Numerical simulation of indoor airflow field using air curtain jet (ACJ) ventilation mode —Analysis of the thermal environment with different heat source conditions

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1. Background

HVAC (Heating, ventilation, and air conditioning) system is the fastest and most effective way to meet human thermal comfort by regulating indoor temperature and humidity, air supply speed and other relevant thermal environment parameters in order to achieve good indoor air quality.[1] At present, the most widely used ventilation methods are mixed ventilation and replacement ventilation, but the mixed ventilation method has high energy consumption and replacement ventilation cannot be applied to winter heating. Due to the disadvantages mentioned above, a new ventilation method combining the advantages of traditional ventilation system, known as air curtain jet (ACJ) ventilation[2] was proposed. Subsequently, a series of studies have been conducted on it, and all of them have shown that ACJ has good ventilation effects. However, the effect of this new ventilation method on high-intensity intensive heat sources has rarely been discussed.

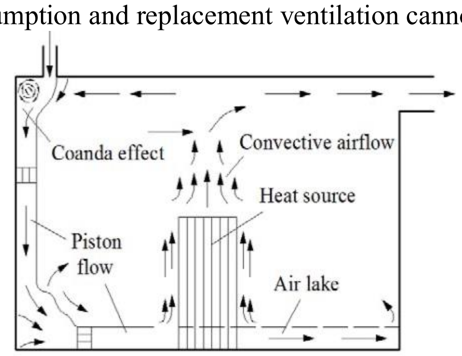
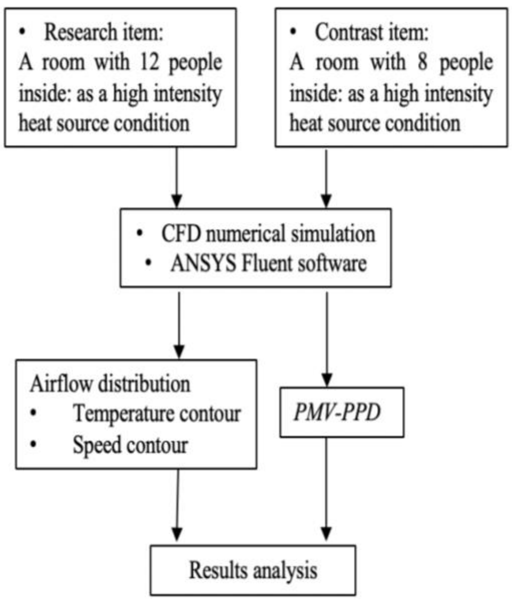


Figure 1 Air curtain jet ventilation [2]

2. Objectives

The research in this paper will be divided into two cases of high intensity heat source and low intensity heat source, adjust the air supply variables by changing the air supply speed (v=2m/s, v=1.5m/s), analyze the indoor flow field characteristics of using air curtain jet (ACJ) ventilation under different heat source conditions by CFD numerical simulation method and ANSYS Fluent software, plus calculate the thermal comfort, get the influencing factors of the vertical wall attached air supply method and the changes of airflow field when the heat source intensity changes. Finally, recommendations for the use of the new ventilation method will be made based on the conclusions of the analysis.

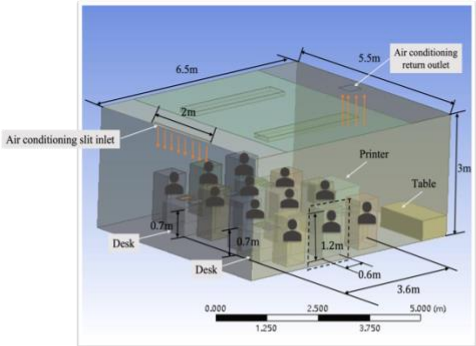
3. Research procedure



The results of this study will provide a reference for future research and promotion of the use of new ventilation system.

4. Research content

4.1 Geometry



The physical model was designed as an office with dimensions of (L × W × H) 6.5 m x 5.5 m x 3 m. In this office, a slit air conditioner is installed in the ceiling at the front of the room. 2 desks are located in the middle of the room, and 12 laptops are placed on the desks, where 12 people sit in silence. At the back of the room, a table and a printer are placed. In addition, there are 2 fluorescent lights and air conditioning return vents on the ceiling.

