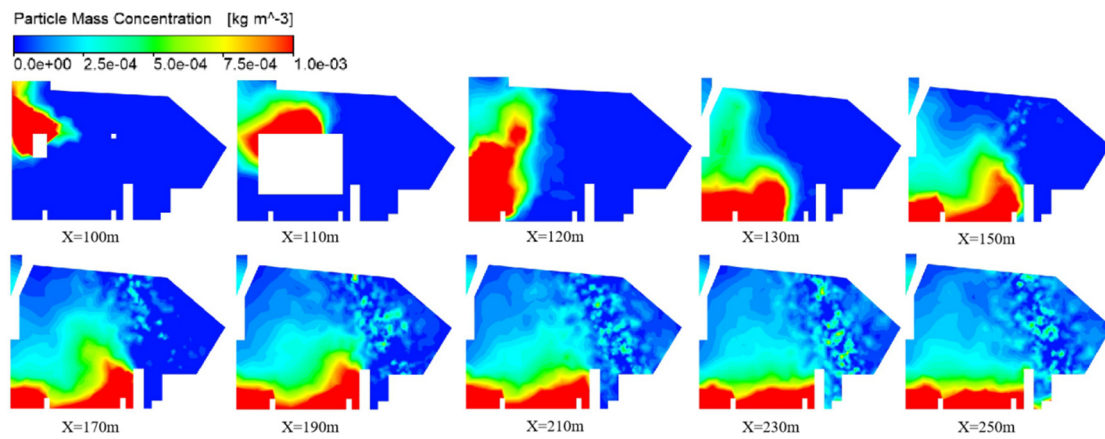


Figure 3. Dust concentration distribution map of YOZ section in the working face

(2) Dust transport law of a single dust source on the support bracket

During the process of hydraulic support relocation, a large amount of dust collapsed due to the compression of the support roof on the coal seam. In order to understand the distribution pattern of dust during the support relocation process, a dust source was set up at the top of the support in the working face (X=120m). The numerical simulation method was used to analyze the dust emission law and the motion behavior of different particle dust over time. The simulation results are shown in Figures 4 and 5.

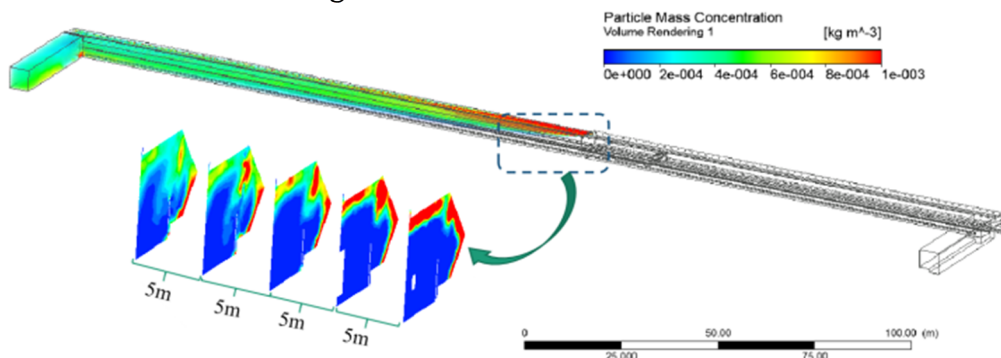


Figure 4. Distribution of dust concentration along the fully mechanized mining face support during relocation

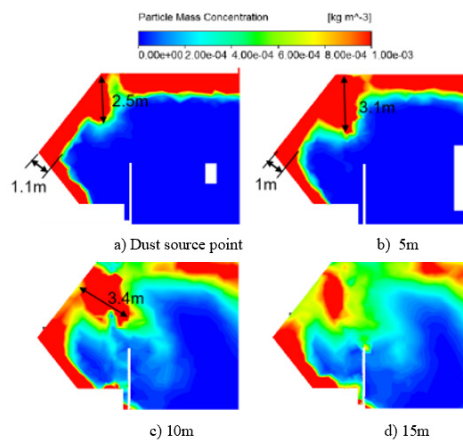


Figure 5. Distribution of dust diffusion in the YOZ cross-section near the dust source point

