Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 4, No. 3, 2022

Research on New Air Supply Mode of Fan-coil Unit Based on CFD

Meng Li[1, *]

[1]Chongqing Vocational Institute of Safety & Technology, Chongqing, 404000, China
*** Corresponding author email**: limeng1568@126.com

Abstract: Fan coil unit air supply is one of the main air supply modes of air conditioning. The fan coil unit system generally adopts the air distribution form of upward supply and upward return on the same side. In this work, a static pressure box is added at the outlet of the fan coil, and a deflector with separate control direction is set at the outlet of the static pressure box. In summer, the combination of up-side air supply and up-attached down-flow air supply is adopted to adjust the deflector to control the distribution of cold air and keep the overall indoor temperature distribution consistent. In winter, the air supply outlet is transferred to the lower part of the fan coil, and the hot air is directly sent to the personnel activity area at the lower part of the room by the adhesive effect of the jet, effectively solving the indoor air stratification phenomenon in winter.

Keywords: Fan coil unit, Air distribution form, Attached and sent down, CFD simulation.

1. Introduction

The air distribution directly affects the air conditioning effect of the air-conditioned room, and relates to the temperature and humidity base, accuracy and regional temperature difference of the working area of the room. The air velocity in the working area is an important parameter in the air conditioning design. Effective ventilation and reasonable air distribution are of great significance for improving indoor air quality, controlling the level of indoor air pollutants, and achieving the goal of healthy and comfortable air conditioning. As one of the main air supply modes of air conditioning, fan coil air supply directly affects the use effect of air conditioning. The traditional air supply and return method of upward supply and upward return can achieve good results in rooms with small depth, but when there are many blocking items in the room, the air supply effect in summer can not be fully guaranteed, while when hot air is supplied in winter, due to the obvious air stratification phenomenon, the hot air is not easy to go down, and the temperature in the personnel activity area can not be guaranteed. Based on this situation, this paper starts with changing the air supply mode of fan-coil unit in winter and summer, and selects the combination of winter attached air supply, horizontal attached air supply and vertical attached air supply in summer to change the indoor air flow organization form and improve the indoor air quality.

At present, in HVAC engineering, there are four main methods to predict indoor air flow distribution: jet formula, Zonal mode model, CFD (Computational Fluid Dynamics) method and model experiment method. The jet analysis method can only give some lumped parameter information in the room, and cannot meet the requirements of designers to understand the indoor air distribution in detail. In fact, the result of Zonal model simulation is only a relatively "accurate" lumped result, and there are still many problems in the application of mechanical ventilation. For the simulation and prediction of indoor air flow and fluid flow in other equipment, generally only model experiments or CFD methods are applicable. Although the model experiment can obtain all kinds of data required by designers, it needs a long experimental period and relatively expensive experimental costs, which affects its wide use in engineering design. CFD, with its unique advantages of low cost, fast speed, complete data and being able to simulate various working conditions, is increasingly popular.

In this paper, the CFD method is proposed to simulate and analyze the air velocity field and temperature field distribution in the air-conditioned room under the commonly used side air supply mode, so as to provide a reference for better air flow organization design of side air supply.

2. Change the Air Supply Mode of Fan Coil

In order to realize the function of changing the air distribution described above, a new type of fan-coil unit is specially designed. The traditional fan coil structure is shown in Figure 1. This work has made some improvements on the basis of the existing fan coil. First, the return air is no longer arranged at the lower part of the fan coil. Second, add a static pressure box at the air outlet. The schematic diagram of the static pressure box is shown in Figure 2.

