Simulation of office air conditioning air supply based on COMSOL

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Abstract

This paper analyzed the summer thermal environment of an office in Tianjin University of Science and Technology based on COMSOL software. Firstly, the principle of indoor thermal environment distribution was introduced. Secondly, according to the actual position of the furniture in the office, the mathematical model is constructed based on the basic theory of computational fluid dynamics. Thirdly, the COMSOL software was used for simulation and calculation, combining boundary conditions. Finally, the simulation results are analyzed through the simulated indoor three-dimensional velocity field and temperature field. The simulation results show that the air conditioning supply can well achieve indoor occupants' comfort.

Keywords: Temperature field, Wind speed field, Indoor thermal environment, CFD simulation, COMSOL

1. Introduction

Indoor temperature and velocity are one of the most important and frequently measured parameters in indoor environments, affecting personnel thermal comfort, energy balance and air flow [1]. Because the indoor temperature field and velocity field is a complex physical field, and there are many influencing factors. The change process of indoor temperature and velocity has the characteristics of large inertia, non-linearity, and easy to be affected by external environmental factors. Therefore, the indoor temperature distribution of most buildings is uneven, and the temperature data of different areas such as the corner, center, floor and ground of the room are very different. Therefore, it is necessary to use COMSOL fluid dynamics simulation software for indoor temperature and velocity simulation.

The first chapter introduces the necessity of simulating indoor temperature and velocity fields. The second chapter mainly introduces the construction of the indoor model, including the indoor objects, the heat transfer coefficient of the wall, the heat transfer coefficient of the window, etc. Meshing of indoor models. In Chapter 3, the simulated temperature and velocity fields are analyzed. In Chapter 4, simulation conclusions are drawn.

2. Indoor Physical Model Simulation

2.1. Model selection

The research object is an office on the fourth floor facing south. The north window and the corridor are adjacent. Due to the different functions of the room, the interior structure will also be different. In addition, the parameters of the office building walls, indoor personnel activities and room ventilation times and other factors, all greatly affect the office internal thermal environment. Since there are many objects in the office, not all objects can be considered, so the physical model only considers two types of objects, one is large objects such as desks, chairs and cabinets, and the other is hot objects such as computers, notebooks, human bodies and refrigerators. All objects are simplified to cuboids, which is conducive to grid division and calculation convergence.

This paper takes an office of Tianjin University of Science and Technology as the research object. The geometric size of the office is 6m×7.m×3.5m, and there is an air conditioner in the southwest corner of the room. The air supply port of the air conditioner is 1m×0.5m. The return air port is simulated as the return air port of the air conditioner, which is located below the air outlet. One of the Windows is located on the south wall with dimensions of 4m×2.3m and 1m above the ground. Suppose there is no turnover in the office，the number of people in the office is six. The physical model of the office is shown in Fig. 1 and Fig. 2.

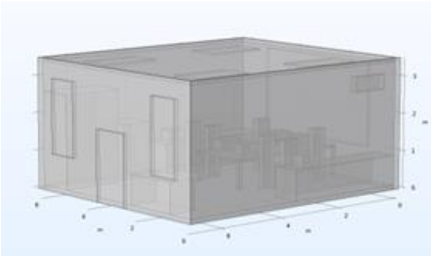

Fig. 1 The exterior of the office physical mode

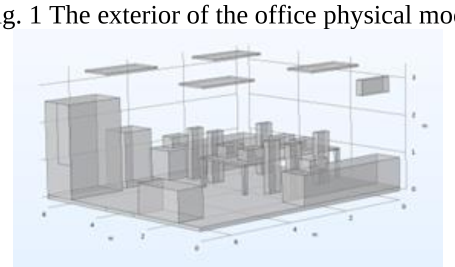

Fig. 2 The interior of the office physical model

2.2. Governing equation

Mass conservation equation is the embodiment of mass conservation law in fluid mechanics [2], as shown in Eq. (1), u,v,w--velocity component, unit m/s,ρ--Fluid density in kg/m^3.

$$\frac{\partial(\rho)}{\partial t}+\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0 \quad (1)$$

