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Experimental Research on Diffusion Distribution of Oil Mist Particles in Large Space Industrial Workshop

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Abstract
In order to study the diffusion distribution of oil mist particles in tall and large space workshops, according to the relevant research results of oil mist emission characteristics experiments, this paper selects oil mist particles with particle sizes of 0.5 μm, 1.0 μm, 2.5 μm and 5.0 μm in the large space of industrial workshops. The diffusion distribution experiment was carried out, and the dimensionless calculation method was used to study the vertical distribution structure of the oil mist with or without internal heat source of these four typical characteristic particle sizes, and to analyze their influence on the diffusion of oil mist particles. The results show that the thermal plume generated by the machine tool heat source can significantly improve the upward transport and diffusion of oil mist particles..

Keywords: *Oil mist particles;heat source;vertical distribution*

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I. INTRODUCTION

In the modern machining process, the metal processing industry is often used to achieve the purpose of lubrication and rust prevention. It can form a large number of oil mist particles through evaporative condensation and mechanical atomization [1, 2], causing obvious oil mist diffusion in industrial workshops, which not only seriously pollutes the production environment, but also easily causes respiratory diseases in the human body [3].

Since most of the mechanical workshops belong to tall spaces, the distribution of oil mist particles is very uneven. How to use airflow organization to control the concentration in the working area is very meaningful..

Dasch et al. [4] found that the oil mist particle size increases with the increase of the viscosity of the metalworking fluid; when the oil mist diffuses into the air environment, the moisture in the oil mist evaporates rapidly, and the non-water part of the oil mist still floats in the air.

When Li Qidong [5] studied the characteristics and influencing factors of oil mist emission in cutting processing, he concluded that under the evaporative condensation mechanism, the particle size of oil mist emitted in the workshop is mainly distributed below 2.5 μm. The typical characteristic particle size is mainly fine particles of 0.5μm and 1.3μm; while under the mechanism of mechanical atomization, the oil mist particle size is mainly distributed above 2.5μm.

Ma Hongliang et al[6] conducted a theoretical analysis on the generation mechanism of oil mist particles, and found through experimental research that the average particle size of oil mist particles decreases with the increase of the mass concentration of oil mist particles.

Jurelionis[7]'s research mainly showed that the ventilation form has a significant effect on the distribution of particulate matter concentration, and analyzed the indoor particulate matter diffusion under two forms of displacement ventilation and mixed ventilation.

1.1 Experimental site

The experimental selection of oil mist particle diffusion distribution was carried out in the indoor thermal environment experimental base of large space building of Shanghai University of Science and Technology. The experimental base covers an area of 650m^2 (36m×18m), as shown in Figure 1.

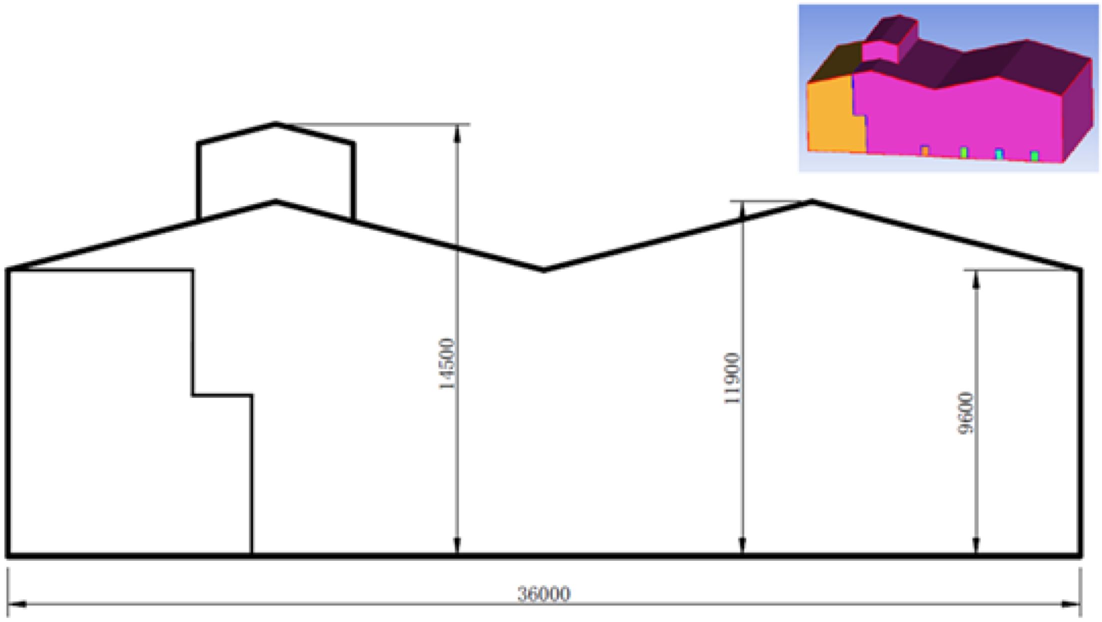
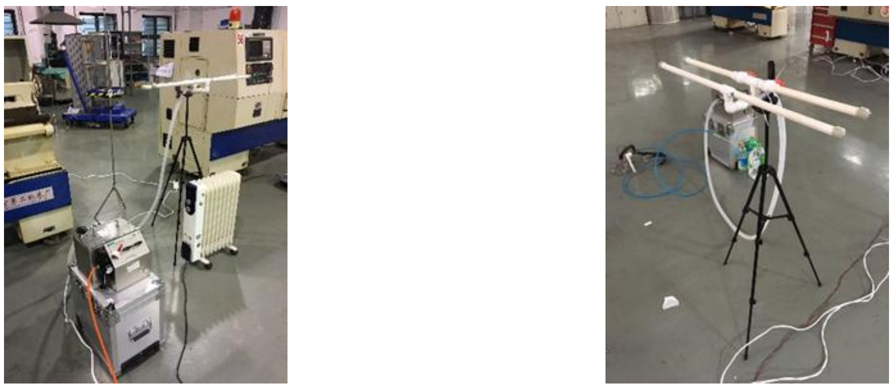


