# Analysis of the Effects of Ventilation Method on Indoor Humidity Distribution and Condensation by CFD method


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## ABSTRACT

People spend 70% -90% of their time indoors. Indoor air quality and human body's health have a close relationship. With the advance of society, user comfort requirements for thermal environment are rising. Humidity is an important parameter for evaluating indoor air quality, which not only affects the thermal comfort of the human body but also seriously restricts the function of the building. In winter, the indoor humidity is dry. When using humidifier, the humidity around the humidifier is higher, but there is still a dry area in the room. It is necessary to study the placement, blowing direction and capacity of the humidifier. In addition, when the room air supply method is different, the indoor humidity distribution is also slightly different. In recent years, with the development of large capacity, high speed of computer, CFD technology has been used to simulate air flow organization. It is possible to simulate the airflow organization, temperature and humidity of the building air conditioning system by using CFD technology.

This paper the effects of different ventilation methods and different humidifier placement positions on the indoor humidity distribution of single room. And exploring the effects of condensation on different ventilation modes.

1)The model can realistically simulate the effect of ventilation on the condensation distribution.

2) Within the scope of the nearby, the air just can hold limited capacity water vapor. The humidifier working efficiency was infected by the different position of humidifiers.

3) The humidity distribution in the room is related to the ventilation mode, and the flow pattern of the indoor airflow affects the distribution of indoor humidity.



## KEYWORDS

Thermal environment, humidity, humidifier, ventilation mode, simulation


## 1 INTRODUCTION

Most people spend their lives indoors, and indoor air quality is inseparable from human life. With the improvement of the quality of life, more and more people are paying attention to the comfort of the indoor thermal environment. Humidity is an important part of the thermal environment. For human which is not only related to human comfort, but also to the health. During the winter time, indoor humidity is dry. There are major impacts on the health when indoor humidity falls outside the appropriate range. We found that when using the humidifier there are some parts which are still dry in the room. So, the humidifier reasonable placement and effective humidification range need to be researched. Humidity condition of each space is influenced by individual variation and the use of humidifier. Condensation is a serious phenomenon while using humidifier. Bacterium and virus will enhance greatly in condensate water. There is also tremendous impact for people's health. The way of using of humidifier also influenced a lot to people's health. We need to place humidifier in an appropriate location for maximizing its effectiveness. In addition, when the room air supply method is different, the indoor humidity distribution is also slightly different. So in this paper the effects of different ventilation methods and different humidifier placement positions on the indoor humidity distribution of single room were simulated.

## 2 THE SUMMARY OF CFD SIMULATION

### 2.1 Establishment of a basic physical model

This paper simulated the effects of two different ventilation method and different placement of humidifier on condensation. The simulation is dedicated to single room(5m*5m*2.8m).The room plan is shown in Figure 1. The case number and humidifier position comparison are shown in Table 2. There are two type of air conditioning system. The way of A type is air supply and air outlets at the same direction. The B type is the air supply and air outlets on the opposite of

