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Research on the Effect of inlet location and air supply angle with displacement ventilation system in machining plants

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Abstract: *In order to improve the working environment of the working area in the machining plants,numerical simulation was taken to study flow field in a large displacement ventilation workshop. The effects of air distribution was adjusted by changing the vertical location and angle of inlet air and brought in particulate concentration in working area to estimate it. The results indicate that in a plant with dense equipment the concentration of particles in the working area will be higher due to the interference of the thermal plume,if the vertical location of the inlet is too high or inlet angle is upward,however particulate concentration in the work area is greatly reduced when higher air inlet chooses the downward air supply angle.*

Key words: *machining plants displacement ventilation inlet location air supply angle numerical simulation*

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I. Introduction

In the process of mechanical processing, a large number of oil mist particles are often produced, causing the concentration of particulate pollutants in industrial plants to exceed the standard 2-3 times [1]. This particulate pollutant is breathed in for a long time. It can cause respiratory infections[2], asthma[3] and other diseases. The effect of displacement ventilation is strongly related to air supply, indoor heat source conditions, target pollutants, etc. In order to improve the ability of displacement ventilation to remove particulate pollutants, a large number of scholars have done a lot of research on the airflow organization of displacement ventilation in industrial plants. Kang Yanming[4] used numerical simulation methods to influence the air supply temperature of industrial plants and offices on the distribution of pollutants.Yaghoubi [5] explored the influence of heat source and pollution source location on spatial pollutant concentration distribution through CFD simulation. Raimo [6] conducted a test study on welding workshops using displacement ventilation, and found that the distribution of different types of pollutants are quite different. Wang H Q[7] conducted simulations on welding workshops and compared the working conditions of air outlets with different air outlet heights, air temperature, air speed, etc., and found that the lower the air outlet height, the lower the particle concentration in the area below 3m. The conclusion. However, Wang H Q only studied the change in the height of the tuyere, and did not change the air supply angle. Li Can [8] conducted a numerical simulation on an industrial plant, studied the influence of the angle of oblique air supply in winter, and concluded that 45° oblique air supply is the best air supply in winter. Li Can only studied the winter operating conditions, and did not study the typical summer operating conditions, and only studied the air supply angle at a certain height.

In summary, displacement ventilation has certain advantages in the control of pollutant concentration in industrial plants. Regarding the oil mist particles produced by machining, the effect of different air outlet heights and air supply angles on the concentration of oil mist particles in the work area is not clear.

In this paper, CFD method was used to carry out numerical simulation research on displacement ventilation of mechanical processing building, and the distribution of particle pollutant concentration in the working area was compared when several different air outlets in the industrial building adopted different air supply angles, which provided a basis for air distribution design of mechanical processing building.

II. METHODS

2.1 The physical model

A mechanical processing workshop is selected as the prototype to establish a physical model, and the schematic diagram of the physical model is shown in Figure 1.The size of the model is 28m*18m*10m (length*height*width), and there are 12 mechanical processing equipment inside the model. The size of each machine tool is 2m*1.5m*1m (length* height*width).Upper factory outlet is equipped with eight, each the size of the air outlet is 1 m * 1 m, and lower model has eight columnar air supply outlet, the air supply outlet is simplified to cut into three sections of the rectangular air supply outlet, each part of the air distribution in a different direction, approximate columnar air distribution, each part of the tuyere length x height size is 0.4 m * 1 m, tuyere simplified as shown in figure 2. Considering that the machining workshop itself has symmetry, the equipment layout in the workshop has spatial symmetry, and the air flow organization has flow symmetry, this paper adopts symmetric boundary conditions to establish a physical model of the original machining workshop.

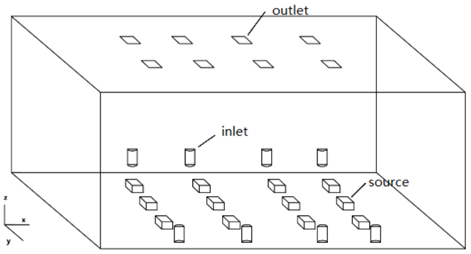


Fig.1 machining plants model

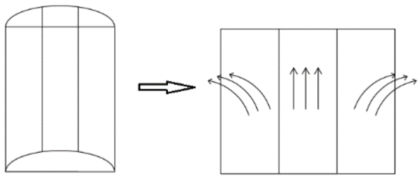


Fig.2 inlet simplify model

2.2 Numerical calculation method

In this paper, ICEM software is used to draw structured meshes and standard$K-\varepsilon$ equation turbulence model is adopted.The standard wall function method is adopted for the near wall area of the model.The second-order upwind scheme was used to discretize the equation, and the SIMPLEC algorithm was used to solve the discrete equation.The average concentration of 2m working surface is monitored, and the average concentration of 2m working surface is considered as convergence when it reaches stability.

2.3 working conditions

This paper studies the air distribution patterns of different air supply angles at different air supply ports at different heights in industrial buildings, and explores their influence on indoor particle pollutants.When the bottom height of the air supply port is 0.5m, 1m, 1.5m and 3m, the air supply Angle is 0° flat feed, 15° oblique feed, 30° oblique feed, 15° oblique feed and 30° oblique feed.In the simulation, the wall adopts the first type of boundary conditions, and the machine adopts the second type of boundary conditions.

