Study on Dust Concentration Distribution in a Construction Tunnel

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Abstract At present, dust is not only the main occupational hazard factor in tunnel construction, which seriously threatens the safety of production and the health of construction workers, but also an important source of environmental pollution. Taking the working face of a construction tunnel as the research object, the numerical model is constructed with the help of fluid software FLUENT, and the dust distribution law of the construction tunnel is simulated and analyzed, so as to provide research direction for environmental protection and personal health protection. The comparative analysis results of numerical simulation and field measured dust concentration show that the dust in the tunnel construction is easy to accumulate in the lower right side of the tunnel. When the fan mouth is 5 meters away from the working face, the dust concentration within 8 meters near the working face is the lowest. When the fan mouth is 10 meters away from the working face, the dust diffusion range is the longest and it is not easy to accumulate.

1. Introduction

In the process of highway tunnel construction, a large amount of dust will be produced in the process of drilling, blasting and slag transportation. The dust not only pollutes the atmospheric environment, but also brings serious harm to the occupational health of operators. At the same time, the working face is an unorganized dust source\cite{1}, and the ventilation condition is poor. The high concentration of dust will aggravate the wear of mechanical equipment, interfere with the operation sight of construction personnel, and also cause other safety accidents; therefore, it is of great significance to study the dust distribution law of tunnel construction, master the dust concentration distribution characteristics, obtain the relevant parameters of ventilation and dust removal design\cite{2}, and reduce the dust concentration near the working face, so as to protect the safety and health of operators and improve the construction environment. In this study, the face of a construction tunnel is taken as the research object, and the "discrete phase" model method is used to build a numerical model for the ventilation system of the construction tunnel, and the distribution law of dust concentration in tunnel construction is analyzed, so as to provide a reliable basis for the control and prediction of dust concentration in tunnel construction\cite{3}.

2. Numerical Model Construction and Parameter Design

In this study, a construction tunnel face is taken as an example to build a geometric model. If the tunnel interception is too long, the number of grids will increase exponentially, and the calculation amount is huge. If the interception is too short, the air flow and dust will leave the calculation area.
quickly, and the calculation area can not complete the whole process of dust migration, which will cause distortion or even error of the results. To sum up, on the premise of meeting the calculation accuracy and amount, combined with the research, the length of the tunnel is 45 m. at the same time, the tunnel adopts the forced ventilation system. According to the field measurement, the tunnel arch height is 3.5 m, the width is 4.8 m, the fan’s diameter is 1.2 m, the vertical height from the air duct center to the ground is 2.2 m, and the distance between the air duct inlet and the tunnel face is 5 m, 10 m, 20 m and 30 m respectively. There are two kinds of wind speed settings, which are 0.8m/s and 5.8m/s, respectively. The initial dust concentration is selected as the instantaneous maximum concentration of 1800mg/m³ when slag is discharged. Considering the actual situation of the construction tunnel and the needs of model analysis, the field situation of the working face is simplified to a certain extent. Several models of tunnel construction face in this study are shown in Fig. 1 and Fig. 2, and the model dust source parameters are shown in Table 1.

![Geometric Model of Construction Tunnel](image1.png)

![Mesh Generation of Geometric Model of Construction Tunnel](image2.png)

| Types of dust sources | Particle size distribution | Minimum particle diameter | Maximum particle diameter | Average particle diameter | Distribution index | Initial speed |
|----------------------|---------------------------|---------------------------|---------------------------|---------------------------|-------------------|--------------|
| Surface dust source  | Rosin-rammler             | $1.0 \times 10^{-6}$      | $1.0 \times 10^{-4}$      | $1.0 \times 10^{-5}$      | 3.5               | 0            |

### 3. Numerical Simulation Results of Dust Concentration

Through iterative calculation, the simulation results of dust concentration distribution in the construction tunnel are obtained. Fig. 3 and Fig. 4 are the flow velocity diagrams of dust particle flow field at four different distances from the fan mouth to the working face under two wind speeds (i.e. 0.8/S and 5.8/S).
Figure 3 (wind speed 0.8m/S) 1 - dust particle flow when the fan mouth is 5m away from the working face

Figure 3 (wind speed 0.8m/S) 2 - dust particle flow when the fan mouth is 10m away from the working face

Figure 3 (wind speed 0.8m/S) 3 - dust particle flow when the fan mouth is 20m away from the working face
Figure 3 (wind speed 0.6m/S) 4 - dust particle flow when the fan mouth is 30m away from the working face

Y = 5 (distance from working face)

Figure 4 (wind speed 5.8m/S) 1 - dust particle flow when the fan mouth is 5m away from the working face

Y = 3 (distance from working face)

Y = 8 (distance from working face)

Y = 40 (distance from working face)
4. Comparative Analysis of Simulated and Measured Values
In this experiment, the filter membrane weight method was adopted. Because of the difficulty of field measurement, this study only measured the dust concentration at the height of the breathing belt (1.5m) of the working face. The dust concentration was measured at 5m, 10m,
20m and 30m at different positions of the fan mouth. The wind speed was 0.8m/S and 5.8m/S. Four rows of measuring points were arranged and measured three times, and the average value was taken. At the same time, the numerical simulation results are derived and compared with the field measurement results. The results are shown in Figure 5.

![Fig. 5 Comparison of Field Measured Data and Simulated Data](image)

Comprehensive analysis of Fig. 3, Fig. 4 and Fig. 5 shows that: (1) when the wind speed is 0.8 and the fan mouth is 5 meters away from the working face, the dust flow field diffusion effect is better, and other locations are easier to cause dust accumulation, which is not conducive to the diffusion and migration of dust, which is basically consistent with the field measurement results; (2) when the wind speed is 5.8, the dust flow field diffusion effect is the worst when the fan mouth is 30 meters away from the working face, and the dust flow field diffusion effect is the best when the fan mouth is 10 meters away from the working face, and the dust accumulation phenomenon is light; (3) on the cross section of the tunnel, the dust concentration near the side wall of the lower right corner of the tunnel is higher than that at other positions; (4) with the increase of wind speed, it is more conducive to the diffusion of the dust flow field of the working face and reduce the dust concentration near the working face.

5. Conclusion
Taking the working face of a construction tunnel as an example, combined with the actual measurement situation, the distribution law of dust concentration in the tunnel is numerically simulated and analyzed by using FLUENT software. It is considered that the dust in the tunnel construction is easy to accumulate in the lower right side of the tunnel. When the fan mouth is 5 meters away from the working face, the dust concentration within 8 meters near the working face is the lowest. When the fan mouth is 10 meters away from the working face, the dust diffusion range is the longest, and it is not easy to accumulate.

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