Figure 4 shows that during the movement of the bracket, dust continuously collapses due to the effects of airflow and gravity, with the highest dust concentration near the dust source. The dust generated during the movement is affected by the airflow, and first undergoes lateral diffusion,

forming a 15m long high concentration dust belt on the top plate. Most of the dust quickly spreads to the downwind side and pedestrian space with the wind flow. At a distance of 10 meters from the dust source, the dust diffuses to the height of the pedestrian breathing zone, with a dust concentration ranging from 450 to 550 mg/m³. The remaining dust continues to diffuse into the return airway under the influence of the airflow, and the dust concentration stabilizes at around 250 mg/m³ after being 80m away from the dust source.

Figure 5 shows the distribution of dust diffusion from the moving dust source to the pedestrian area at different distances in the YOZ cross-section. From the graph, it can be seen that the dust from moving the frame is affected by wind flow and spreads relatively quickly. As the distance from the dust source point increases, the diffusion of dust into the pedestrian area increases, and the distance to the bottom plate also increases. The overall diffusion distance of high concentration dust clusters can reach up to 3.4m. And 10 meters away from the dust source point, there are high concentrations of dust on the pedestrian floor.

(3) Along wind dust source superimposed dust transport law

Figures 6 and 7 show the distribution of dust generated by the drum cutting coal and the hydraulic support lowering column moving frame during downwind coal cutting on the working face.

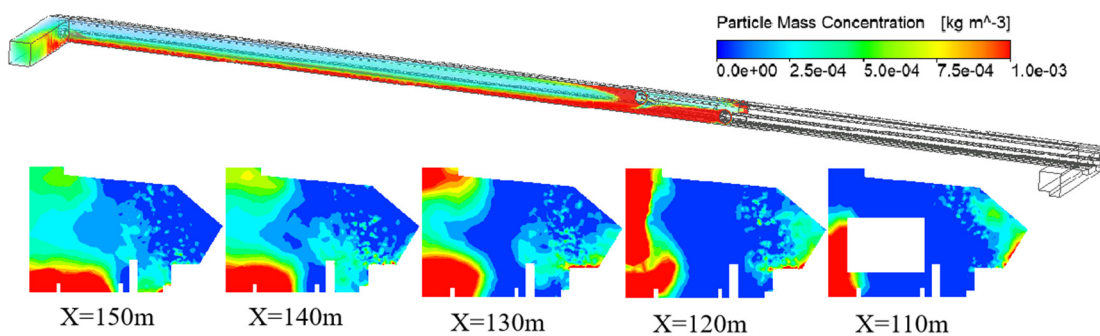


Figure 6. Three dimensional spatial distribution map of dust concentration for all dust sources in downwind coal cutting