2.4 Model validation

In order to verify the accuracy of the numerical simulation used to calculate the concentration of large space particles, this paper carried out experimental verification in a workshop with a similar size to the model, namely 28m×18m×10m (length × height × width). In the experiment, a single measuring line in the center of the plant was selected to measure the temperature value and the concentration value of particulate matter. In order to facilitate comparison, the experimental results were normalized to the particle concentration. The results measured in the experiment are compared with those obtained by the numerical simulation software, and the verification results are shown in Figure 3.

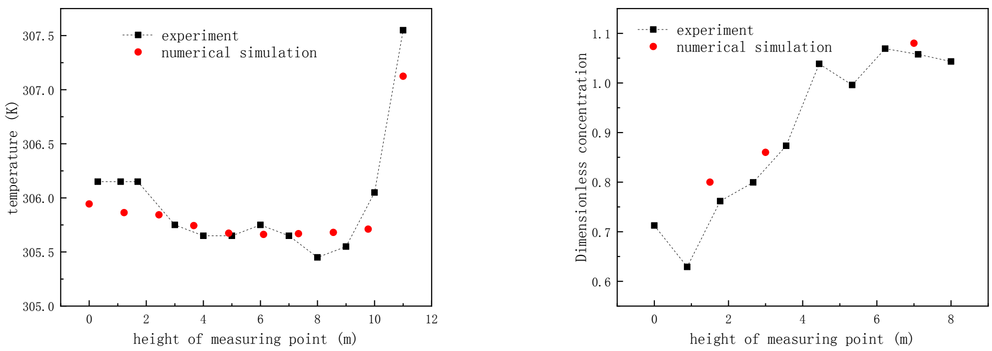


Fig.3 Comparison of simulated and measured at Vertical direction

III. DISCUSS

3.1 inlet at different heights

Firstly, the indoor particle concentration distribution of different tuyere height was simulated numerically. The lower edge heights of the air supply port are respectively. Figure 4 shows the average particle concentration in the working area (below 2m) when the lower edge of the air supply outlet is 0.5m, 1m, 1.5m and 3m. It can be seen from Fig. 4 that the lower edge of tuyere is 1m, 1.5, 0.5m and 3m from the ground in descending order of particle concentration. The concentration of particles in the working area is relatively low when it is 1m away from the ground and 1.5m away from the ground, while the concentration of particles in the working area increases when the position of tuyere rises to 3m. This result is consistent with that of Wang H Q [13], but the difference is that particle concentration in the working area increases slightly when the tuyere position is reduced to 0.5m.

It can be seen from the flow diagram of the section x=5.3m (Fig. 5A). As shown in Fig.5 and 6, when the lower edge of the tuyere is 0.5m, when the tuyere is flat feeding, the supply air will form eddy currents near the machine tool, which will easily produce the aggregation of oil mist particles.

Because the air supply port is too low, the air supply flow can not be sent to the middle part of the plant because of the shelter of the machine tool, resulting in the aggregation of particles in the middle part of the plant. When the air supply height is 1m (Fig. 5b), although some air flow is blocked, the enrolling of air supply at the upper part of the processing equipment brings particles out of the working area, so the concentration of particles in the working area is slightly lower than 0.5m when the air outlet

height is 1m. When the height of the tuyere is 3m (Fig. 5C), there is no shelter from the equipment, the distance of air supply is longer, and the encoiling of air flow can bring particles away from the nearby equipment. However, the heat plume generated by air supply and equipment heating interferes with the height of the air supply port. As a result, particles are mixed in the position below the air supply port, but cannot be brought to a higher position, resulting in higher particle concentration in the working area.
From the above analysis, it can be seen that in the machining workshop, due to the density of equipment, too high or too low air supply height will make the particle concentration in the working area increase.

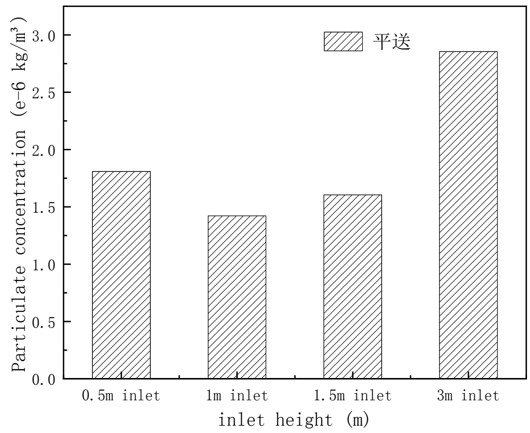
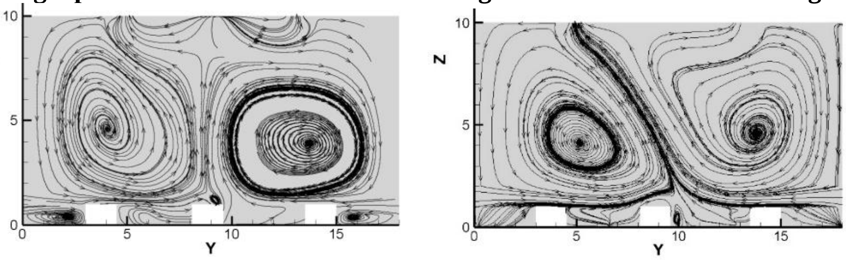
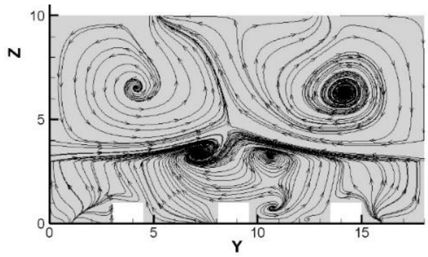


