Simulation and experimental study of air flow organization in a laboratory

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Abstract. Taking the air flow organization laboratory of a university in Dezhou City as an example, airpak simulation software was used to study the effect of three air supply modes (side up and down, top down and down) selected by the laboratory under typical summer conditions for simulation analysis and evaluation, and the change rules of its internal velocity field and temperature field were obtained, and compared with the experimental results. Finally, under the same conditions, side air supply is the most reasonable way.

Keywords: airpak software;airflow organization;Indoor environment

1 Introduction

The quality of indoor environment is related to everyone's life quality and physical and mental health, especially for the elderly and children who live indoors for a long time, there are different degrees of "sick building syndrome"[1]. Comfortable indoor environment is not only beneficial to people's physical and mental health, but also can improve the efficiency of staff[2]. In order to make the indoor environment meet the requirements of thermal comfort, it is necessary to reasonably control the air temperature and air flow speed of the indoor environment, and different air flow organization forms will make great differences in the indoor environment, so it is crucial to choose the right air flow organization form[3]. For the research of indoor thermal environment and air quality, Airpak software is a more widely used tool.

Xu Tongtong[4] used Airpak software to numerically simulate the indoor thermal environment of a small conference room in summer under three air distribution forms (same side air supply and exhaust, different side air supply and exhaust, and displacement ventilation), obtained the distribution of indoor temperature, speed, PMV value and PPD value under different air distribution forms, and compared and analyzed the thermal comfort of personnel with different air distribution. The results show that the displacement ventilation can satisfy the thermal comfort level higher, and the indoor airflow velocity fluctuation is small, which can better meet the thermal comfort requirements of human body, and is an ideal airflow organization form. Zhang Zhi[5] calculated the winter heat load based on the location and building information of a rural bedroom, and used Airpak software to simulate the indoor ambient

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temperature field, velocity field and PMV-PPD values under two installation positions of air conditioners. The results show that under air supply mode 2, there are better indoor wind speed and temperature distribution, higher PMV-PPD value, and better airflow organization, which can effectively ensure the fresh air in the working area. Rong Chuanliang[6] took a postgraduate studio in Jinan City as the research object, used Airpak software to conduct simulation analysis, and analyzed the temperature field, velocity field, pressure field, air age and PMV-PPD to meet the requirements of thermal comfort. Chiang[7] conducted experimental tests and CFD simulation verification for the radiant roof plus fresh air system. By analyzing the indoor temperature field and PMV results, the author concluded that when the supply air temperature was increased from 18°C to 24°C, the energy saving of the chiller was 13.2% compared with the original, and the energy consumption of the whole system was reduced by 8%.

Taking the air flow organization laboratory of a university in Dezhou as the research object, this paper uses Airpak software to simulate and study the effects of different air supply forms on indoor temperature field and velocity field, and compares and analyzes the results, thus providing reference and theoretical basis for selecting reasonable air supply forms for small indoor environments.

2 Establish physical model and design scheme

2.1 Building model building

The simulation object was selected as an indoor laboratory. Basic engineering information is as follows:

The laboratory is rectangular, 6 meters long, 4 meters wide and 2.6 meters high. The laboratory is located in a room regardless of solar heat through the glass window, and there is no other heat source in the laboratory by default. The geometric model of the laboratory was built with Airpak software.

2.2 Basic design parameter

Design parameters are as follows:

Summer: outdoor average temperature 24°C; Relative humidity 60%; Inlet fresh air temperature 20°C; Air supply speed 1m/s.

3 Simulation result analysis

3.1 Three air flow organization schemes

In this study, three air flow organization schemes are selected, as follows:

1.Supply air from Over side and return air from below;

2.Supply air from above and return air from below;

3.Supply air from below and return air from above.

The relevant parameters of the return tuyere are shown in Table 1. The discharge direction of the air supply outlet is perpendicular to the direction of the air supply outlet, and the negative sign in the table indicates the opposite direction of the air supply.

Table 1. Return tuyere related parameters

parameter	Side up and back down	up supply and down return	down supply and up return
Number of air supply ports	2	3	4
Size of the air supply port	0.5m×0.2m	0.3m×0.3m	0.7m×0.5m
Number of return air outlets	2	2	1
Dimensions of the return air outlet	0.7m×0.5m;0.7×0.2 m	0.7m×0.2m	0.5m×0.2m

3.2 Results and analysis

Supply air from Over side and return air from below

According to the temperature cloud map (FIG. 1 and 2), the temperature on the air supply side drops significantly, forming a temperature gradient. The temperature difference between y = 1.3m (when people sit) and y = 1.7m (when people stand) is less than 1°C, that is, the human body will not feel the obvious uneven distribution of hot and cold. In the yz plane, there is a certain temperature stratification in the vertical direction, but the temperature difference between different stratification is small.