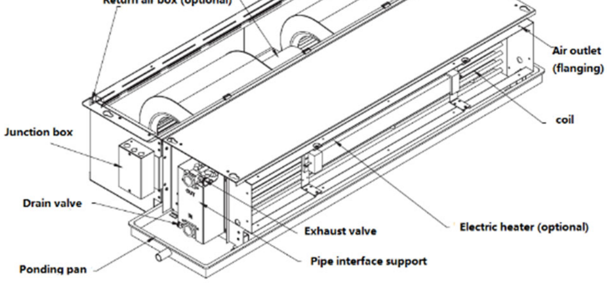


Figure 1. Structure of traditional fan-coil unit

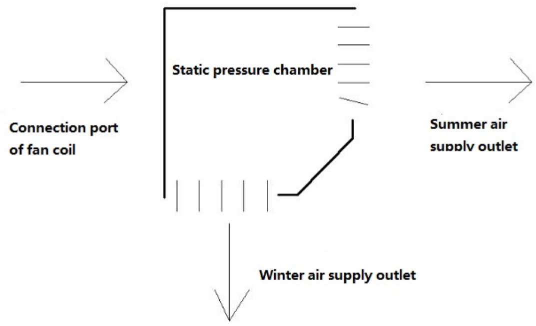


Figure 2. Schematic diagram of static pressure box at fan coil outlet

When supplying hot air in winter, the summer air supply outlet is closed, and the winter air supply outlet is open, as shown in Figure 3. The hot air is sent out from the winter air supply outlet and sent to the personnel activity area through the adhesive effect.

When supplying cold air in summer, the winter air supply outlet is closed, and the summer air supply outlet is open, as shown in Figure 4 below. The cold air is sent out from the summer air supply outlet. Under the effect of adhesion, cold air will flow along the ceiling, as shown in Figure 2, so that people in the working area near the fan coil can not be cooled. In order to change this situation, we changed the way of summer air supply in two ways. (1) One part of the cold air is attached in the original way, while the other part of the cold air is attached to the lower part along the vertical wall, so that even if there are office desks, computer tables and other obstructions in the room, the cold air can still take into account most of the personnel activity areas; (2) Change the control mode of the deflector at the outlet. The deflector at the lower part of the outlet is controlled separately, rather than always parallel to the deflector at the upper part. If the staff close to the fan coil feels too hot, they can adjust the independently controlled deflector to directly send part of the cold air to the working area close to the fan coil, as shown in Figure 4, which improves the comfort of air supply.

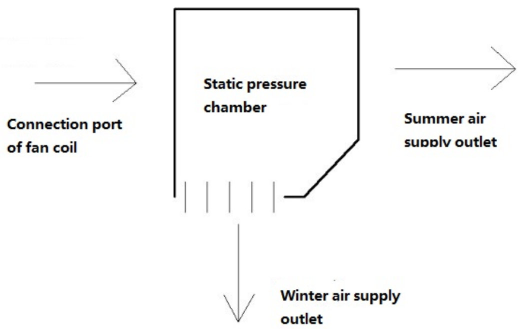


Figure 3. Schematic diagram of winter air supply of static pressure box at fan coil outlet

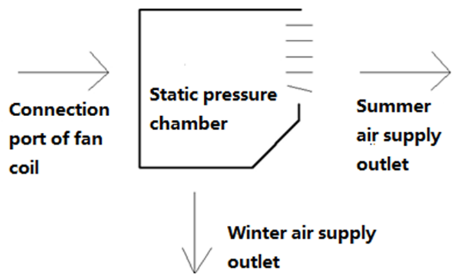


Figure 4. Schematic diagram of summer air supply of static pressure box at fan coil outlet

When supplying hot air in winter, the air supply outlet is arranged at the lower part of the fan coil, as shown in Figure 3. Due to the adhesive effect of the jet, the air from the air supply outlet will first flow downward against the wall. At the lower part of the wall, due to the weakening of the adhesive effect, the air supply will enter the main space at the lower part of the room, so as to directly send the hot air into the personnel activity area at the lower part of the room, fully mix the hot air with the indoor air, improve the temperature of the personnel activity area, and effectively solve the indoor air stratification phenomenon in winter. This is equivalent to the partial role of displacement ventilation in the air distribution. The advantages of this air supply mode are as follows: (1) The energy utilization efficiency is improved, the heat produced by the air conditioner is directly transferred to people, and the upper space of the room is no longer heated unnecessarily; (2) It improves the thermal comfort of the personnel. Although the outlet hot air temperature is higher than the human body temperature when the existing fan coil is used for air supply, the air temperature reaching the human body area will be lower than the human body temperature to some extent due to the sufficient mixing of indoor cold air along the way, resulting in a certain degree of "blowing feeling". The supplied hot air will first be sent to the human activity area, reducing the "blowing feeling", Play the role of partial floor heating and radiation heating; (3) When the ventilation system operates, the working area is close to the air supply environment, which is beneficial to human health. The CFD simulation method will be used to study the effect of this air supply mode.