Figure1Outline dimension drawing of indoor thermal environment experimental base of large space building

1.2Experimental equipment and instruments

In the experiment, a set of oil mist generation device is assembled by itself, which can continuously and stably generate oil mist into a large space, simulating the dust generation process of machine tools in actual large-scale industrial plants to the greatest extent.

The oil mist generating device is shown in Figure 2, which includes: 1) an American ATI aerosol generator (TDA-4B), so that the aerosol oil is broken up into oil mist particles with different particle sizes and sprayed 2) A self-designed parallel smoke row with circular holes of varying diameters on it, erected on the side rod of the tripod, with a height of 1.5m, connected to the aerosol generator by a rubber hose 3) One set A heat sink with a power of 1.6kW, placed directly under the smoke exhaust, is used to simulate the high temperature hot air flow of the machine tool.



(a)Assembly diagram (b)Schematic diagram of smoke exhaust

Figure2: Schematic diagram of oil mist generating device

1.3 Experimental method and arrangement of measuring points

The dust source of this experiment adopts the method of continuous point dust source, and uses an aerosol generating device to simulate the generation of oil mist particles in machine tools. Under a certain air distribution condition, aerosol particles are continuously emitted to the large space environment. After sufficient diffusion, the aerosol concentration at a certain point in the space will remain constant (ignoring the interference of other external factors). At this time, the particle counter is used to measure the mass concentration and number concentration of the measuring points at different horizontal positions and different vertical heights, so as to analyze the law of the movement and diffusion of oil mist particles in space with different airflow organizations. In order to truly reflect the motion state of oil mist particles with airflow, the number of discrete points should be increased as much as possible. The layout of the specific experimental measurement points is shown in Figure 3:

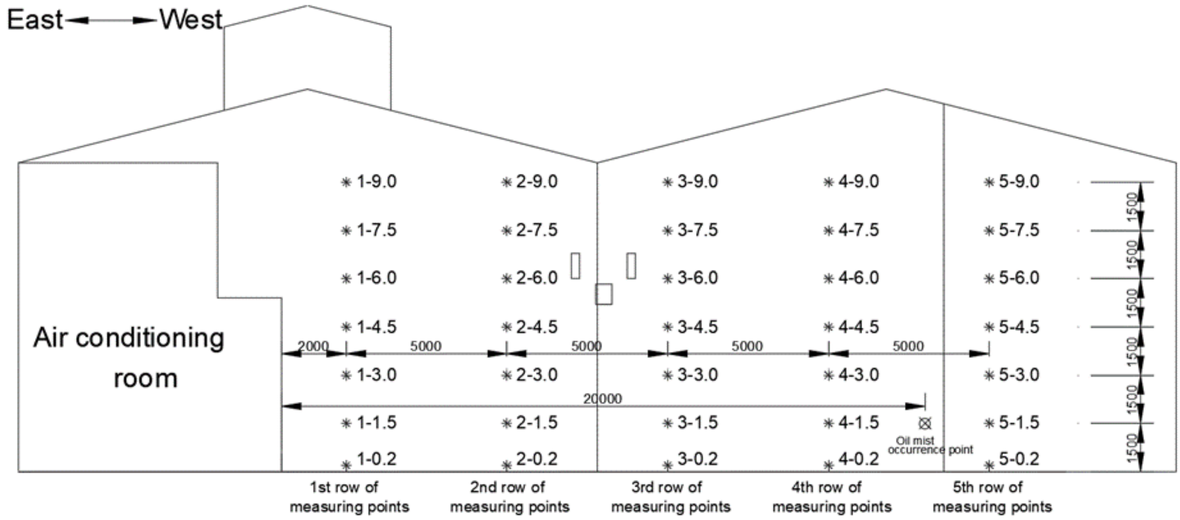


Figure3: Measuring point layout diagram

A total of 5 rows of measuring points are set up in the east-west direction, and the horizontal distances are 2m, 7m, 12m, 17m and 22m. There are 7 measuring points respectively arranged on the vertical height of the five rows of measuring points, 0.2m, 1.5m, 3m, 4.5m, 6m, 7.5m and 9m from the ground from bottom to top, a total of 35 measuring points. Install the particle counter on the elevator, move the elevator to each row of horizontal measurement points, and then test the oil mist concentration value of the 7 vertical measurement points on the row from low to high. The sampling time of each measurement point is 1min , until a total of 35 measuring points in 5 rows have been tested. The position of the oil mist generation point is set at a distance of 20m from the air-conditioning room, and the vertical height is 1.5m, which is consistent with the oil mist emission height of the actual machine tool equipment.

1.4 Experimental steps

In this study on the diffusion of oil mist particles in the large space of industrial plants, the heat source factors were analyzed to analyze their influence on the diffusion of oil mist particles.

The experimental steps are briefly described as follows:

1) Turn on the air-conditioning unit, and other parameters on the control panel of the air-conditioning unit remain unchanged under each working condition.

2) After the air supply is turned on, the ambient particle concentration in the large space begins to gradually decrease, and the aerosol display concentration of the particle counter is monitored in real time until the particle concentration in the large space is reduced to a minimum, and it is used as the background ambient concentration. Reduce the effect of background concentration on the measured oil mist concentration.

3) Turn on the oil mist generator and heat sink.

4) During the formal test, move the elevator to each row of horizontal measurement points, and then test the oil mist concentration values of the 7 vertical measurement points on the row from low to high.

5) Turn off the oil mist generating device and the heat sink to end the test work. In order to avoid the influence of the oil mist concentration emitted by this working condition on the next working condition, only one working condition is tested every day.

1.5 Spatial dimensionless concentration

In order to better reflect the diffusion distribution of oil mist particles in a large space, the data processing of this experiment has made dimensionless processing on the vertical height of the measuring point and the concentration of oil mist particles

The dimensionless height is expressed as h/H, which refers to the ratio of a certain vertical height position to the total height of the building.

The dimensionless concentration is expressed by the following formula :

$$C_w(x,y,z) = \frac{C-C_0}{C_{max}-C_0} \quad (1)$$

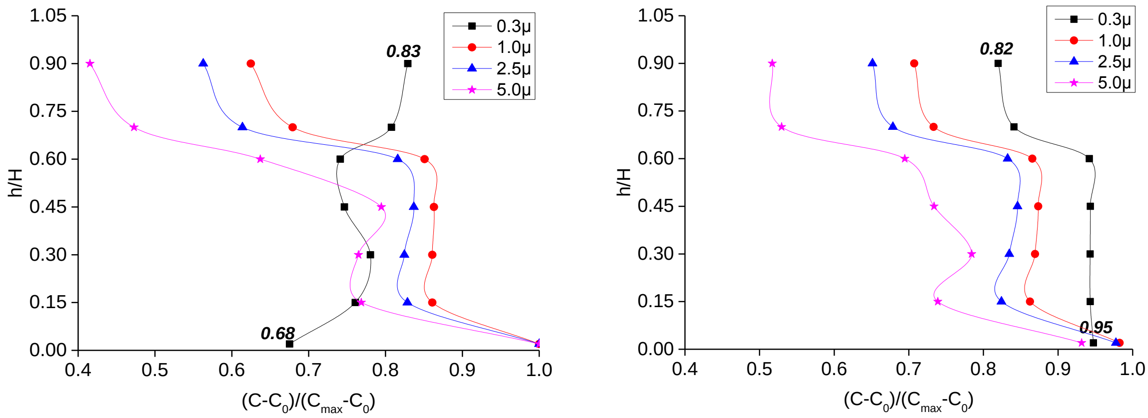
$C_w(x, y, z)$ is dimensionless concentration; C is actual concentration at a point; C_{max} isbackground concentration;C_0ismaximum concentration in space.

