Comparative study on the ventilation mode of the residential building in Beijing area in winter

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Abstract. With the development of residential energy conservation technology, the air tightness requirement of the window is higher and higher. So in winter the cold penetration wind cannot satisfy the requirement of indoor personnel to fresh air. The common ventilation mode includes natural ventilation, natural inlet and mechanical exhaust, wall type ventilator with heat exchange, ventilation unit with heat exchange. Looking for energy saving, comfortable way of ventilation, the application effect of the way of ventilation is evaluated in air distribution and comfort performance and the initial investment by FLUENT software. The conclusion is that the mode of ventilation unit with heat exchange has higher superiority compared with the others.

1. Introduction

With the development of residential energy conservation technology, the air tightness requirement of the window is higher and higher. That is to say, the amount of air exchange between indoor and outdoor is greatly reduced, and the heat loss caused by cold air infiltration is also largely deceased. For the commonly used plastic steel window, when the test pressure is 10 Pa, its air infiltration is very little, less than 0.7 $m^3/(m\ h)$, which is considered to be nearly enclosed [1]. The amount of air infiltration is largely less than the requirement of indoor personnel to fresh air, and indoor pollutants can't be timely ruled out. The indoor air quality problems are becoming more and more prominent. However, the basic requirement for healthy housing is give a good indoor air quality, and ventilation is considered as the most basic and effective way to reach this aim. Therefore, there is a conflict between the residential energy conservation technology and ventilation. In this case, how to operate the ventilation of the residential building has become a more prominent problem [2].

In this study, air distribution, energy consumption characteristics, and initial investment of different ventilation modes including natural ventilation, natural inlet and mechanical exhaust, wall type ventilator with heat exchange, ventilation unit with heat exchange are analyzed and evaluated to present their advantages and disadvantages. This study can guide to find a ventilation mode that can meet the thermal comfort, air quality and energy saving.

2. Evaluation method

2.1 Air distribution

The aim of ventilation is realized by the reasonable air distribution. A reasonable air distribution not only

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gives a healthy and comfortable environment, but also makes the initial investment and operating costs to be relatively low. Therefore, according to characteristics and requirements of the indoor environment, it is very important to adopt the most appropriate ventilation system and air distribution to achieve high quality and efficient operation. In this study, the indoor air velocity field is simulated by FLUENT software, then it is evaluated using the indicator, namely, airflow distribution uniformity.

2.2 Thermal comfort index

Thermal comfort index is considered to be a comprehensive response of human body to various factors of thermal environment, whose indicators includes effective temperature, thermal stress index, predicted mean vote (PMV) and so on. According to ISO7730 standard, the thermal environment can be described and evaluated using indicators, namely, PMV and PPD [3]. In this study, the indoor air temperature and velocity are simulated by FLUENT software, then PMV is calculated based on its definition, and it is used to evaluate thermal environment.

2.3 Initial investment

Initial investment is a barrier of technology promotion. Therefore, initial investment is an important indicator evaluating technical products.

3. Physical model and boundary conditions

In this study, the research object is a residential building with area of 120 m^2, which is shown in Fig.1. In order to make an effectively comparative study, air volume of different common ventilation mode including natural ventilation, natural inlet and mechanical exhaust, wall type ventilator with heat exchange, ventilation unit with heat exchange, are set to the same. The air velocity is calculated, according to their vent area. Their temperature boundary conditions also are set to be the same. Details of their boundary conditions as follows,

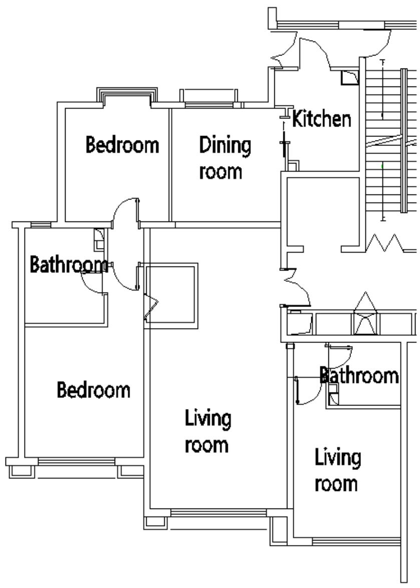

Figure 1. Plan of research object

Velocity boundary conditions

1) Air volume. According to indoor air quality standard [4], fresh air requirement should be 30m^3/(h p). There are 3.5 peoples in a room. So the total fresh air rate is 105m^3/h. According to design standard for energy efficiency of residential buildings in severe cold and cold zones [5], air change rate should be $0.5h^{-1}$. So the

total fresh air rate is 168m³/h. According to design code for heating ventilation and air conditioning of civil buildings [6], air change rate should be $0.5h^{-1}$, when the room area is 20 m^2-50 m^2. So the total fresh air rate is 168m³/h. Therefore, the total fresh air rate is 168m³/h.