3. Simulation Study

3.1. Model establishment

3.1.1. Establishment of physical model

(1) Air flow organization form of air-conditioned room

Air distribution is also called air distribution, which means that designers should organize the reasonable flow of air. Only a reasonable air distribution can give full play to the role of air supply, evenly eliminate the indoor excess heat and humidity load, and more effectively remove harmful gases and dust suspended in the air. The common air distribution forms of fan coil system are upper air supply and upper air return on the same side (hereinafter referred to as "upper air supply and return on the same side"), and the specific form is shown in Figure 5 below

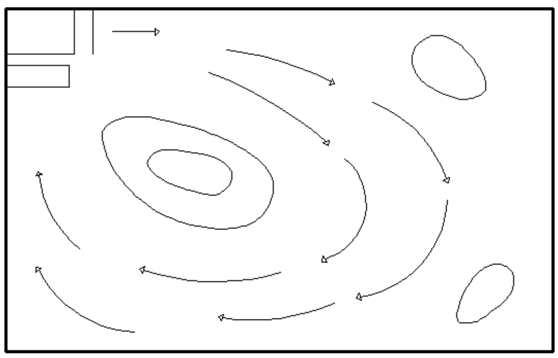


Figure 5. Form of upward feed and upward return on the same side

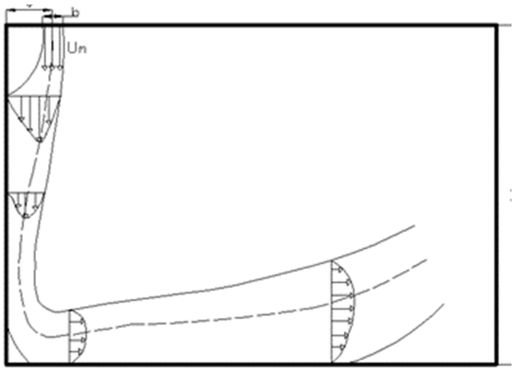
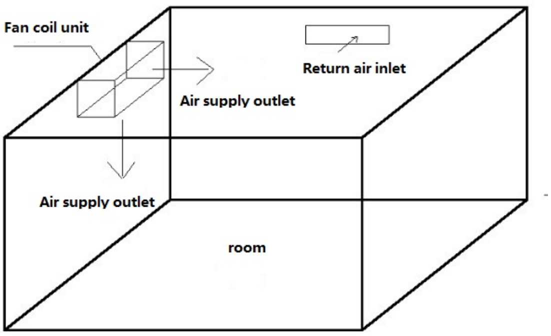


Figure 6. Schematic diagram of vertical wall attached air supply

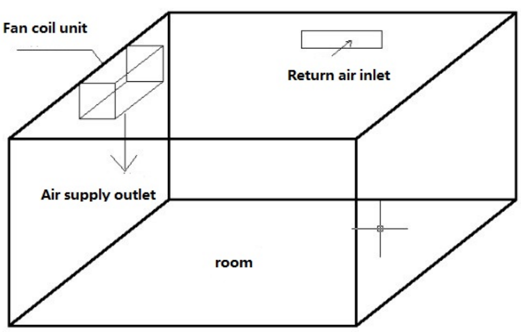
As mentioned in the introduction, in order to change the indoor thermal stratification phenomenon in winter and improve the indoor air distribution form in summer, a new type of air distribution form of fan coil system is established. The combination of upper side air supply in summer and vertical wall attached air supply is selected. In winter, the vertical wall attached air supply is completely selected. The specific form of vertical wall attached air supply is shown in Figure 6 below.

(2) Structural model

The size of air-conditioned room studied in this paper is 6m (long) × 4m (width) × 3.5m high. It is a common office situation at present. It can also be regarded as a basic unit in a large open office. The size of the traditional air supply outlet in the air-conditioned room is 400mm × L50mm, the size of the upper air supply outlet is 400mm in summer when the vertical wall is attached and the horizontal wall is attached × L00mm, lower part 400mm × L50mm, the size of return air inlet remains 400mm × l50mm. Figure 7 (a) shows the ventilation mode of fan coil system in summer; Figure 7 (b) shows the ventilation mode in winter.