4.2 Discretization

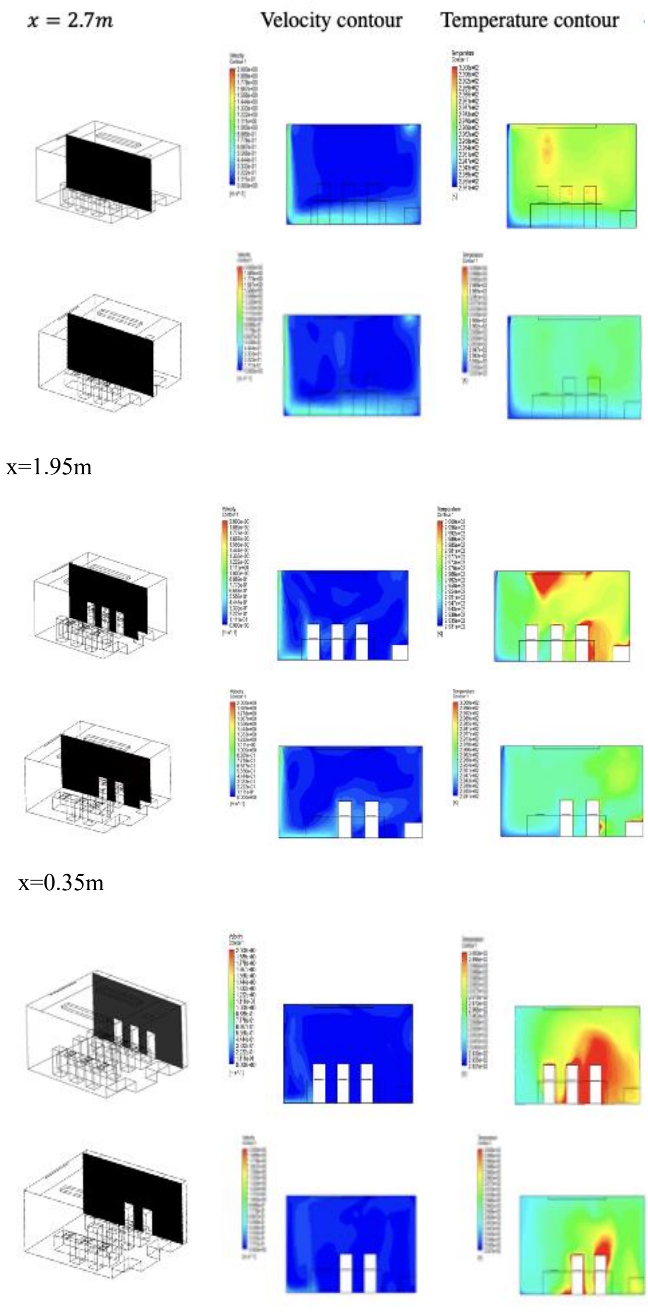
The Meshing component of ANSYS Fluent 2021 R2 software was used for discretization and Fluent used the Finite Volume Method (FVM) to discretize the physical model. The structured hexahedral structure was meshed for the study area. After the mesh independence verification, the number of meshes is determined as 137502.