2) Vent area. The vent area of natural ventilation is equal to the area of open surface of window. The vent area of natural inlet and mechanical exhaust, wall type ventilator with heat exchange, ventilation unit with heat exchange is the same to its actual size.

3) Air velocity. Air velocity is calculated, according to their air volume and vent area. The direction of natural ventilation is the same as that of the leading wind in winter, according to design code for heating ventilation and air conditioning of civil buildings [6].

Temperature boundary conditions

1) External wall temperature. In winter, heat is transferred from indoor air to the inner surface of external wall by convection. Then, this heat is transferred from the inner surface to the outer surface by conduction. At last, this heat is transferred from the outer surface to outdoor air by convection [7]. According to the fact that the heat transferring from indoor air to outdoor air is equal to that transferring from indoor air to the inner surface of external wall, the temperature of inner surface of external wall can be calculated, which can be considered as the dirichlet boundary condition of external wall. The temperature of interior wall is set as same as the indoor design temperature.

2) External windows temperature. Similar to the external wall temperature, the temperature of the external windows is calculated. Of course, the heat transfer coefficient of the external window is different from that of the exterior wall.

3) Inlet air temperature. For these ventilation modes without heat recovery, the inlet air temperature is the same to the heating outdoor temperature. For these ventilation modes with heat recovery, the inlet air temperature is calculated, according to the fact that its heat recovery efficiency is 60%.

4. Comparative analysis of ventilation modes

4.1 Air velocity field

The air velocity field of different ventilation modes is simulated by FLUENT software, and they are shown in figure 2-5, which indicate the simulation results of room 1.5m.

From these figures, when the natural ventilation is operated, the air distribution of rooms except bathrooms and kitchens is relatively uniform. However, its comprehensive effect is not stable, due to the limitation of opening time and area of windows, the outdoor meteorological environment. When the natural inlet and mechanical exhaust is operated, the air distribution of rooms is relatively uniform, and the temperature distribution is also relatively reasonable. When the wall type ventilator with heat exchange is operated, the air distribution of rooms is not reasonable. The fresh air is concentrated in the area near the vents, and they have a little influence on the air inside the room. When the ventilation unit with heat exchange is operated, the air distribution of rooms is relatively reasonable.

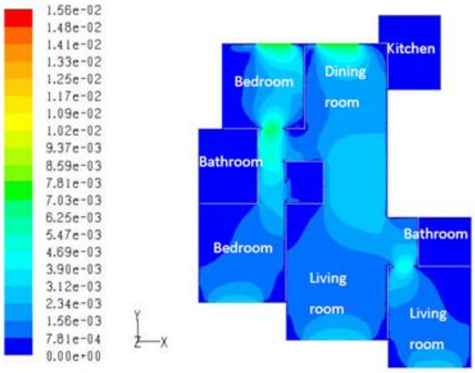

Figure 2. Air velocity field of natural ventilation

Figure 3. Air velocity field of natural inlet and mechanical exhaust

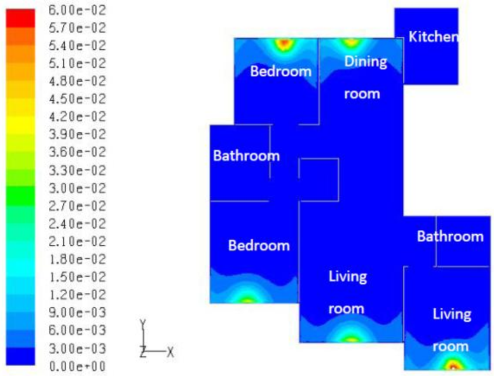

Figure 4. Air velocity field of wall type ventilator with heat exchange

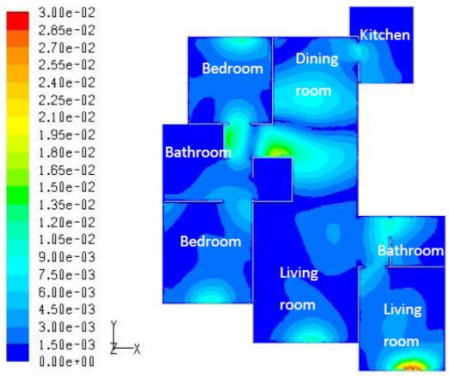

Figure 5. Air velocity field of ventilation unit with heat exchange

4.2 PMV

The air temperature and velocity of different ventilation modes are simulated by FLUENT software, then their PMV distributions are calculated and shown in Figure 6-9, whose height is 1.5m.