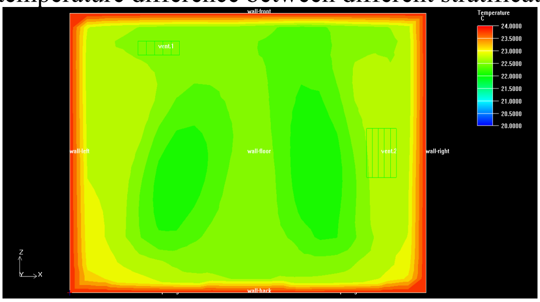

Fig. 1. Temperature cloud map (y = 1.3m)

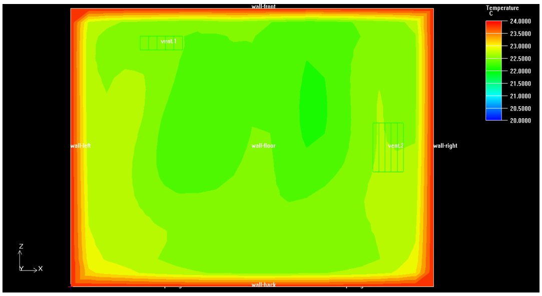

Fig. 2. Temperature cloud map (y = 1.7m)

From the velocity cloud map (FIG. 3 and 4), it can be seen that after fresh air enters the room through the air supply outlet, under the influence of floating lift, the wind speed weakens rapidly, and coupled with the suction of the wall and the ventilation hole, two symmetrical cyclones are formed. The wind speed at the center of symmetry is larger, which is caused by the arrangement of tuyere and the attenuation of velocity, so on the same plane, it can be better mixed together to achieve better absorption, release and exhaust of polluted air in the laboratory, and is conducive to the formation of a reasonable temperature distribution[8]. Under the action of floating lift, the fresh air sent into the ground to spread, which is similar to the "sticking jet" phenomenon in jet science, and thus trigger the surrounding air flow, making the air flow slowly upward. From y= 1.3m (people's breathing area when sitting) and y= 1.7m (people's breathing area when standing), it can be seen that the flow of air in the whole space is very uniform.

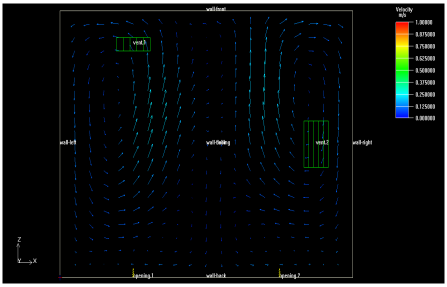

Fig. 3. velocity cloud image (y = 1.3m)

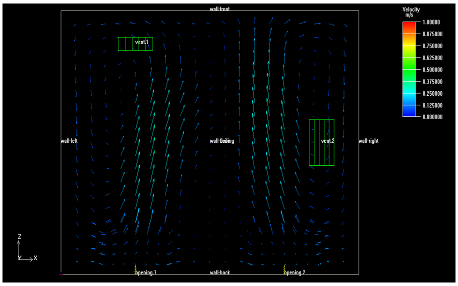

Fig. 4. velocity cloud image (y = 1.7m)

Supply air from above and return air from below

According to the temperature cloud map (FIG. 5, 6), the temperature distribution in the whole laboratory is relatively stable, and stratification phenomenon appears, and the temperature is relatively comfortable for the entire activity area of the laboratory. When y = 1.3m (when people sit) and y = 1.7m (when people stand) the temperature difference does not exceed 1℃, that is, the human body will not feel the obvious uneven distribution of cold and heat. In the yz plane, the lowest temperature near the air supply outlet is 20℃, and it gradually rises downward to form temperature stratification, but the temperature difference between different layers is small.

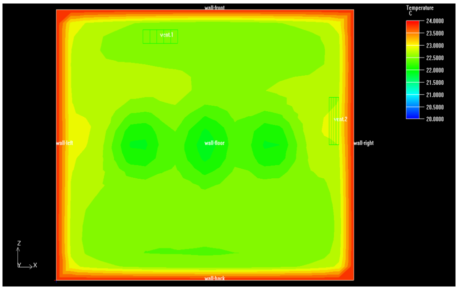

Fig. 5. Temperature cloud map (y = 1.3m)

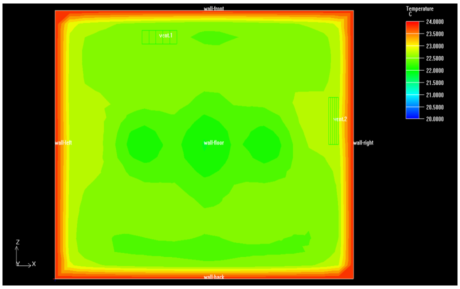

Fig. 6. Temperature cloud map (y = 1.7m)

