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Numerical Simulation Study of Dust Transport of Comprehensive Mining Working Surface

Liang WANG [a,c], Fengfeng LI [a,1], Yuyin GUO[b], Qingzhen LI[b], Tianming CHEN[a,c] and Jingjian WU[b,2]

[a] *School of Mechanical and Electronic Engineering, Shandong University of Science and Technology, Qingdao, China*
[b] *Shandong Ji Mine Luneng Coal Power Co., Ltd, China*
[c] *Qingdao Ecotek Intelligent Technology Co., Ltd, Qingdao, China*

Abstract. In order to study the wind flow field and dust transport law of the comprehensive mining work surface, taking the 21103 comprehensive mining working surface of Hulusu Coal Mine as the research object, SolidWorks was used to establish the comprehensive mining working surface model, and the comprehensive mining working surface under different inlet wind speed conditions was simulated and analyzed by Fluent. The results show that due to the existence of the high-speed wind flow belt, dust is mainly distributed near the downwind side working surface; when the inlet speed is $2.5m/s$, the dust mass concentration of the comprehensive mining working surface is low and it is not easy to cause secondary dust, which is the optimal inlet speed; the dust distribution within $10\ m$ of the downwind side of the shearer is the most, which is the key area of dust prevention and control.

Keywords. Fluent simulation, wind flow field, high-speed wind flow band, transport law

1. Introduction

In the process of mining coal will inevitably produce a large amount of dust [1][2], dust concentration is too high when prone to explosion, seriously threatening the life of workers, and the comprehensive mining work surface is one of the most important dust production sites [3][4][5], the mass concentration of dust can reach $2000mg/m^3$, has been far higher than the quality concentration standard of safe production [6][7]. With the further development of mining machinery, improving dust reduction efficiency and solving the harm caused by dust is the top priority of safe production [8]. At present, the comprehensive mining work surface mainly uses spray dust reduction, and there is less research on ventilation and dust reduction, mainly because the situation in the roadway is more complicated, and it is more difficult to change the ventilation amount and other

[1] Corresponding author: Fengfeng LI, Shandong University of Science and Technology Campus, Qingdao, Shandong Province, E-mail:321935581@qq.com.
[2] Corresponding author: Jingjian WU, No.2299 Chongwen Avenue, High-tech Zone, Jining City, Shandong Province, Tel: 0537-2379087, E-mail: wujingjian52@163.com.

conditions, so it is impossible to obtain the flow field and the movement law of dust in the roadway through field experiments [9]. Therefore, this paper conducts numerical simulation of the comprehensive mining working surface model through Fluent simulation software [10], mainly to study the influence of inlet wind speed on the dust movement law in the roadway under different conditions, and to obtain the dust distribution in different locations in the roadway [11], so as to find out the key areas of dust prevention.

2. Comprehensive Mining Work Surface Dust Transport Model

2.1. Physical Model and Meshing

In this paper, taking the site situation of the 21103 comprehensive mining surface of Cucurbitasin Coal Mine as the background of the study, ignoring other equipment with small influencing factors in the roadway, only considering the hydraulic support and shearer, using the 3D modeling software Solidworks to establish a simplified physical model, as shown in Figure 1. Mesh is used to mesh the comprehensive mining work surface model, which is divided into tetrahedral meshes with high degree of conformity and automation, and the average mesh quality of the model is 0.83, the number of nodes is 295826, and the number of elements is 1526924. The size of the working surface is 50 m, 4 m, and 4 m, the shearer is arranged at 10 m from the air inlet, the hydraulic support is simplified to a cylinder with a radius of 0.2 m, and it is arranged sequentially along the air inlet to the outlet of the comprehensive mining work surface, and the distance between each hydraulic support is 2 m.

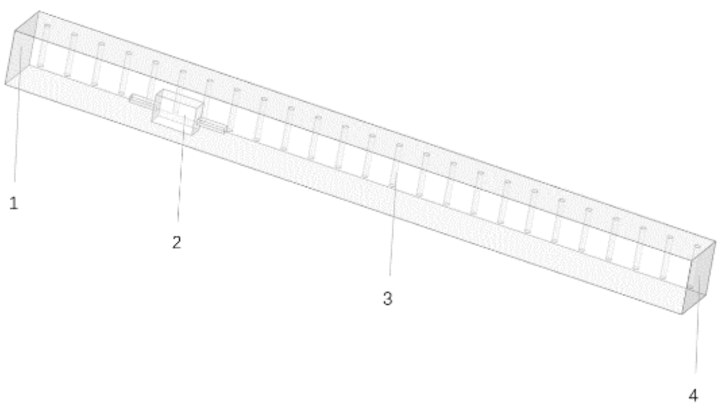


Figure 1. Simplified physical model of the comprehensive mining work surface: 1- Air inlet; 2- Shearer; 3- Hydraulic support; 4- Output.