The hysical meaning of the energy conservation equation is that the increment of the total energy of the fluid controlled in the body per unit time is equal to the sum of the energy increment generated by the fluid capacity of the inflow control and the external action, which includes the energy increment generated by thermal radiation, heat conduction, work done by volume force, work done by pressure and work done by viscous force.as shown in Eq. (2).

$$\frac{\partial(\rho T)}{\partial t}+\frac{\partial(\rho uT)}{\partial x}+\frac{\partial(\rho vT)}{\partial y}+\frac{\partial(\rho wT)}{\partial z}= \frac{\partial}{\partial x}\left(\frac{\mu}{pr}\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{\mu}{pr}\frac{\partial \emptyset}{\partial y}\right)+\frac{\partial}{\partial x}\left(\frac{\mu}{pr}\frac{\partial \varphi}{\partial z}\right)+S_T \quad (2)$$

2.3. Mesh partition

COMSOL 6.0 software was used to model the office, the transient solver was used to solve the established model, and the dynamic simulation of the air conditioning supply situation of the office was carried out. The computed boundary conditions include the properties of the wall structural materials, the outdoor temperature of 30 degrees Celsius, the corridor temperature of 30 degrees Celsius, the air outlet speed of the air conditioner of 1m/s, and the air outlet temperature of the air conditioner of 20 degrees Celsius. Assuming that the indoor and ambient temperatures are the same at the beginning, the whole office is divided using a conventional grid to calculate laminar flow, solid and fluid heat transfer, and non-isothermal flows. The state of the office temperature field and velocity field within 6000s of air supply is simulated and calculated. The boundary conditions and heat sources are shown in Table 1 and Table 2.

Table 1 Boundary condition

Boundary	Heat transfer coefficient
Body of wall	5(W/(m2*K))
Windows	10(W/(m2*K))
Door	4(W/(m2*K))

Table 2 Source of heat

Source of heat	Flux of heat(W)
computer	100
people	50
80	80

3. Image Analysis

The temperature cloud image at room x=1, x=3, x=5m (as shown in Fig. 3, Fig. 4, Fig. 5) and velocity cloud image (as shown in Fig. 6, Fig. 7, Fig. 8) were captured respectively. The scale on the right of the temperature cloud image is the size of the temperature, corresponding to 20 to 30 degrees Celsius from blue to red, and the scale on the right of the velocity cloud image corresponds to the size of 0 to 2m/s. Fig. 3 shows the temperature cloud map at x=1m. The upper left corner is close to the air outlet of the air conditioner, where cold air blows into the room and the temperature is low. The temperature is about 20 degrees Celsius according to the scale. Fig. 4 and Fig. 5 are x=3m and x=5m respectively. The reason why the temperature in the lower left corner is relatively low is that the cold air from the air conditioner blows out and falls down due to gravity, and the cold air gathers to the ground on the left side, where the temperature is about 25 degrees Celsius. The combination of the three images shows that the temperature on the upper floor of the room is evenly distributed, about 27 degrees Celsius. However, the position temperature of the air outlet is low, which is not conducive to the comfort of indoor personnel.