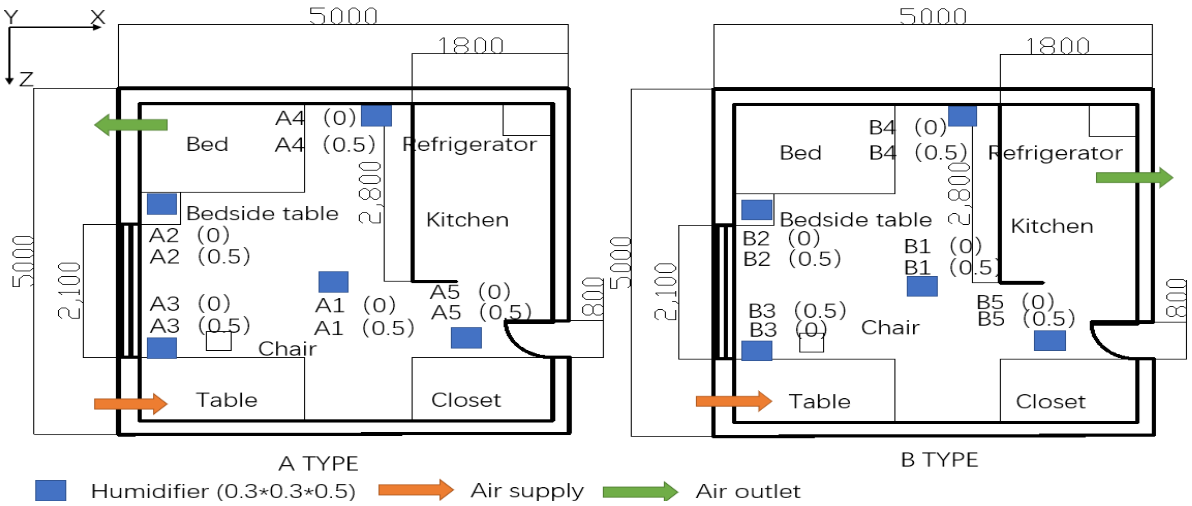


Figure 1 Physical Model of Each Case

Table 1: Model Boundary Conditions

| Boundary | Parameter Setting |
|---|---|
| Air supply | Air volume： 216m^3/h, Temp.: 30℃，Relative Humidity：20% |
| Air Outlet | Outflow |
| Wall | Dehumidification，overall heat transfer coefficient 1.74W / (m^2 • K)，Outdoor temperature 5 ℃ |
| Ceiling and Floor | Insulation |
| window | heat transfer coefficient 0.63W / (m^2 • K) |
| Initial environment | Temp. 23℃ RH Φ=20% |
| Penetrating wind | 0.2m/s |
| Humidifier | Amount of moisture 300ml/h |

Table 2: Case number and the humidifier position

| | | | |
|---|---|---|---|
| case 1 | no humidifier | | |
| case 2 | A1(0) | case 12 | B1(0) |
| case 3 | A1(0.5) | case 13 | B1(0.5) |
| case 4 | A2(0) | case 14 | B2(0) |
| case 5 | A2(0.5) | case 15 | B2(0.5) |
| case 6 | A3(0) | case 16 | B3(0) |
| case 7 | A3(0.5) | case 17 | B3(0.5) |
| case 8 | A4(0) | case 18 | B4(0) |
| case 9 | A4(0.5) | case 19 | B4(0.5) |
| case 10 | A5(0) | case 20 | B5(0) |
| case 11 | A5(0.5) | case 21 | B5(0.5) |

the room.A total of 10 placement for the humidifier in the simulation experiment is shown in the Figure 1. In the model, the humidifiers are placed in five locations, two heights, in short ten places. The letters indicate two different ways of ventilation(A,B). The height is indicated in parentheses. For example, A1(0) and A1(0.5) indicate that the humidifier is placed on the ground at position 1 of the ventilation mode A and placed at the height of 0.5 m from the ground at position 1 of the ventilation mode A.

In the model the wall on the side of window are made by concrete with overall heat transfer coefficient of 1.74W/m$^2 \cdot$ K. The heat transfer coefficient of the window is 0.63 W/m$^2 \cdot$ K. The other walls are insulated and desiccated. A humidifier was placed in the room to simulate humidification. The model boundary conditions are set in the Table.1

### 2.2 Simplification of the physical model

5 points simplifying assumption were made for the model：

1.The effects of gravity fields on air and water vapors are ignored;

2.Both air and water vapor are considered to be incompressible fluids with a constant density;

3.When the water vapor evaporates from the water surface, only latent heat exchange is performed, and sensible heat exchange is not considered;

4.When water vapor condenses on the wall, the heat release ignored from the phase change process;

5.Wall surfaces moisture absorption capacity is not considered during wall condensation.

### 2.3 Mathematical model

The FLUENT 14.0 turbulence module (Standard k-ε) is used to analyze the flow field characteristics. The component transport module (Species Transport) and the multiphase flow module (Multiphase) simulated the mass transfer phase transition of water vapor in the air. The governing equation is as follows:

$$\frac{\partial (\rho \emptyset)}{\partial \tau} + div(\rho u \emptyset) = div(\Gamma grad\phi) + s \quad (1)$$

Where: $\phi$is a general variable;

Γ is a generalized diffusion coefficient;

s is a generalized source term.