2.2. Mathematical Models

In order to better study the movement law of dust, combined with Euler's equation and constructing a Lagrange mathematical model, the trajectory of dust is obtained.

1)Continuous equations

$$\frac{\partial\rho}{\partial t}+v\frac{\partial\rho}{\partial x}=K\cdot\frac{\partial^2\rho}{\partial^2 x} \tag{1}$$

wherein: ρ is the average mass concentration of dust, v is the average speed, K is the composite diffusion coefficient, t is the diffusion time.

2) Equation of motion of dust in air

$$m_P\frac{dv}{dt}=\frac{\pi}{6}d_P^3\left(\rho_P-\rho_g\right)-C_P\frac{\pi}{4}d_P^2\frac{v^2}{2}\rho_g \tag{2}$$

wherein: m_P is the total mass of dust, v is the relative speed of dust and air, t is the time, ρ_P is the dust density, ρ_g is the gas density, d_P is the particle size of the dust,g is acceleration for gravity, C_P is the resistance coefficient.

2.3. Primary boundary condition settings

After the partitioned mesh is updated and imported into Fluent, some parameters need to be set in Fluent before solving, and the main parameter settings are shown in Table 1.

Table 1. Main parameter settings

type	Parameter settings
Air intake	Speed entry
outlet	Speed exit
Speed entry	1.5 m/s
Speed exit	Outflow
Solver	SIMPLE
Time properties	Steady-state computation
Turbulence intensity	5%
Hydraulic diameter	0.4m
Coupled to each other	on
Injection Type	Surface
Material	Coal-hv
Min Diameter	1μm
Max Diameter	100μm
Mid Diameter	10μm

3. Numerical calculation results analysis

3.1. Distribution of wind flow fields on the comprehensive mining work surface

Wind flow is an important factor affecting the diffusion of dust in the roadway, and the analysis and study of the distribution of the wind flow field of the comprehensive mining work surface is conducive to analyzing the movement law of dust. After the parameter setting is completed, the model is simulated with an initial wind speed of 1.5 m/s, and the distribution of the flow field at different positions of the comprehensive mining working surface is obtained, which is 1 m and 1.5 m from the ground height and 0.6 m and 1.5 m parallel to the roadway length, respectively, as shown in Figure 2-5.

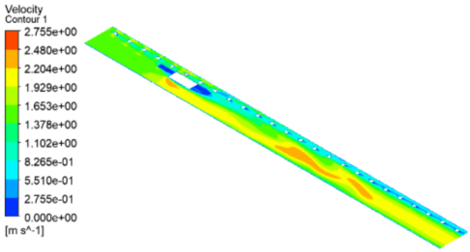


Figure 2. The distribution of the current field at a height of 1 m from the ground.

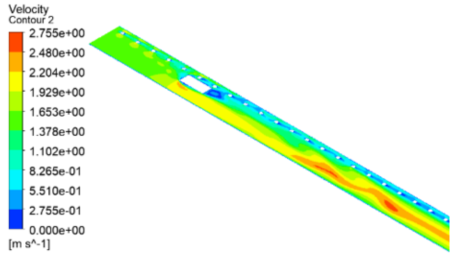


Figure 3. The distribution of the current field at a height of 1.5 m above the ground.

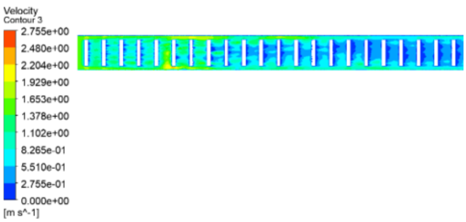


Figure 4. The distribution of the current field is 0.6m from the comprehensive mining surface.