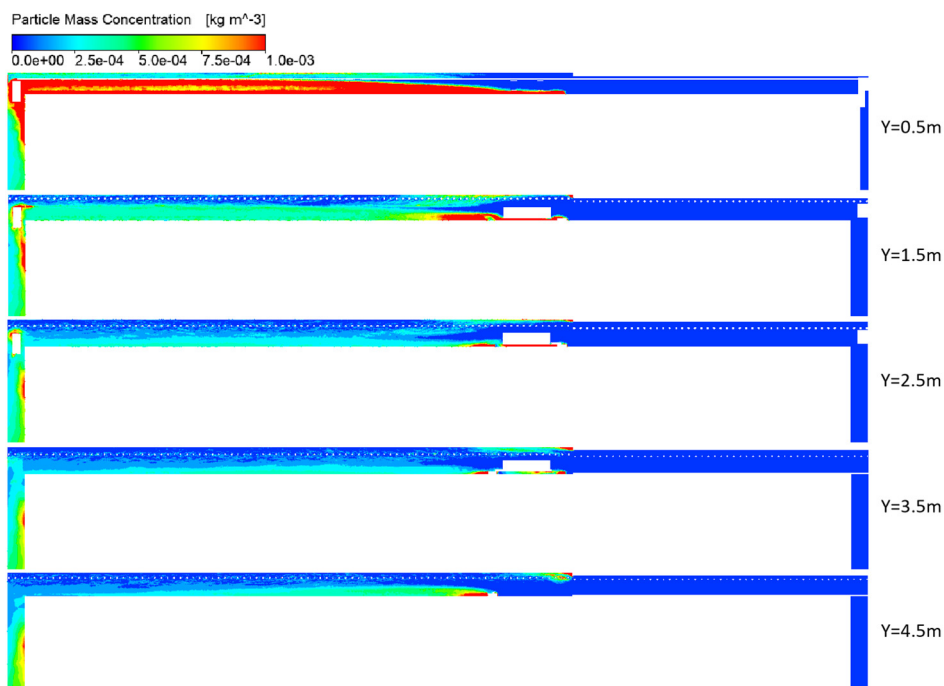


Figure 7. Distribution of dust concentration in the XOZ cross section of the full dust source for along wind coal cutting

From the figures 6 and 7, it can be seen that when cutting coal in the downwind direction, due to the upper drum of the shearer cutting the bottom coal and the downwind side drum cutting the top coal, the dust generated by the upwind side drum cutting coal moves along the coal wall towards the bottom plate and gathers with the dust generated by the downwind side drum cutting coal. The dust diffusion generated by the downwind side drum of the shearer during coal cutting can be divided into two directions: one part of the dust diffuses towards the top plate, and the other part diffuses towards the bottom plate. Most of the high concentration dust deposits on the bottom plate near the coal wall. The dust generated by the relocation of hydraulic supports collapses into the sidewalk from the gap between adjacent supports, and then spreads to the coal mining space. At a distance of 30 meters from the relocation dust source, small particles of dust gradually cross the cable trench and drift into the coal mining space. In addition, from the XOZ section of the working face, it can be seen that the dust generated by the shearer drum cutting coal and the dust generated by the hydraulic support mainly gather in the section below 3.5m from the bottom plate, with a dust concentration of about 220mg/m³ at the intersection. The main affected area is the rear space of the shearer, which has no significant impact on the pedestrian side inside the support. At a cross-section below Y=1.5m, the superposition phenomenon of dust generated by the two dust sources is obvious, located 45m away from the dust source point of the moving frame. Starting to affect the activity area of miners, the dust concentration is around 450mg/m³. Most of the dust generated by drum coal cutting and frame moving ultimately settles on the bottom plate, with a small amount drifting into the return airway with the airflow.

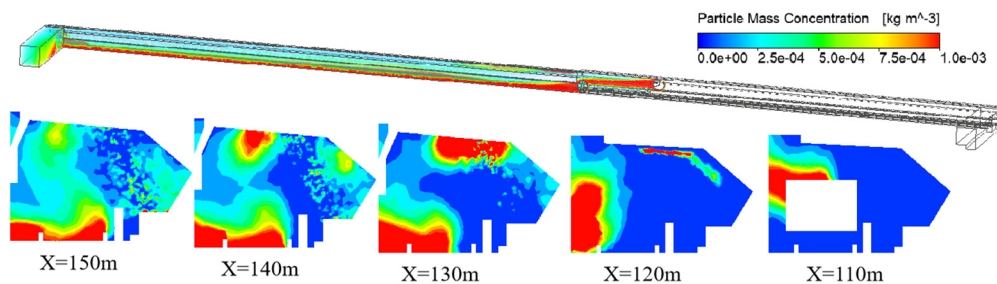


Figure 8. Three dimensional spatial distribution of dust concentration for all dust sources in upwind coal cutting