### 2.4 Criterion of wall condensation

Wall condensation conditions: When the absolute humidity $D_{air}$ of the air node around the wall surface is higher than the saturated absolute humidity $D_{wall}$ corresponding to the wall temperature, the wall surface is considered to be condensation.

Conditions for no condensation on the wall: Any time τ, when the absolute humidity $D_{air}$ of the air node around the wall is less than the saturated absolute humidity $D_{wall}$ corresponding to the wall temperature, the wall is not considered to be condensation

$$D_{wall} < D_{air} \quad (2)$$

## 3 SIMULATION RESULTS AND ANALYSIS

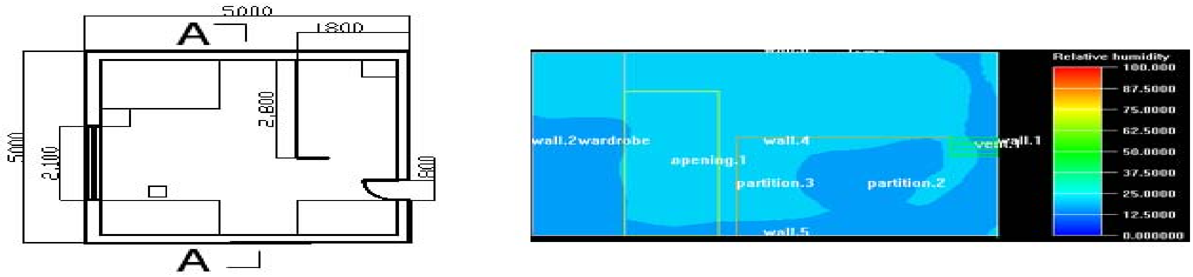
### 3.1 The result of the simulation without humidifier and the humidity diagram of each case.

For the first time, the simulation without a humidifier has been completed. The indoor humidity distribution is shown in Figure 2. It can be seen that the indoor humidity is about 25%

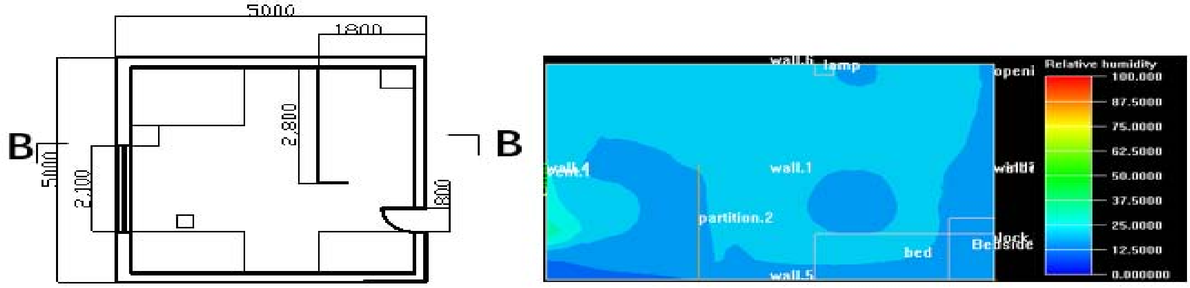
when the humidifier is not used in winter, which is lower than the indoor humidity comfort range.

This simulation verifies that the indoor humidity range is not in the comfort range without using a humidifier in winter and verifies the need for a humidifier in winter. In addition, it is necessary to study the placement position of the humidifier.

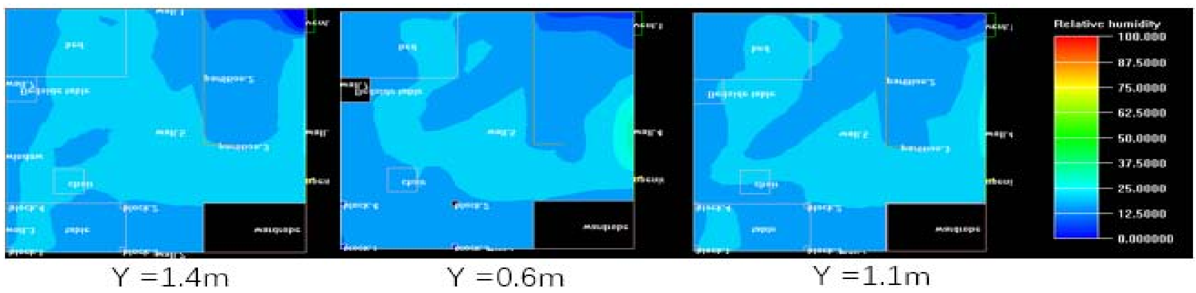
A total of 21 simulations were performed. Figure 3 shows the humidity of each simulation case. It can be seen that after using the humidifier, the indoor humidity environment is