(a) Schematic diagram of summer air supply form



(b) Schematic diagram of winter air supply form

Figure 7. Model diagram of air-conditioned room under two side air supply modes

3.1.2. Establishment of mathematical model

(1) In this paper, commercial CFD software Fluent is used for numerical simulation, and RNG is used κ-ε The model solves the indoor air flow field, due to RNG κ-ε The two-equation turbulence model is applicable to the high Reynolds number turbulent flow, so the standard wall function method is used to deal with the near wall. The general form of the control equation is:

$$\mathrm{div}(\rho V\Phi) = \mathrm{div}(\Gamma\Phi\ \mathrm{grad}\Phi) + S\Phi$$

Where, div (ρ V Φ) Is the convection term, div (ΓΦ grad Φ) Is the diffusion term, S Φ Is the source item.

(2) SIMPLE algorithm with pressure-velocity coupling is adopted.

(3) The indoor air velocity is low, and it is considered as incompressible Newtonian fluid. The steady flow meets the Boussinesq hypothesis, that is, the viscous dissipation in the fluid is ignored, and only the change of density is considered when calculating the buoyancy.

(4) The traditional air supply rate is 2.7m/s. In summer, when the vertical wall attached downward air supply and horizontal attached air supply are combined, the upper air supply outlet speed is 2.58 m/s, and the lower air supply outlet speed is 1 m/s. The air supply temperature is 22 ℃ in summer and 30 ℃ in winter. Setting of boundary conditions: the heat transfer of the enclosure is limited, and its heat is attributed to the indoor heat source, and the wall conditions are set as adiabatic wall.

3.2. Numerical method and grid division of CFD simulation

CFD commercial software Fluent is used in the simulation, and the finite volume method is used to solve the standard κ-ε Double-equation model: the first-order upwind scheme is used for the discretization of momentum, temperature, turbulent kinetic energy and its diffusivity, and the conservation of chemical components. The mass force weighting method is used for the discretization of pressure equation. The convergence standard of the energy equation in this simulation is: 1 × 10-6；The convergence standard of the flow equation is taken as 0.001. The mesh is divided into three dimensional structural grids with 671328 grids. The grid division is shown in Figure 8:

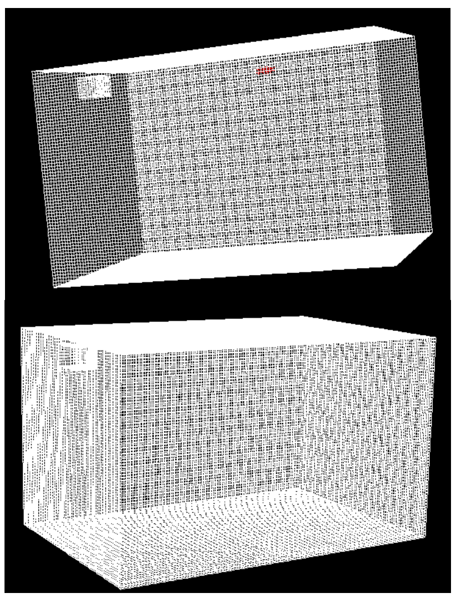


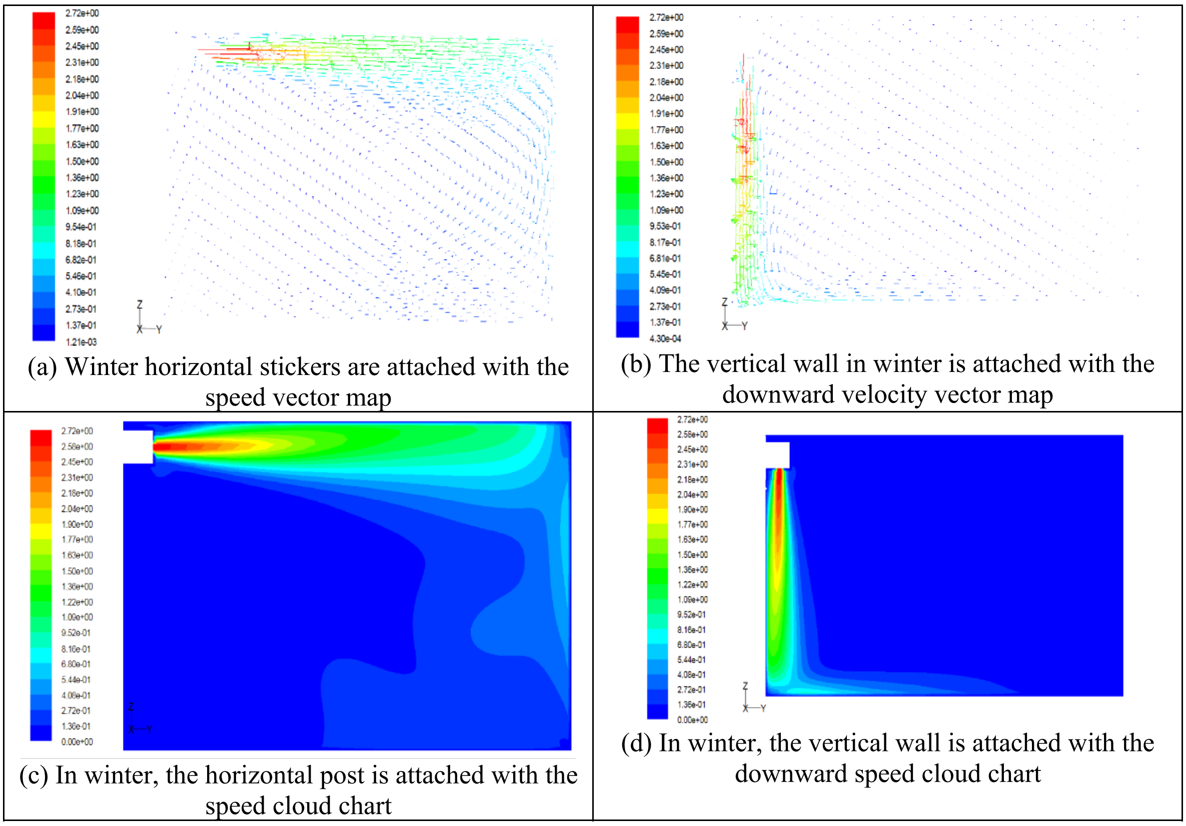
Figure 8. Grid division diagram

3.3. Simulation results and analysis

In this paper, the indoor air distribution of air-conditioned rooms with fan-coil system under two air supply modes is simulated. Through the simulation and analysis of air distribution in winter and summer, we can get the conclusion. This paper gives the partial simulation and analysis results of the same side up supply and up return in summer and winter, and the combination of winter attached down supply and summer upper side supply and vertical wall attached air supply.

3.3.1. Simulation and analysis of velocity field

3.3.1.1 Simulation and analysis of the velocity field of horizontal and vertical wall attachment in winter



(a) Winter horizontal stickers are attached with the speed vector map

(b) The vertical wall in winter is attached with the downward velocity vector map

(c) In winter, the horizontal post is attached with the speed cloud chart

(d) In winter, the vertical wall is attached with the downward speed cloud chart

Figure 9. Air flow velocity vector diagram and velocity nephogram on X=0 under two air supply modes in winter

It can be seen from the figure that the incoming air flow in rooms 9 (a) and 9 (c) changes direction after meeting the right wall in the process of moving forward. However, due to the existence of buoyancy, the hot air cannot flow smoothly along the wall to the ground. Some of the air flows back from right to left after touching the ground, while the other part of the air will climb due to the influence of heat sources or obstacles, thus forming some vortices at a height of 1.5m. In general, the wind power supply reaches the right half of the working area of the room.

It can be seen from Figures 9 (b) and 9 (d) that the air flow in the room is based on the principle of vertical wall attached flow. The hot air flow can obviously enter the working area at the lower part of the room, and can move along the floor to the 3/4 area of the room. The air supply and indoor air are fully mixed, and the wind speed in the working area is low. Vortex appears in the space with height less than 1m.

It can be seen from Figure 9 that the hot air can be better delivered to the working area by sticking to the wall in winter, so that a large amount of heat can be saved when the working area reaches the same temperature, and the vortex appears in the breathing area when the person is standing, because the velocity within the scope of the vortex is almost zero, which is easy to cause the accumulation of pollutants.