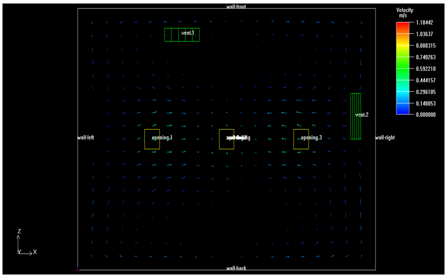

Fig. 7. velocity cloud image (y = 1.3m)

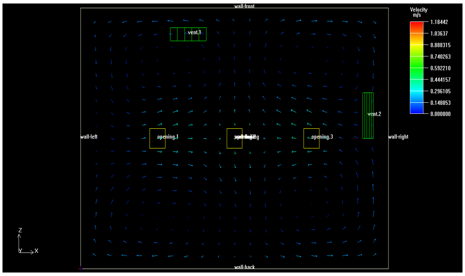

Fig. 8. velocity cloud image (y = 1.7m)

According to the velocity cloud image (FIG. 7 and 8), after fresh air enters the room through the air supply outlet, the wind speed gradually decreases under the action of buoyancy. Due to the enrolling effect of the air flow on the wall and the air supply outlet, the air flow forms two cyclonic movements around the room at y = 1.3m, and at y = 1.7m, the air flow is rotated. The airflow formed four cyclones around the room to rotate; From y= 1.3m (people's breathing area when sitting) and y= 1.7m (people's breathing area when standing), we can see that the flow of air is very uniform throughout the space, thus making the comfort of the whole area better.

Supply air from below and return air from above.

The wind speed is high in most places in the central area of the laboratory, and the personnel feel a little wind. According to the temperature cloud map (FIG. 9 and 10), when the air supply speed is 1m/s, there are four temperature lows (about 20°C) along the four corners of the laboratory, and the temperature starts to rise from the four corners to the interior of the laboratory. The temperature of the same horizontal plane in the laboratory is relatively uniform, and the air supply outlet is located on the lower side, which will make the lower part of the laboratory low temperature, and the temperature above is relatively high. The upper part belongs to the non-human activity area, and its temperature change has little influence on human thermal comfort. For the personnel activity area in the laboratory, the overall temperature difference does not exceed 3°C, and the vertical temperature difference can meet the requirements of human thermal comfort. When y = 1.3m (when people sit) and y = 1.7m (when people stand) the temperature difference does not exceed 1°C, that is, the human body will not feel the obvious uneven distribution of cold and heat. In the yz plane, the lowest temperature near the exhaust air outlet is 21°C, and it gradually rises downward to form temperature stratification, but the temperature difference between different layers is small.

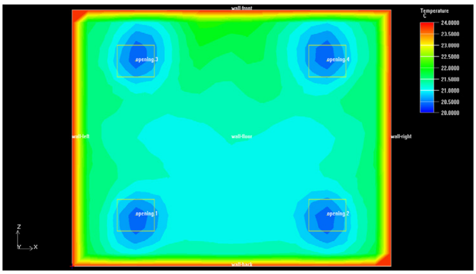

Fig. 9. Temperature cloud map (y = 1.3m)

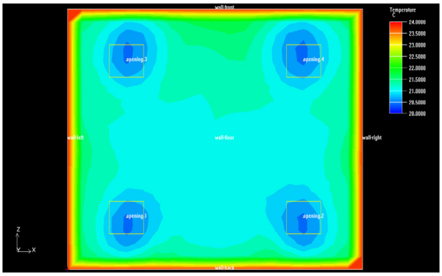

Fig. 10. Temperature cloud map (y = 1.7m)

According to the velocity cloud image (FIG. 11 and 12), after fresh air enters the room through the air supply outlet, the wind speed quickly attenuates under the action of floating lift, and is subjected to the enrolling action of the wall and the air supply outlet. At y = 1.3m, the air flow forms four cyclons around the room and moves upward. At y = 1.7m, the air flow forms two cyclones above and below the room and moves up and down. The air flow velocity at the middle symmetry is weaker than the air flow velocity around the wall, mainly because of the location of the tuyere and the attenuation of wind speed. Therefore, in the laboratory, the same plane can be better mixed to achieve better absorption, release and expulsion of polluted air in the laboratory, and is conducive to the formation of a reasonable temperature distribution. From y= 1.3m (people's breathing area when sitting) and y= 1.7m (people's breathing area when standing), we can see that the flow of air is very uniform throughout the space, making the comfort of the whole area better.