The Humidity Plane Cut of Section A




The Humidity Plane Cut of Section B




The Humidity Plane Cut of Height Section

Figure 2 The Humidity Plane Cut of Case 1 (Initial conditions)

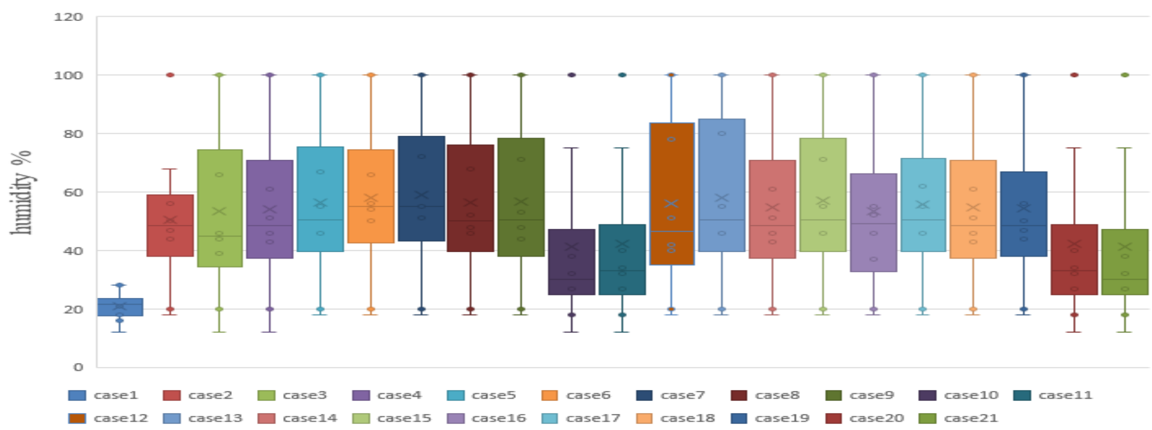



Figure 3 The Humidity Box Diagram of Each Case.

significantly improved. Under the ventilation mode of B, the indoor humidity is better than the ventilation mode A.

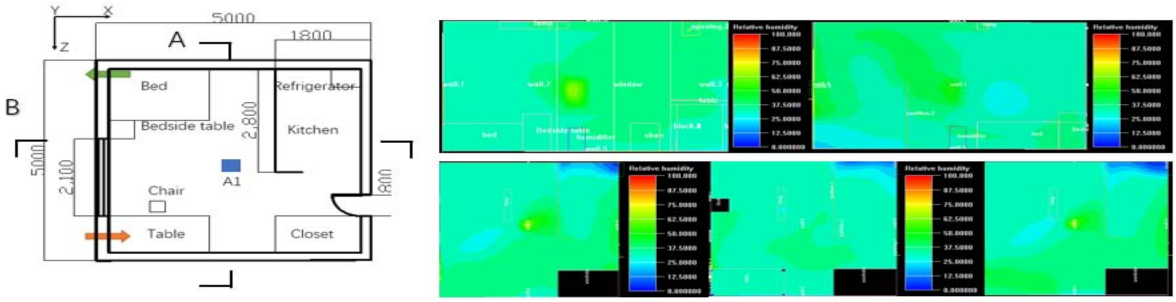
### 3.2 Influence of different ventilation methods on indoor humidity distribution

In Figure 3, it can be seen that the humidity environment of case 2 is very good, between 40% and 60%. However, in case 12 there are many parts of the humidity above the comfort range. The humidity plane distribution of case 2 and case 12 is shown in Figure 4.