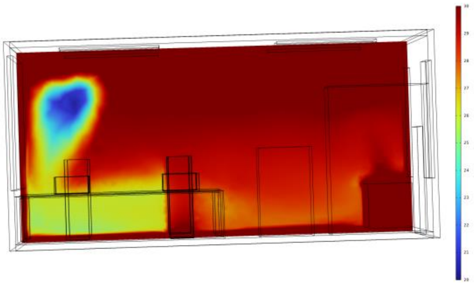

Fig. 3 The temperature field at x=1m

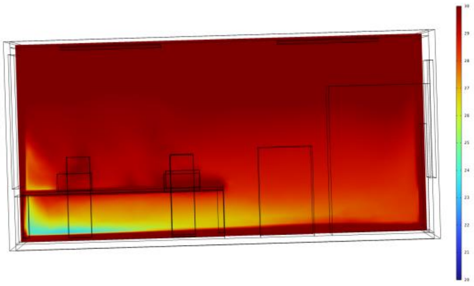

Fig. 4 The temperature field at x=3m

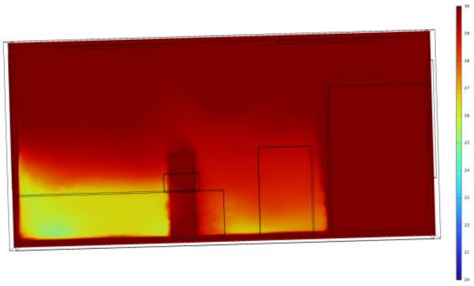

Fig. 5 The temperature field at x=5m

Fig. 6 shows the indoor velocity cloud map at x=1m. The reason for the large wind speed in the upper right corner is that it is located at the air conditioning outlet, and the wind speed is 2m/s. The reason for the large wind speed in Fig. 7 and Fig. 8 is that the wind speed in other places is evenly distributed due to the cold air blown by the air conditioner. The comprehensive wind speed cloud map shows that the wind speed in other places is evenly distributed except for the air conditioner outlet, and the indoor personnel are more comfortable.

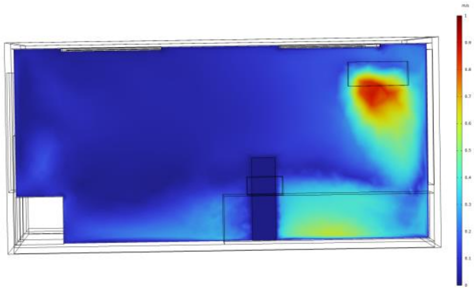

Fig. 6 The velocity field at x=1m

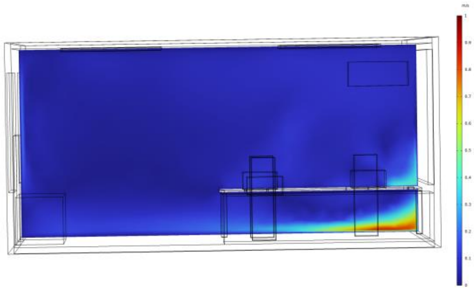

Fig. 7 The velocity field at x=3m

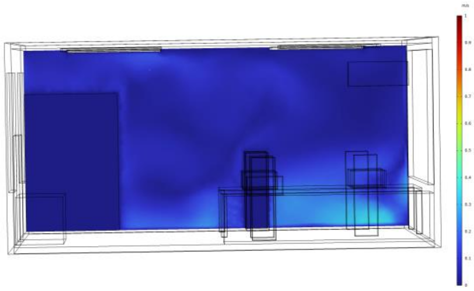

Fig. 8 The velocity field at x=3m

The cross sections at y=1m and y=3.5m were intercepted, respectively, where Fig. 9 and Fig. 10 show the temperature cloud, and Fig. 11 and Fig. 12 show the velocity cloud. Fig. 9 shows the position of the air outlet of the air conditioner. It can be seen from the figure that after the air from the air conditioner blows out, it falls to the position of the table due to gravity, and the temperature is low. Fig. 10 shows that the temperature distribution in the upper and lower parts of the room is relatively uniform for the location located in the center of the room at y=3.5m.

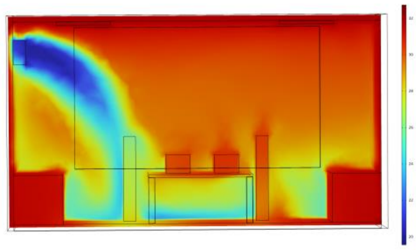

Fig.9 The temperature field at y=1m

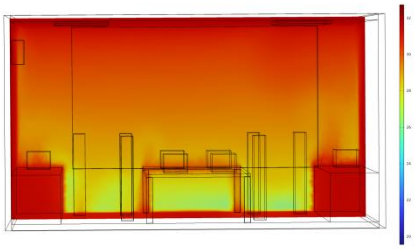

Fig. 10 The temperature field at y=3.5m

Combined with Fig. 11 and Fig. 12, the comfort of indoor personnel is not high under the air conditioning, and the comfort of personnel is good in the middle position of the room.