Fig.4 particulate concentration in working area with different inlet heights



a. inlet height 0.5m **b. inlet height 1m**



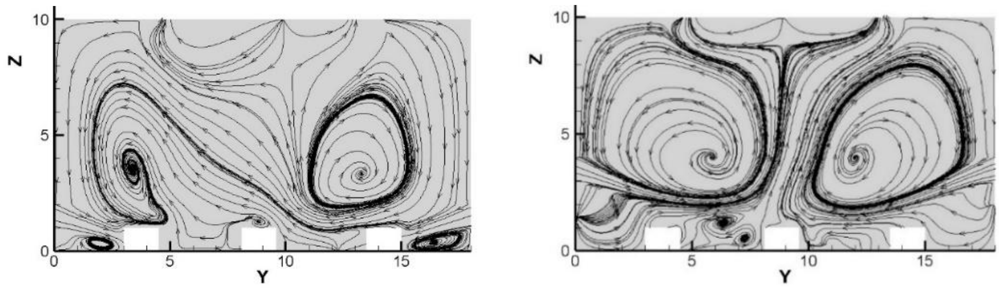
c. inlet height 3m

Fig.5 Flow diagram of flat feed at different air outlet heights

3.2 Downslope feed of different tuyere height
When the air supply mode of the tuyere is flat or up, the working environment of the working area has not been greatly improved. Therefore, this paper continues to study the particle concentration in the working area when the air supply mode of the four tuyere at different heights is slant supply at 15° and slant supply at 30°.

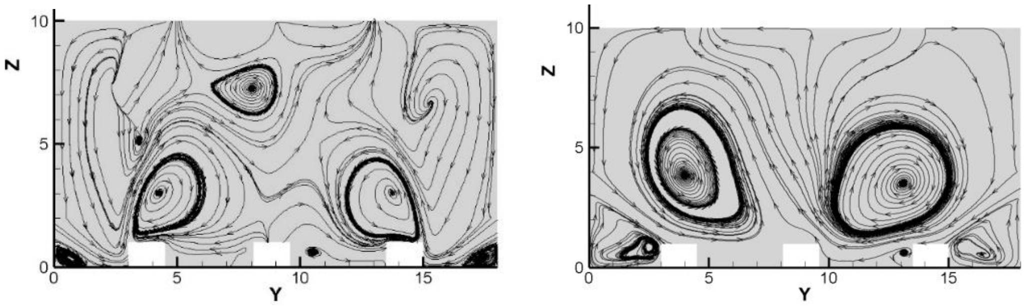
As can be seen from Figure 6, except that the air inlet height is 1m and the particle concentration in the working area is slightly higher than that in the flat air supply at 30°, other conditions are improved.

Fig.6 particulate concentration in working area when inlets of different heights choose downward



a. inlet height 1m **b. inlet height 3m**

Fig.7 spatial contours of streamlines when inlets of different heights choose 15°downward



a. inlet height 1m **b. inlet height 3m**

Fig.8 spatial contours of streamlines when inlets of different heights choose 30°downward

When the air supply height is 0.5-1.5m, the air supply Angle has little influence on the particle concentration in the working area. As can be seen from Fig. 7-8, due to the shielding of the equipment, the air supply cannot reach the middle part of the workshop, and particles still accumulate in this position.

When the air supply height is 3m, the downslope air supply has a long range and can be sent to the middle part of the plant with little interference from the hot plume (Fig. 7, 8). Relative to the upper slope and the flat feed, the particle concentration in the working area is greatly reduced.

The air supply effect of the upper tuyere can be effectively improved and the concentration of particulate matter in the working area can be reduced when the tuyere is downward sloping. In the ventilation design of industrial buildings, if the tuyere needs to be designed in a higher position, the way of downward sloping delivery can be used to provide a healthy working environment for the working area.

IV. CONCLUSION

1.When the tuyere is low, it is easy to be sheltered, resulting in higher particle concentration in the middle part. When the tuyere is high, it is easy to be interfered by the hot plume, resulting in higher particle concentration in the whole working area.

2. Under the oblique air supply, due to the shielding of the equipment, the particle concentration in the middle part of the factory is still high when the height of the tuyere is low. However, when the position of the tuyere is raised to 3m, the air supply can form displacement effect on both sides and the middle part at the same time, greatly reducing the particle concentration in the working area.

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