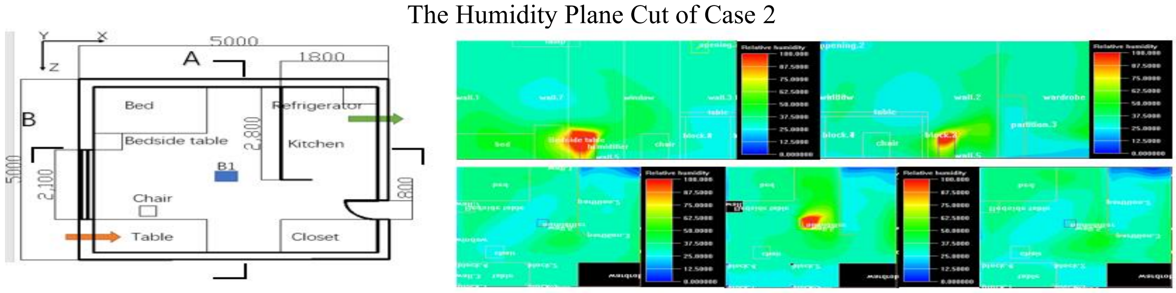
Figure 4 is a good illustration of the effect of different ventilation methods on the indoor humidity distribution with the same placement of the humidifier. In case 2, the indoor humidity is between 40% and 60%. The average humidity is around 50%. No obvious condensation in the room occurred. In case 12, the humidifier position is the same as in case 2, and the ventilation is different. Indoor humidity is mostly distributed between 40% and 60%. However, there is obvious condensation in the area around the humidifier, and the humidity in the centre of the room is high. The humidity in the room varies greatly. It can be concluded that the humidity distribution in the room is related to the ventilation mode, and the flow pattern of the indoor airflow affects the distribution of indoor humidity.

### 3.3 Influence of humidifier placement height on indoor humidity distribution

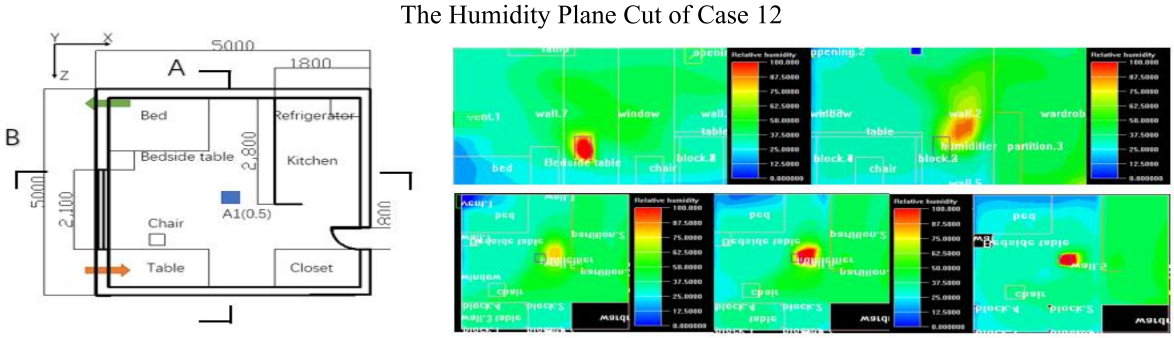
In Figure 4, case2 and case3 are used to analyse the effect of humidifier placement height on indoor humidity distribution under the same ventilation mode. Comparing case2 and case3, the humidifier is placed 0.5 meters away from the ground, and water mist gathers around the humidifier, which may cause condensation. The indoor average humidity of case3 is higher than the indoor average humidity of case2. and at the same time, the humidity in the near-ground area is low.