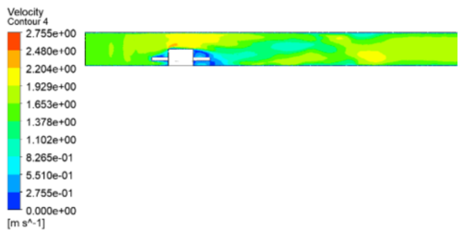


Figure 5. The distribution of the current field is 1.5 m from the comprehensive mining surface.

As can be seen from Figures 2-5, the wind flow enters from the entrance of the roadway at 1.5m/s, the wind speed gradually increases in the roadway, and the closer to the center of the roadway, the greater the wind speed, the maximum wind speed in the local position can reach 2.75 m/s, and near the shearer, due to the obstruction of the wind flow, a high-speed turbulence area is formed around the shearer, the average wind speed reaches 2.1m/s, which affects the shearer to the roadway exit to form a wind flow belt, and the average wind speed reaches 2.2 m/s. When the air flow flows through the working surface, due to the obstruction of the working face of the wind flow, a laminar flow will be formed, resulting in a small air flow speed in contact with the working surface, and the hydraulic support is affected by the low wind speed near the hydraulic support due to its proximity to the working surface.

3.2. Distribution of dust mass concentration on the working surface of comprehensive mining

After the continuous phase simulation is completed to obtain the flow field distribution, continue with the initial wind speed of 1.5 m/s unchanged, open the discrete phase model, set the injection source and spray conditions, simulate the model, and obtain the dust mass concentration distribution of the working surface of different heights, which are 0.5 m, 1 m, 1.5 m and 2 m from the ground height, respectively, as shown in Figures 6-9.

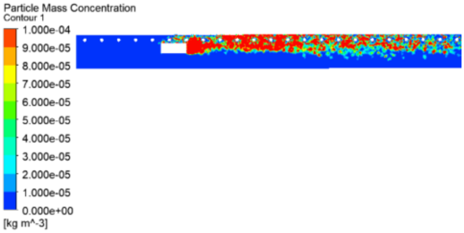


Figure 6. Dust mass concentration distribution 0.5 m above ground level.

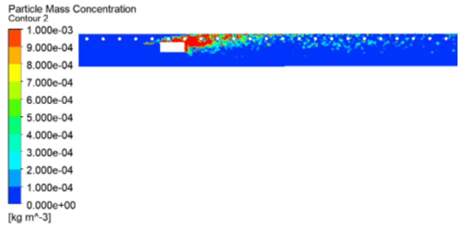
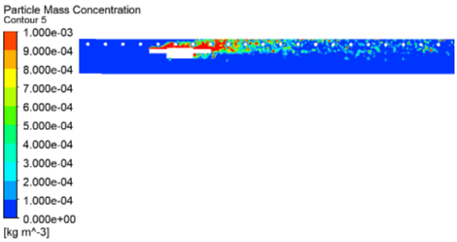


Figure 7. Dust mass concentration distribution 1 m above ground level.



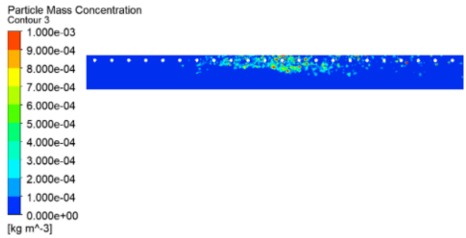


Figure 8. Dust mass concentration distribution 1.5 m above ground level.

Figure 9. Dust mass concentration distribution 2 m above ground level.

As can be seen from Figures 6-9, the farther away from the ground the dust mass concentration is lower, the height from the ground reaches more than 2 m, the dust content in the roadway is significantly lower, and the dust mass concentration near the shearer due to the existence of dust sources, so the dust mass concentration near the shearer is the highest, which can reach 1000 mg/m^3, and the wind side of the shearer due to the air inlet, the dust will be affected by the wind after the dust generation, and then spread in the direction of the air outlet, so the dust mass concentration in the wind side roadway on the shearer is less than 100 mg/m^3 . When the dust generated at the dust source spreads in the direction of the air outlet, due to a high-speed wind flow belt formed in the center of the roadway, the wind speed in the roadway of the same height is low, which in turn makes it difficult for the dust to spread to the center of the roadway, making the dust mass concentration near the comprehensive mining work surface high.