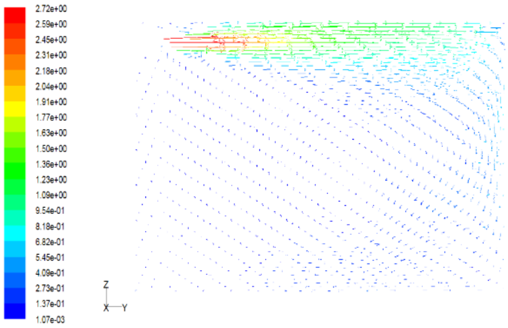
3.3.1.2 Simulation and analysis of velocity field in combination of horizontal attached delivery and vertical wall attached delivery and horizontal attached delivery in summer

The following figure 10 (a)~(d) shows the air flow velocity vector diagram and velocity cloud diagram of the room under the two air supply modes in summer on its main stream symmetry plane X=0 (the vertical axis of the middle of the air outlet).

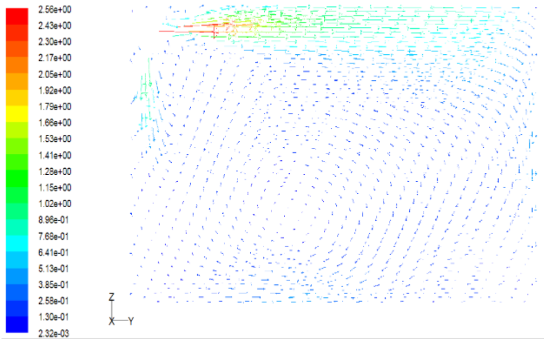
It can be seen from the figure that the incoming air flow in rooms 10 (a) and 10 (c) changes direction after meeting the right wall and flows along the wall towards the ground. After touching the ground, it flows back from right to left. In general, the right half of the working area of the room is basically in the return area. The air supply and indoor air are fully mixed, and the wind speed in the working area is relatively low.

In contrast, the air distribution in rooms 10 (b) and 10 (d) in summer is a combination of vertical wall attached downward delivery and horizontal wall attached delivery. The velocity distribution in the working area of the whole room is uniform. The air supply and indoor air are fully mixed. The wind speed in the working area is low, which can meet the project requirements.

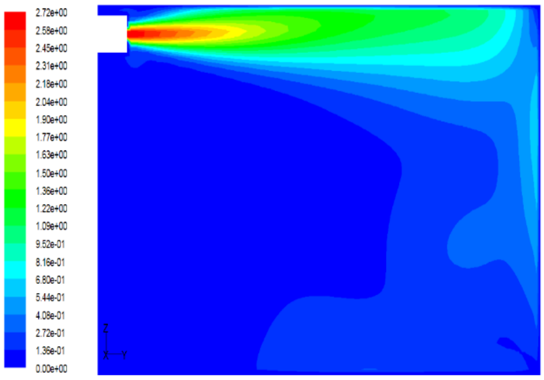
From the analysis of the movement direction of the air flow in Figure 10, if there are office desks, computer tables and other blocking items in the office, it will be difficult to reach the left half of the office with the horizontal attached air flow, and if the vertical wall attached jet is completely adopted, it will cause the cold air flow to be unable to move to the right area.



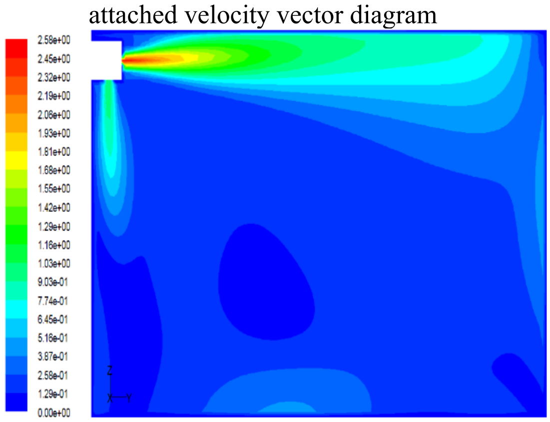
(a) Attach the delivery speed vector map horizontally



(b) Vertical wall attached downward and horizontal attached velocity vector diagram