The Humidity Plane Cut of Case 2




The Humidity Plane Cut of Case 12

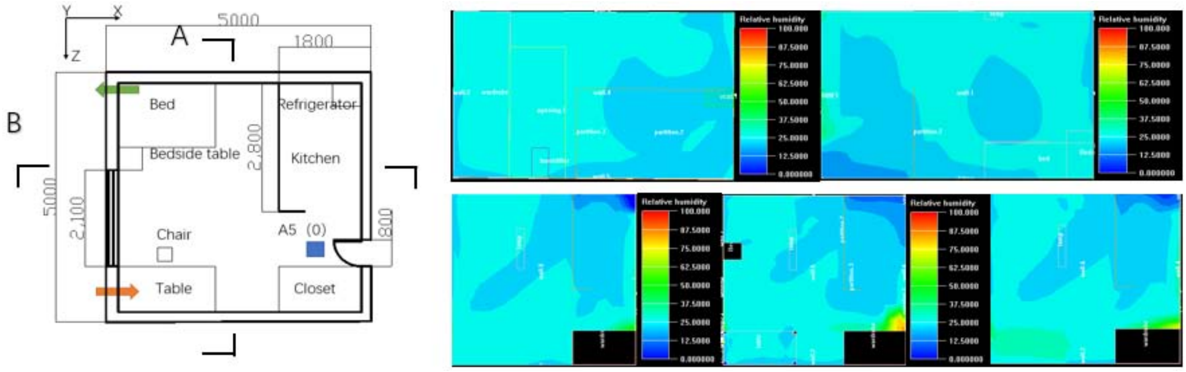



The Humidity Plane Cut of Case 3

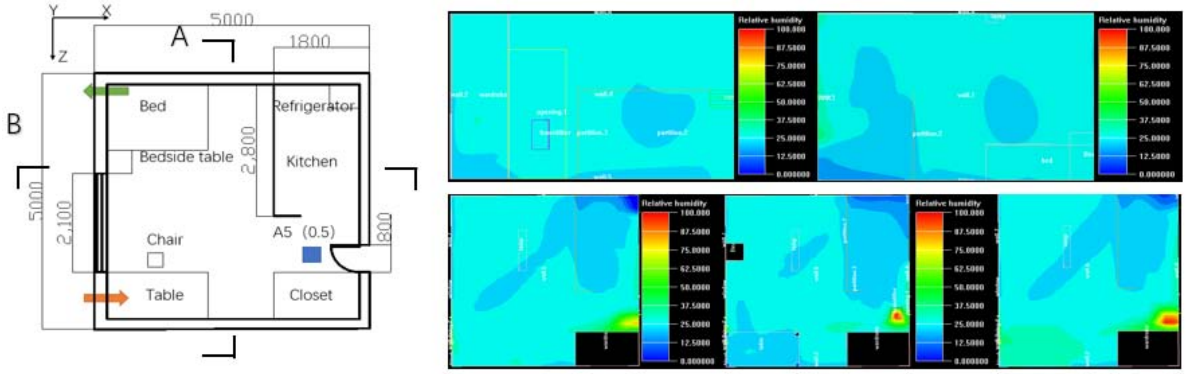
Figure 4 The Humidity Plane Cut of Case 2, Case 3 and case12

### 3.4 Influence of different humidifier placement positions on indoor humidity distribution

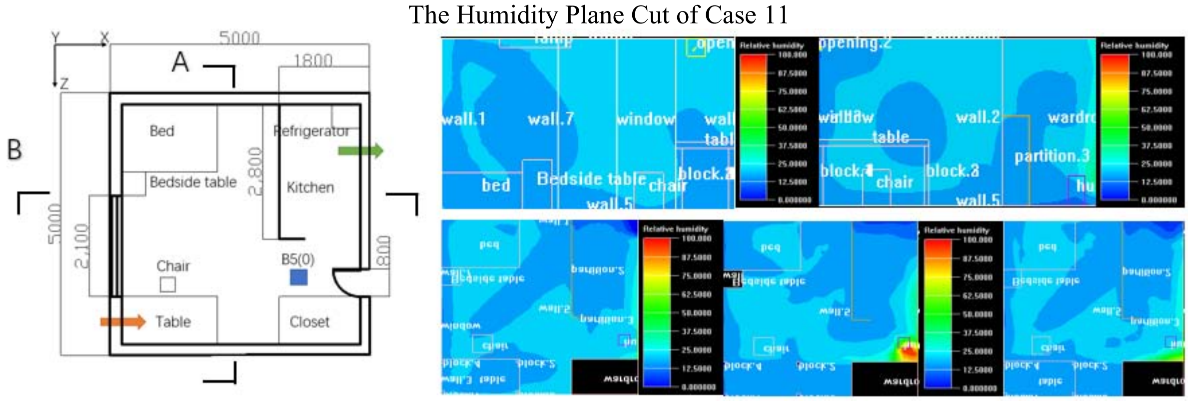
In addition, it can be clearly seen in Figure 3 that there are four cases of simulations and other significant differences. The humidity plane cut for these four cases are shown in Figure 5.