According to the definition, the dimensionless concentration of any point in space is a function of its spatial position, which can also be understood as the concentration distribution coefficient, and its size can intuitively reflect the concentration structure at the vertical height. Moreover, the reason why the reference standard of the dimensionless concentration at a certain point is the spatial maximum concentration is because this method is convenient for normalization processing, that is, the calculated maximum dimensionless concentration is 1, and the minimum dimensionless concentration is 0. Any value between 0 and 1 can uniquely and accurately reflect the concentration field at the location of the measuring point.

II. RESULT AND DISCUSSION

In the actual factory, the machining process will be accompanied by the generation of high-temperature airflow, resulting in uneven thermal pressure and density of the space, thereby changing the force and movement trajectory of the oil mist particles. The diffusion of oil mist particles in a large space is not simply flowing with the air flow in the space, but the coupling effect of the heat source and the air flow, and its flow is more complex and closer to reality. Therefore, it is necessary to study the influence of internal heat sources on the transport capacity and distribution characteristics of oil mist particles.

This paper studies the influence of a single heat source on the diffusion of oil mist particles, and maintains a fully enclosed state of the large space in the experiment to avoid the influence of infiltrating wind and people walking. The single heat source here is the heat sink placed directly under the oil mist generating device, with a power of 1.6kW. It relies on radiant heat to generate a thermal plume around the oil mist generating device to drive the oil mist particles to move. Figures 4(a) and (b) respectively show the vertical distribution of the oil mist concentration of each typical particle size with the building height when there is no internal heat source and when there is an internal heat source, and the concentration values are dimensionless.



(a) No internal heat source (b) There is an internal heat source

Figure4:Vertical distribution of oil mist concentration of each typical particle size without heat source and internal heat source

Figure 4(a) is actually the free diffusion of oil mist particles without power. After the oil mist particles are emitted, they are not affected by any airflow and heat source, and only move in a large space by their own gravity and Brownian force. It can be seen from the figure 4(a) that the distribution of the oil mist concentration with a particle size above 1.0u on the vertical height generally shows a decreasing trend with the height. The concentration is basically uniform in the range of space height of 1.5~6.0m. In the space above 6.0m, the concentration of oil mist decreases rapidly, and the oil mist with larger particle size decays faster with height. In contrast, for an oil mist concentration of 0.3u, the overall trend increases with height, from 0.68 near the ground to 0.83 at the highest point. On the whole, the oil mist particles are concentrated in the range of 1.5~6.0m in the large space, indicating that no matter the oil mist with large particle size or small particle size, it can "float" at a height of about 6m by natural convection. The 0.3u oil mist has a very small particle size, and the Brownian effect between molecules is more obvious, so it can "float" in a higher space of about 9m over time.

Figure 4(b) shows the vertical distribution structure of oil mist particles under the action of an internal heat source. It can be seen that the trend of the concentration of oil mist with a particle size above 1.0u changing with height is basically unchanged, and only the vertical distribution of oil mist with a particle size of 0.3u changes significantly. Compared with other particle sizes, the oil mist concentration of 0.3u reaches the highest at all vertical heights. Especially at the vertical height below 6.0m, the dimensionless concentration value of 0.3u oil mist reaches about 0.95, which is a serious threat to the respiratory disease of the operators in the work area. In addition, sinceFigure 4 (a) and (b) the abscissa and ordinate of the two figures are the same. It can be seen that when there is an internal heat source, the oil mist concentration of each particle size is higher than that of the same height without the heat source, resulting in an increase in the average concentration of oil mist in the upper space. This shows that under the influence of the heat source, the air convection is enhanced, and the oil mist particles will be affected by the thermophoretic force, pushing the oil mist particles to diffuse to higher spaces. It can therefore be concluded that the mechanically processed hot air flow in the factory significantly improves the transport capacity of oil mist particles.

III. CONCLUSION

When there is an internal heat source in a large space, the vertical distribution structure of oil mist with a particle size above 1.0u is basically unchanged, and only the diffusion concentration of oil mist with a particle size of 0.3u below 6.0m increases significantly. At the same time, the buoyancy force of the oil mist particles increases, and the concentration of each particle size segment is higher than that at the same height without a heat source, resulting in an increase in the average concentration of oil mist in the upper space. It shows that the mechanical processing hot air flow in the factory has an enhanced effect on the transmission capacity of oil mist particles.

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