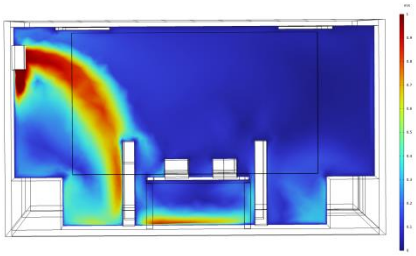

Fig. 11 The velocity field at y=1m

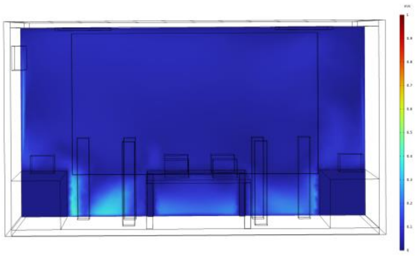

Fig. 12 The velocity field at y=3.5m

Screenshots at z=0.2m and z=1.75m were taken, respectively, where Fig. 13 and Fig. 14 show the temperature cloud, and Fig. 15 and Fig. 16 show the velocity cloud. Combined with the above analysis, the upper temperature of the room is higher than the lower temperature, and with the height increase, the temperature also increases. The temperature distribution is uniform in the z plane.

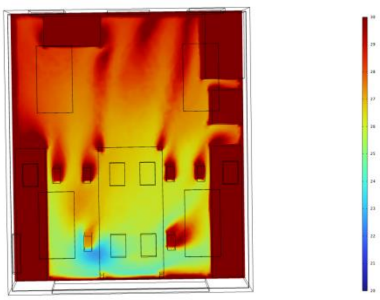

Fig. 13 The temperature field at z=0.2m

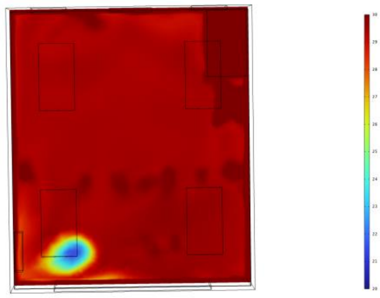

Fig. 14 The temperature field at z=1.75m

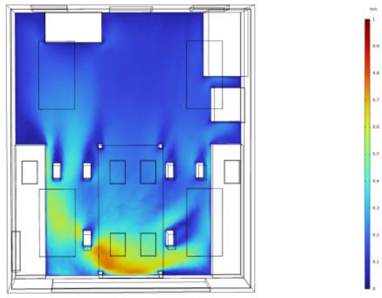

Fig. 15 The velocity field at z=0.2m

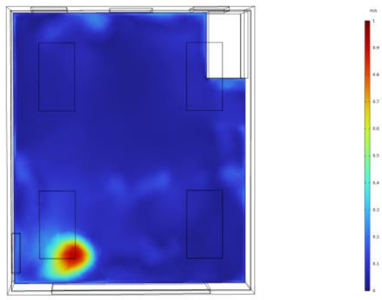

Fig. 16 The velocity field at z=1.75m

Fig. 17 shows the 3D diagram of the room, where the green line represents the path of the wind sent by the air conditioner, and the red arrow represents the direction and magnitude of the wind speed. The figure shows that the air provided by the air conditioner can cover the whole room. In addition to the position of the air outlet of the air conditioner, the wind speed is also moderate, which can meet the comfort of indoor personnel.

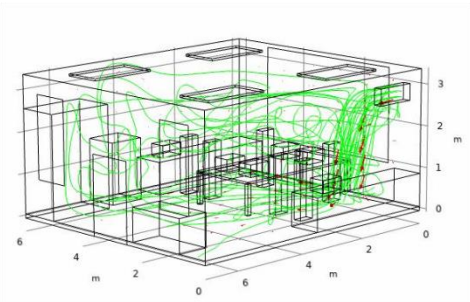

Fig. 17 3D air supply path diagram

4. Conclusion

Based on the above simulation analysis, the air provided by the air conditioner can cover the whole room, and the air supply by the air conditioner can meet the comfort of indoor personnel.

References

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Authors Introduction

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