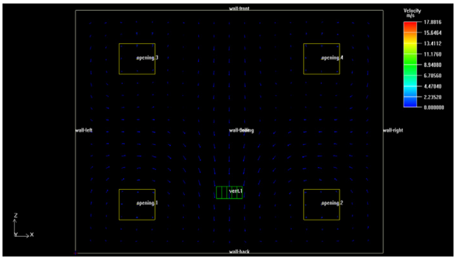

Fig. 11. velocity cloud image (y = 1.3m)

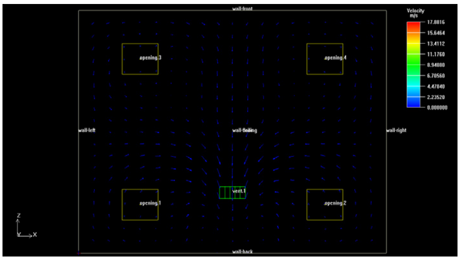

Fig. 12. velocity cloud image (y = 1.7m)

4 Analysis of experimental results

4.1 Experimental equipment

The comprehensive experimental device is mainly composed of air flow organization test chamber, air processing equipment, pipeline transmission and distribution system, parameter measurement and acquisition system[9]. The air handling equipment realizes the control and adjustment of the air supply parameters (temperature, humidity and air volume) in the test chamber by a heat pump type air conditioner, and the parameter measurement and acquisition system is used to measure the temperature, humidity, flow rate (flow rate) and pressure parameters at the setting point in the room. The physical diagram of its laboratory is shown in Figure 13:

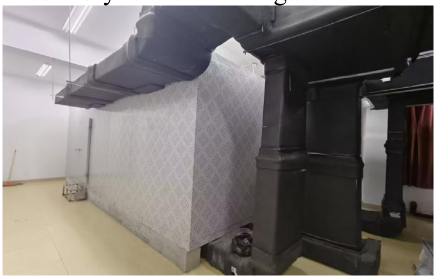

Fig. 13. Physical picture of the laboratory

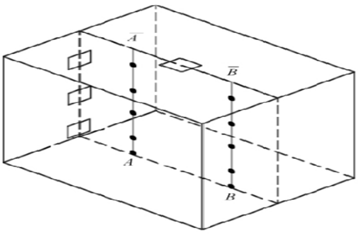

Fig. 14. Temperature measurement points

4.2 Experimental result

In this experiment, two temperature measurement points (A and B) were selected, as shown in Figure 14, and the parameter measurement and acquisition system was used for measurement, as shown in Figure 15 and Figure 16:

As can be seen from FIG. 15 and 16, when the temperature at A is the lowest at the same height (such as 1.5m), it is generated under the downward feeding mode. When the temperature at place B is the lowest, it is generated under the top air supply mode and is mainly affected by the tuyere arrangement[10]. By comparing the temperature variation with height of the three air supply modes at A and B, it can be found that the temperature gradient of the side air supply mode is more stable than that of the top and bottom air supply mode, and the temperature difference between the five selected temperature measurement points does not exceed 1°C. The temperature values at A or B at different heights can be read through the temperature cloud map, which is basically consistent with the measured results.

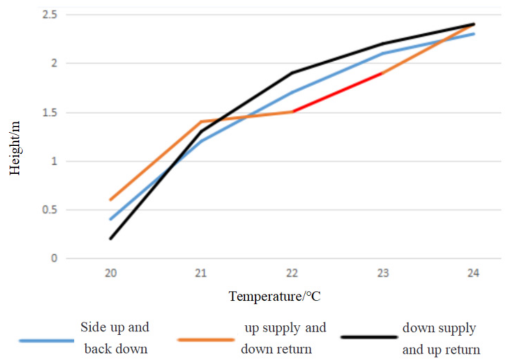

Fig. 15. Temperature change at place A

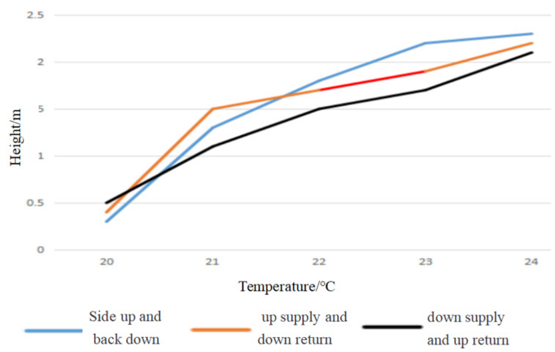

Fig. 16. Temperature change at place B

5 Conclusions

In this study, airpak software was used to conduct simulation analysis and experimental research on the indoor air distribution of three different air supply modes in a laboratory. The results showed that under the same air supply temperature and air supply speed, the temperature field and velocity field in the laboratory under different air supply modes changed greatly, and the lower and upper air supply were in areas other than the ground heat source. A relatively significant temperature gradient and velocity gradient are formed, while the side-down delivery and return are not significant, so it is concluded that the side-down delivery and return air supply mode is more comfortable. In addition, the accuracy of the simulated data can be verified from the side through experimental research.

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