(c) Attach the delivery speed cloud chart to the horizontal post



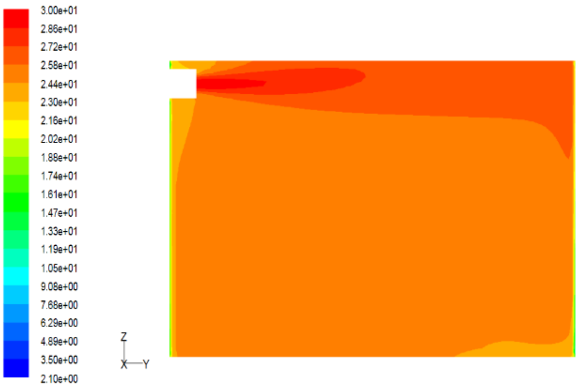
(d) Vertical wall and horizontal wall are attached with the speed nephogram

Figure 10. Flow velocity vector diagram and velocity nephogram on X=0 under two air supply modes in summer

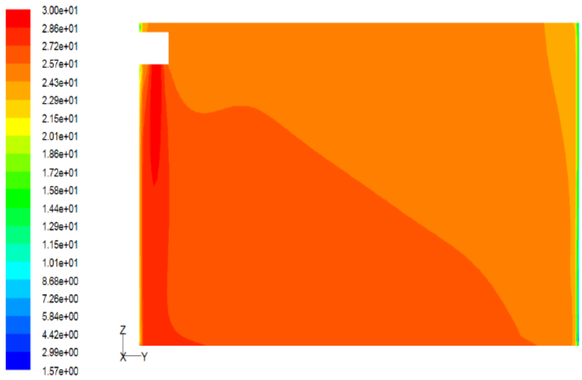
3.3.2. Numerical simulation and analysis of temperature field

3.3.2.1 Temperature field simulation and analysis of horizontal and vertical wall attachment in winter

Figure 11 (a)~(b) shows the temperature distribution diagram of the room on X=0 (vertical axis plane in the middle of the air outlet) under two air supply modes in winter.



(a) Temperature nephogram is attached to the horizontal post in winter



(b) Temperature nephogram attached to vertical wall in winter

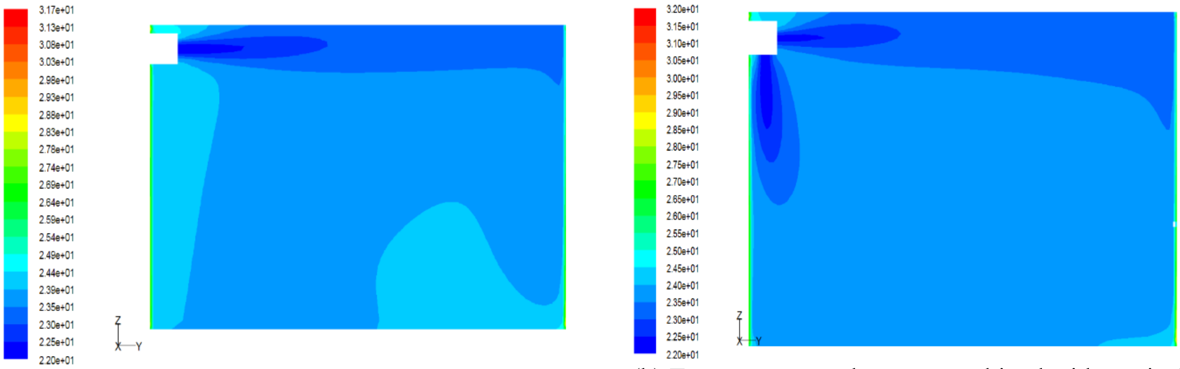
Figure 11. Temperature nephogram on X=0 under two air supply modes inwinter

Figure 11 (a) shows the temperature nephogram attached to the horizontal post in winter. It can be seen from the figure that the air distribution pattern of the supply and return air on the same side, the temperature distribution in the working area is uniform, but the temperature gradient from the top of the room to the bottom changes significantly, the temperature above is high, the temperature below is low, the natural convection is weakened, the air with high temperature is difficult to flow downward, the heat exchange of cold and hot air is not sufficient, and a lot of energy is consumed.

