Simulation of Optimized Air Supply for Air Conditioning Systems in Large Spaces

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Abstract. Simulate and compare the air distribution when the air outlets on both sides of the stratified air-conditioning are arranged on the same horizontal plane and the air outlets on both sides are arranged at different levels to study the distribution law of temperature and velocity fields in the workshop. The simulation results show that under the same air supply conditions, when the air outlets on both sides are arranged at different levels, the air velocity in the workshop is lower and the velocity field distribution is more uniform. The temperature distribution effect of the two in the workshop is almost the same.

1. introduction

For process production, some workshops are large workshops, and radioactive aerosols will inevitably be produced during the process production [1]. To ensure the safety of the surrounding environment, it is required to maintain a negative pressure in the workshop [2]. According to the "Energy Conservation Design Standard for Public Buildings" [3], "When the height of the building space is greater than or equal to 10m and the volume is greater than 10000m\textsuperscript{3}, it is advisable to use a layered air conditioning system", so the design of the workshop uses layered air conditioning technology. Using CFD for simulation [4-5], the air supply method is optimized and compared to improve the environment of the staff work area. The location of the plant is close to the river, and the river can be considered as a natural cooling source [6], to appropriately reduce the operating cost of the air conditioning system.

2. Simulation approach

The size of a workshop building (length × width × height) is 42m×16m×18m, and the design temperature of the air conditioner is 26°C, mainly considering the cooling situation in summer. The total air volume designed in the production workshop is 6.8×10\textsuperscript{4} m\textsuperscript{3}/h, the size of the air outlet is 0.3m×0.3m, and it is arranged at a distance of 7m from the ground, the distance between the air outlets is 2.1m, and there are 30 air outlets. The wind speed is 7.03m/s; the air outlets are arranged at 0.3m from the ground on both sides, the size is 0.9m×0.6m, the spacing is 3.9m, and there are 8 on each side. Using numerical simulation to study the air distribution when the air outlets on both sides of the air conditioning system are arranged on the same horizontal plane [7-8] and the air outlets on both sides are not at the same level.

According to the design plan, a 1:1 model of the workshop is established. The production line in the workshop is a high-temperature heat source, which is closely arranged. For the convenience of modeling and calculation, the heat source is simplified into two cubes of 7.5m×3m×10m. Each calorific value is 132KW. The simplified model of the design is shown in Figure 1, part of the section is selected for research. The air supply mode in which the air outlets on both sides of the air conditioning system are
arranged at the same horizontal plane is set as case 1, and the air supply mode in which the air outlets on both sides are arranged at different levels is set as case 2.

Case 2 will keep the air outlet on one side unchanged at 7m from the ground, and reduce the horizontal height of the air outlet on the other side by 1m, and set it at 6m from the ground, so that the height of the air outlet on both sides maintains a certain level difference.

3. Results and discussions

3.1 Simulation results of case 1

Four parts are selected to analyze the distribution law of the flow field under this air supply mode. The four parts are: part 1, X=28.20m, focusing on the collision of the supply air jet; part 2, Z =1.50m, focusing on the temperature and velocity field of the researcher’s working height; part 3, Y=10.50m, to study the effect of heat source on indoor air distribution.

Figures 2 and 3 show that the average temperature of the workshop work is 27℃ and the wind speed is 0.2m/s; due to the influence of the air supply jet, there is a clear layering phenomenon in the vertical direction, and the two air supply jets are in the same At the horizontal level, a collision occurs at the end of the jet, and a part of the cold wind enters the non-air-conditioned area, so that the cooling capacity carried by this part of the air-jet jet exchanges heat in the non-air-conditioned area, making the middle temperature of the non-air-conditioned area lower.

Part 2 is located 1.5m from the ground, which is the height of the breathing surface and the head of the workers in the workshop. It can be seen from Figure 4 that the temperature distribution on the section...
is relatively uniform. The temperature is around 27°C far away from the heat source, and the temperature is higher near the heat source. The temperature near the two ends of the workshop is higher than the temperature in the middle of the workshop, mainly because part of the heat flow at the two ends of the workshop flows along the wall, which drives the surrounding air and makes the temperature higher. It can be seen from Figure 5 that at the working height of the personnel, the air velocity is mostly below 0.5m/s, which will not produce a strong blowing sensation to the personnel. At the same time, due to the collision of the air supply jet ends, the air velocity in some areas of the air-conditioned area Higher.