According to these figures, the feeling of the human body in bedroom and dining room with the natural ventilation is cold. Sometimes PMV is less than -1. The feeling in all rooms with the natural inlet and mechanical exhaust is comfortable, and PMV is between 0 and 0.5. PMV distribution of all rooms with the wall type ventilator with heat exchange is reasonable. But PMV in the area near the vents is low, less than -0.5. PMV of all rooms with the ventilation unit with heat exchange focuses on -0.5-0.5, where the feeling of the human body is comfortable.

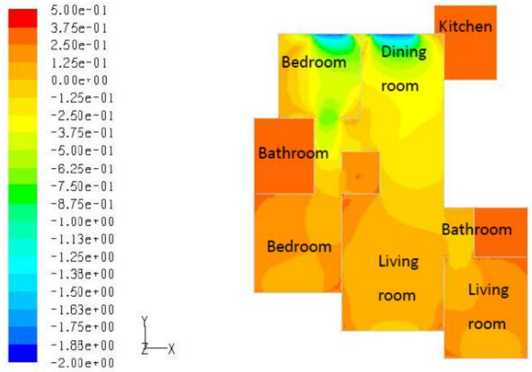

Figure 6. PMV distribution of natural ventilation

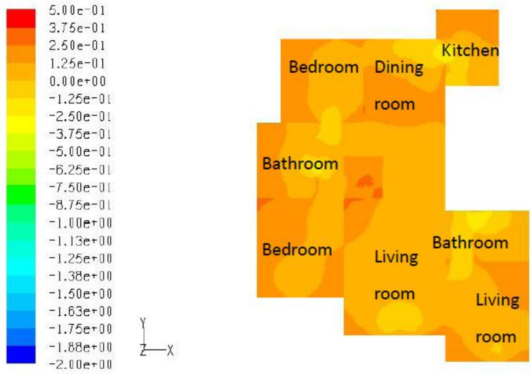

Figure 7. PMV distribution of natural inlet and mechanical exhaust

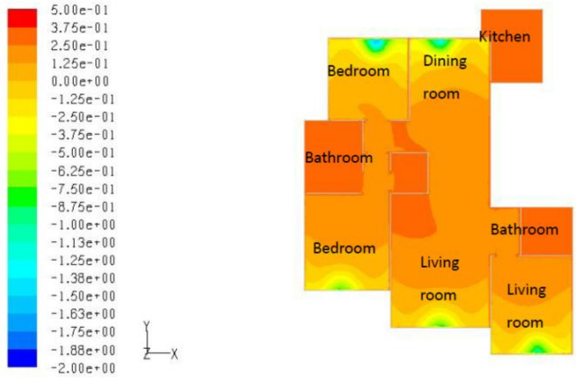

Figure 8. PMV distribution of wall type ventilator with heat exchange

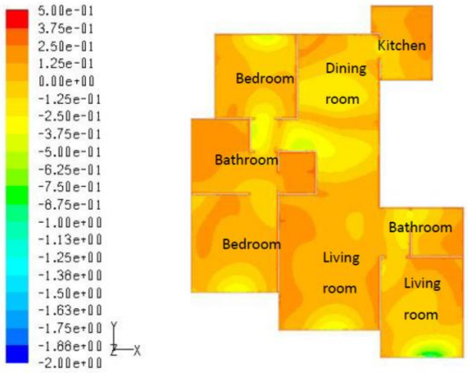

Figure 9. PMV distribution of ventilation unit with heat exchange

4.3 Initial investment

Initial investment of different ventilation modes are listed in Table 1.

Table 1. Initial investment of different ventilation modes

	Natural ventilation	Natural inlet and mechanical exhaust	Wall type ventilator with heat exchange	Ventilation unit with heat exchange
Required equipment	——	1 fan+6 inlets+4 outlets+ air duct	5 wall type ventilators	1 air exchange unit+5 inlets+4 outlets
Initial investment	——	3000-3600 RMB	20000-25000 RMB	5000~6000 RMB

5. Conclusions

In this study, air distribution, thermal comfort index, and initial investment of different ventilation modes are analyzed and compared. Therefore, their comprehensive evaluation index are listed in Table 2.

Table 2. Comprehensive evaluation of different ventilation modes

Ventilation modes	Air distribution uniformity	thermal comfort performance	Economic performance	Comprehensive performance
Natural ventilation	Common	Common	Best	Common

Natural inlet and mechanical exhaust	Better	Best	Best	Better
Wall type ventilator with heat exchange	Common	Better	Common	Better
Ventilation unit with heat exchange	Best	Best	Better	Best

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