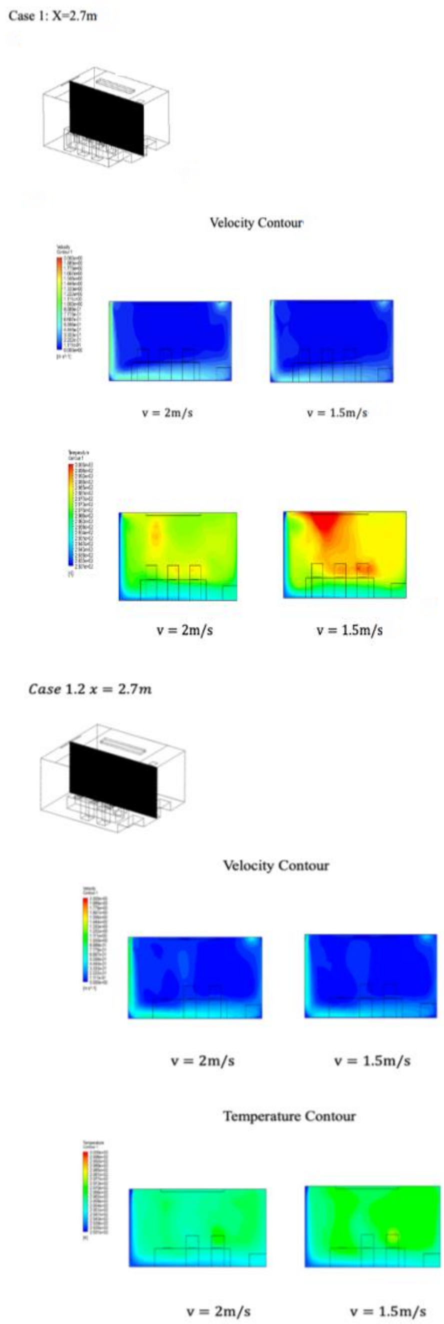
4.3 Boundary conditions

Air in the room is incompressible three-dimensional unsteady turbulence, air can be considered as an ideal gas, the variation of density with temperature is in accordance with Boussinesq hypothesis, and the solid walls are all stationary without sliding walls, people in the room and the electronic devices are used as heat sources to dissipate heat to outside.

4.4 Simulation results

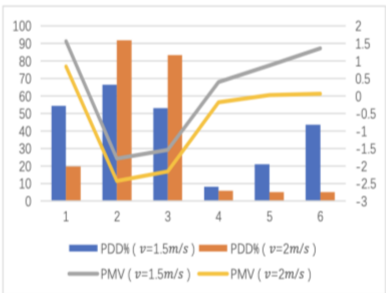
Another physical model of a room with 12 people sitting quietly in the office is designed to simulate a space with a dense distribution of heat sources and high heat load intensity. Working condition with 8 indoor personnel is designed as a comparison.

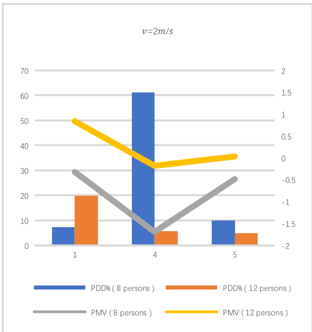


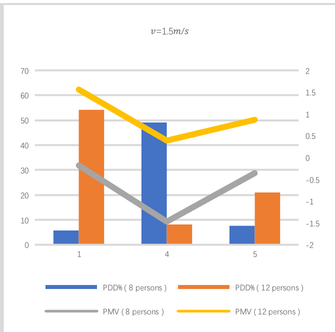


v=2m/s

4.5 Thermal comfort







5. Conclusions

(1) The difference in the distribution of the air flow field is strongly related to the distance from the air supply outlet. The farther the distance from the air outlet, the smaller the inertial force of the ground-attached air supply, which prevents the spread of air. The cool air cannot affect the room in its entirety, and it is difficult to be sufficiently delivered to the working area.

(2) The comparative analysis of the velocity field and temperature field of air supply found that when the room is crowded with people, it is necessary to keep a large air supply velocity to maintain the cooling effect in the room. When the velocity of air supply in the room is large, the people on the near side from the air outlet feel cold.

(3) When using vertical wall attachment ventilation, the distance of horizontal attachment range can directly affect indoor thermal comfort and energy utilization. For vertical wall attachment ventilation, the airflow moves down along the vertical wall, and after passing through the impact area, near the floor, the airflow is spread outward from the air supply outlet area. If the airflow is blocked at the stage of adhering to the floor, so that it is not sufficiently developed, the cold air cannot spread to a greater distance, resulting in turbulent and uneven flow field, which will have a great impact on the overall airflow distribution, and the cooling effect is decreased.

(4) When the indoor heat source is dense, in order to need to ensure the diffusion of the air supply floor attached to the air supply, the wind speed in the design should not be too small when using the new vertical wall attached ventilation method, it is recommended that the wind speed is not less than 1.5 m/s. However, due to the large wind speed, personnel near the air outlet will feel cold. The cooling effect will be significantly decreased when the floor air supply airflow is obstructed. Therefore, it is recommended that the horizontal distance of 1 to 2 m from the air conditioning outlet is appropriately reserved space, and no personnel are arranged, or no items are set up for placement to ensure the transmission of cool air and the comfort of personnel.

References:

[1] Clausen, G., Fernandes, E. O., De Gids, W. and Delmotte, C. (2003) ECA Report No 23: Ventilation, Good Indoor Air Quality and Rational Use of Energy. Luxembourg: European Commission.

[2] Yin, Haiguo & Li, Angui. (2012). Airflow characteristics by air curtain jets in full-scale room. Journal of Central South University. 19. 10.1007/s11771-012-1056-8.