It can be seen from Figures 6 and 7 that the temperature stratification effect is more obvious in the vertical direction. Under the blockage of the heat source, the temperature of the air-conditioning area on the side with more air outlets is lower than that on the side with fewer air outlets. Under the influence of the heat source, a heat flow zone is formed above it. As the air supply jet collides at the end, a part of the cold air jet enters the non-air-conditioned area, which reduces the temperature and lowers the energy utilization rate. Moreover, the effect of thermal buoyancy above the heat source is very small; under the collision of the jet end, a part of the non-air-conditioned area flows and heat exchange occurs.

3.2 Simulation results of case 2

Combining the above simulation situation, select the same four parts as in case 1 to compare the distribution law of the flow field under this air supply mode. Select: part 1, vertical section at X=28.20m; part 2, Z =1.50m horizontal section; part 3, vertical section at Y=10.50m.

It can be seen in Figures 8 and 9 that there is also obvious stratification in the vertical direction. In the non-air-conditioned area, the higher temperature air is in the middle part, and the outer wall side temperature is lower than that in the middle part. The reason can be seen from the picture. Since the air supply ports on both sides are set at different levels, the ends of the air supply jets did not collide, and only a small part of them entered the non-air-conditioned area; The effect of the blowing jet is in the recirculation zone, and the higher temperature air is concentrated in the middle. The hot air on the outer wall side is induced by the blowing jet to exchange heat with it, resulting in lower temperature.
In Figures 10 and 11, the temperature change is more obvious near the heat source, and there is a phenomenon of heat flow retention between the two heat sources. The overall flow velocity in the work area of the workshop is also lower than 0.5 m/s, and the air supply velocity in the workshop is relatively uniform. Compared with the situation where the air supply outlet is at the same height, the air velocity in the work area is smaller. There are air outlets at 0.3 m from the ground on the two outer walls, which makes the flow velocity higher at the adjoining wall, and air outlet has a certain influence on the airflow against the wall.

In Figures 12 and 13, there is obvious stratification in the vertical direction of the workshop, and a thermal buoyancy flow area is formed above the heat source. By reducing the collision strength of the air supply jet end, the air supply jet entering the non-air-conditioned area is reduced. Therefore, most of the cooling capacity is mainly used for cooling of air-conditioning areas and equipment. The velocity flow field in the working area of the personnel is affected by the superimposition of the various supply air jets, and moves to the two ends of the workshop under the influence of the superposition of the airflow to improve the environment of the entire working area.

### 3.3 Temperature and Velocity Comparisons

Compare the temperature field and velocity field of the personnel working area to verify the rationality of the air-conditioning design. Pick points 1.5 m away from the ground in the workshop. The diagram of the points is shown in the Figure 14. The comparison results are shown in Figure 15 and Figure 16.
It can be seen from Figure 15 that the air-conditioning area is divided into two areas due to the location of the heat source blocking the supply air jet. On the side with fewer air supply openings, the cooling effect of the workshop personnel working area is poor. By comparing the points taken in the personnel working area, the temperature distribution in the area is within 1 °C between the two air supply schemes. It can be considered that the temperature field distribution of the two at 1.5m in the workshop personnel working area is basically the same.

It can be seen from Figure 16 that the wind speed at the pick-up point in the workshop is below 0.5m/s, but in the velocity flow field of the personnel working area in Case 1, the air velocity in some areas is higher than 0.5m/s mainly due to After the blower jet collides at the end, the flow rate of the part flowing into the air-conditioned area is still high, which does not meet the wind speed requirement. Through the comparison of the two cases, it is found that the air velocity at 1.5m of the personnel working area is lower in case two than case one. According to the velocity flow field diagram in the working area, it can be seen that the air velocity change in most areas is almost within 0.1m/s, and the flow field is relatively stable.

4. Conclusions
Mainly by changing the height difference of the supply air, reducing the collision of the supply air jet, achieving the purpose of reducing the heat transfer load of the air conditioning system, and improving the working environment of the personnel.

The two air supply methods can achieve the same effect on the temperature control of the personnel working area, the temperature fluctuates at 1 °C; however, for the distribution of the air flow rate in the working area, the effect of the case 2 is better than that of the case 1. The flow velocity of the case 1 in some areas is higher than the wind speed requirement. It can be considered that the air flow uniformity of the latter is better than the former.

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