3.3. Effect of wind speed on the mass concentration of dust on the working surface of comprehensive mining

The height at which people inhale dust in the roadway is around 1.6 m, so the height of 1.6 m is selected for study. Keep other parameters unchanged, only change the size of the inlet wind speed, in order to study the effect of different inlet wind speed on the mass concentration of the working surface of the comprehensive mining, so as to find the optimal inlet wind speed, respectively, the inlet wind speed of 1.5m/s, 2 m/s, 2.5m/s and 3m/s to simulate, respectively, to obtain the dust mass concentration of 1.6 m from the ground height after adding dust ventilation 30 s, as shown in Figures 10-13.

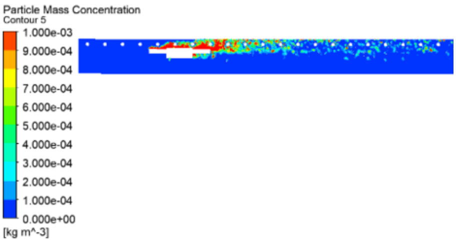


Figure 10. Dust mass concentration distribution at inlet wind speed of 1.5 m/s.

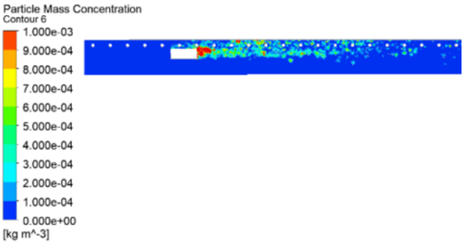


Figure 11. Dust mass concentration distribution at inlet wind speed of 2 m/s.

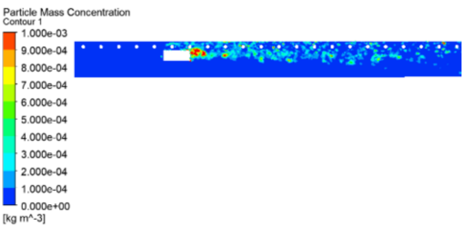


Figure 12. Dust mass concentration distribution at inlet wind speed of 2.5 m/s.

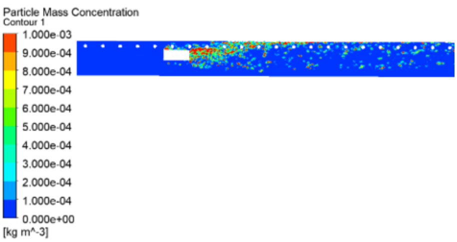


Figure 13. Dust mass concentration distribution at inlet wind speed of 3 m/s.

As can be seen from Figures 10-13, with the increase of the inlet wind speed, the average mass concentration of dust in the roadway appears to decrease first and then increase the trend, within 1.5-2.5m/s, the dust concentration decreases with the increase of wind speed, which is due to the increase of wind speed can quickly take away the dust, reduce the dust concentration, when the wind speed reaches 3m/s, the dust concentration in the roadway turns to increase, which is due to the excessive wind speed, resulting in the difficulty of settling the dust, and the dust that has settled appears secondary dust phenomenon. Therefore, when the inlet wind speed is 2.5 m / s, it is conducive to dust removal and is not easy to raise dust, which is the optimal inlet wind speed. At the same time, it can be seen from Figures 10-13 that the dust mass concentration within 10m on the right side of the shearer has been very high, and the average concentration is maintained at about 600 mg/m^3, which belongs to the key dust suppression area.

4. Conclusion

(1) From the entrance of the roadway to the exit of the roadway, the wind speed gradually increases, the closer to the center of the roadway, the greater the wind speed, and due to the influence of the high-speed turbulence area, the shearer to the center of the roadway outlet forms a high-speed air flow belt, and the working surface near the laminar flow, resulting in low wind flow near the hydraulic support.

(2) The greater the height from the ground in the roadway, the lower the dust mass concentration, and the dust in the roadway is difficult to spread on the upwind side, and it is concentrated on the downwind side, due to the influence of the high-speed wind flow belt in the roadway, the dust distribution in the roadway is mainly concentrated near the

downwind side working surface.
(3) When the inlet wind speed is 2.5 m/s, the average mass concentration of dust in the roadway is low, it is not easy to cause secondary dust, which is the optimal inlet wind speed, and the downwind side of the shearer belongs to the key area of dust prevention and control within 10 m, and dust reduction should be taken in time to prevent dust from staying in the air for too long.

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