Figure 11 (b) is the temperature nephogram attached to the vertical wall. It can be seen from the figure that the hot air is first sent to the lower area and fully mixed with the indoor cold air. The heat exchange between the hot and cold air streams is sufficient. The temperature of the working area is significantly higher than that of the same area in the figure (a). In this way, the heating temperature can be appropriately reduced to save energy. In addition, fresh air can be sent to the work area first to improve the air quality of the work area.

3.3.2.2 Simulation and analysis of temperature field in combination of horizontal attached delivery and vertical wall attached delivery and horizontal attached delivery in summer

Figure 12 (a)~(b) shows the temperature distribution diagram of the room on X=0 (vertical axial plane in the middle of the air outlet) under two air supply modes in summer.



(a) Temperature nephogram attached to the horizontal post

(b) Temperature nephogram combined with vertical wall attached and horizontal wall attached

Figure 12. Temperature nephogram on X=0 under two air supply modes in summer

It can be seen from Figure 12 (a) that when cooling in summer, the upper cold air flow density is high, moving downward, natural convection is strong, and the heat exchange of cold and hot air flow is sufficient, but the temperature distribution of the working area near the air supply outlet and the working area far away from the air supply outlet is uneven. This is because, under the action of gravity, the cold air flow of air supply gradually forms an inclined and descending air flow, and diffuses around to mix with the indoor hot air flow for heat exchange. At the right side of the central section, the air heat exchange near the measuring point is more sufficient, making the temperature in this area low. On the left side of the central section, the exchange with the cold air flow is not sufficient, and the temperature is slightly higher.

It can be seen from Figure 12 (b) that when using the combination of vertical wall attached down and horizontal attached air supply in summer, the temperature on each section along the Y direction is uniform, and the heat exchange between hot and cold airflow is sufficient, which gives good consideration to the air conditioning requirements of most of the room, and also sends a part of fresh air directly to the personnel work area, improving the air quality of the personnel work area.

4. Conclusion

In this paper, the traditional air supply mode of fan coil air conditioning system is changed, and the two air supply modes are simulated by CFD in winter and summer. The simulation results are compared and analyzed, and the following conclusions are drawn:

(1) In winter, the wall is attached and the energy utilization efficiency is improved. The heat is directly transferred to the personnel working area, and the upper space of the room is no longer heated unnecessarily.

(2) In winter, the thermal comfort of personnel is improved by sticking to the wall and sending down the air. The hot air will first be sent to the human activity area to weaken the "sense of blowing" and play the role of partial floor heating radiation heating;

(3) In summer, the combination of vertical wall attached downdraft and horizontal wall attached downdraft can also partially improve the energy utilization efficiency, and part of the cooling capacity is sent to the work area first.

(4) When the fan coil system operates, the working area is close to the air supply environment, which is conducive to improving the air quality in the personnel activity area. In winter, the air supply vortex appears in the breathing area when the personnel are standing, because the velocity within the vortex range is almost zero, which is easy to cause the accumulation of pollutants.

(5) In summer, the combination of vertical wall attached downward and horizontal wall attached air supply can effectively solve the temperature control of the whole room air conditioning when there are a lot of barriers in the room.

The next step is to carry out field test and model test research, compare with CFD simulation, further improve CFD model, and get more accurate and instructive conclusions, providing reference for designers to design the air distribution of fan coil.

References

[1] Cao Zhenhua. Simulation study on temperature fuzzy control of variable frequency air conditioning room [J]. Refrigeration and Air Conditioning (Sichuan), 2019 (4): 433-436.

[2] Jin Haikui, Wang Ying, Wang Jian. Research on indoor air flow organization of a room with heating problems in a hotel [J]. Building thermal ventilation and air conditioning. 222 (07): 69-74.

[3] Yang Haonan. Study on the flow characteristics of the impinging zone of a vertical wall attached jet [D] Xi'an University of Architecture and Technology, 2021.

[4] Lai Fenglin, Liang Hui, Zhang Huaqiang, Peng Huisheng. Numerical study on optimal design of fan coil unit duct [J]. Electromechanical Information, 2018 (01): 78-81.

[5] Duan Guannan. Research on room temperature adjustment energy conservation based on human comfort analysis [D]. Shenyang University of Architecture, 2018.

[6] Wang Chenhui. Numerical simulation of pollutant diffusion and ventilation control in public building toilets [D]. Xi'an University of Architecture and Technology, 2020.