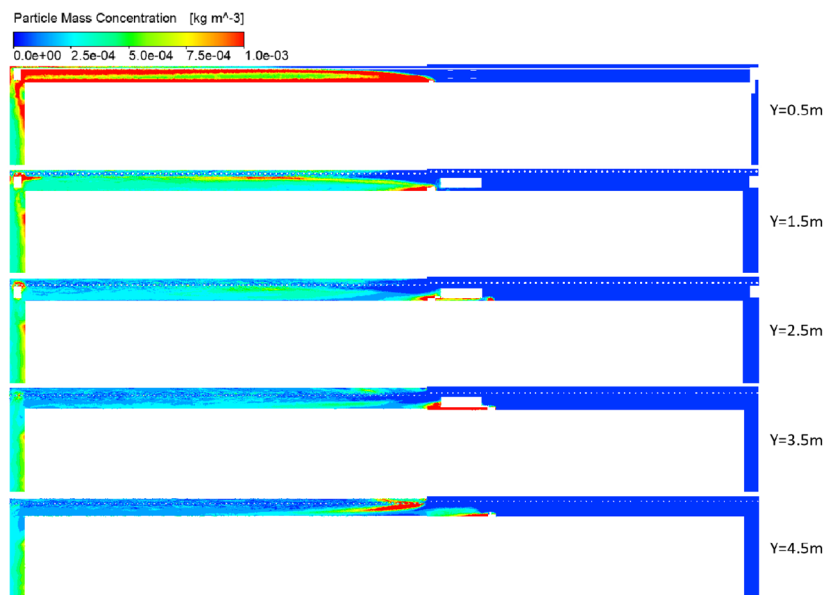


Figure 9. Distribution of dust concentration in the XOZ cross section of the full dust source for upwind coal cutting

(4) Upwind dust source superimposed dust transport law

Figures 8 and 9 show the distribution of dust generated by the drum cutting coal and the hydraulic support lowering column moving frame during upwind coal cutting on the working face.

From the figures 8 and 9, it can be seen that the dust pollution of the flour during upwind coal cutting is significantly more severe than that during downwind coal cutting. Because when cutting coal against the wind, the upper drum of the shearer cuts the top coal, the lower drum cuts the bottom coal, and the dust generated by the upper drum cuts the coal, with a diffusion height of up to 4 meters. At the same time, the influence of wind flow will cause serious diffusion and spread throughout the entire coal mining space. In addition, during the process of backward diffusion and settlement of dust generated by the drum cutting coal on the shearer, high concentration dust clusters tend to diffuse towards the pedestrian side, occupying most of the rear space of the shearer, with a dust concentration exceeding $1000\text{mg}/\text{m}^3$. Under the influence of wind, the dust generated by the relocation of hydraulic supports first moves laterally, with a large amount of high concentration dust moving towards one side of the coal wall. It intersects with the dust generated by the drum cutting coal at a distance of 4.5 meters from the bottom plate and 6 meters behind the relocation position. Subsequently, longitudinal diffusion occurred and gradually spread to the entire pedestrian area within the support frame. At a distance of 20 meters from the dust source of the moving frame, the greatest impact on personnel pollution reached over $680\text{mg}/\text{m}^3$. At the same time, from the XOZ section of the working face, the high concentration dust generated by the hydraulic support mostly moves to the coal wall side at a distance of 4.5m from the bottom plate due to wind disturbance, with a dust concentration exceeding $1400\text{mg}/\text{m}^3$. At this section and above, the main source of spatial dust pollution comes from the support moving. At a section 3.5m away from the bottom plate, a large amount of dust generated by the drum coal cutting begins to diffuse towards the pedestrian side, mainly occurring 38m away from the dust source point. The superposition with the moving dust causes great pollution to the pedestrian side environment. Under the influence of the final airflow, the entire work dust gradually settles to a position below 0.5m from the bottom plate.

5. Conclusion

(1) Part of the dust generated by the windward side drum of the shearer when cutting coal diffuses along the gap between the shearer and the coal wall to the downwind side drum, while the other part moves along the windward side of the shearer body. The high concentration of dust generated by drum coal cutting is mainly concentrated in the front and rear drums of the shearer, and accumulates near the downwind side bottom plate 0-1m away from the shearer, with a dust concentration exceeding $1000\text{mg}/\text{m}^3$.

(2) During the relocation process of the bracket, the dust concentration near the dust source is the highest, and most of the dust generated by the relocation quickly spreads to the downwind side and pedestrian space with the airflow. As the distance from the dust source point increases, the diffusion of dust into the pedestrian area increases, and the distance to the bottom plate also increases. The overall diffusion distance of high concentration dust clusters can reach up to 3.4m. And 10 meters away from the dust source point, there are high concentrations of dust on the pedestrian floor.

(3) When cutting coal downwind, the dust generated by the windward side drum of the shearer moves along the coal wall towards the bottom plate and collects with the dust generated by the windward side drum of the shearer. The dust pollution of flour during upwind coal cutting is significantly more severe than that during downwind coal cutting.

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