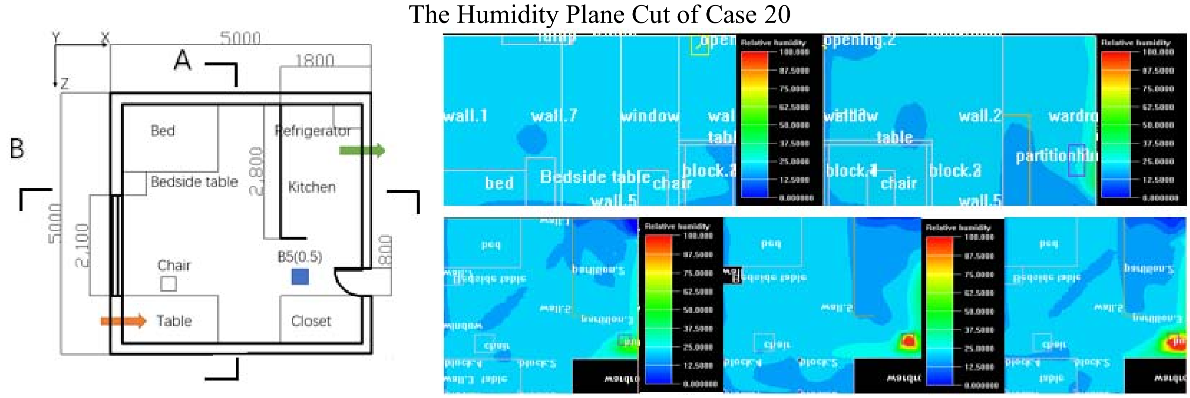

The Humidity Plane Cut of Case 10




The Humidity Plane Cut of Case 11




The Humidity Plane Cut of Case 20




The Humidity Plane Cut of Case 21

Figure 5 The Humidity Plane Cut of Case 10,11,20,21.

As can be seen from Figure 5, when the humidifier is placed beside the door, the humidifier does not improve the indoor humidity. The humidity in ventilation mode A is higher than the humidity in ventilation mode B. And when the humidifier is placed 0.5 meters above the ground, condensation may occur on the surface of the wardrobe of the room. The reason why the indoor humidity environment is not improved can be considered in the direction of air flow. When the humidifier is placed beside the door, the air at the door of the room is not well mixed. At the same time, the air flow on the refrigerator side is also poor. However, as can be seen from Figure 5, when the humidifier is placed 0.5m from the ground, the humidity of the room is slightly higher than the humidifier placed on the ground.

## 4 CONCLUSION

This paper establishes a mathematical model and uses FLUENT software to simulate the effects of ventilation on indoor humidity and condensation. The simulation results show that the ventilation mode and the placement of the humidifier have a great influence on the condensation distribution. The results can be summarized as follows:
1) The model can realistically simulate the effect of ventilation on the condensation distribution.
2) Within the scope of the nearby, the air just can hold limited capacity water vapor. The humidifier working efficiency was infected by the different position of humidifiers.
3) The humidity distribution in the room is related to the ventilation mode, and the flow pattern of the indoor airflow affects the distribution of indoor humidity. The room with the air supply and the return air outlets in the same direction, there is a difference in humidity on both sides of the room, and when the humidifier is used, the humidity on the other side of the room changes little. 4) The placement height of the humidifier also affects the indoor humidity distribution. When the humidifier is placed in a slightly higher position, the average humidity in the room will increase, and it will be easier to reach a comfortable humidity environment at a sleep height of 0.6 meters. But at the same time, there will be condensation of water near the humidifier.
5) The placement of the humidifier also has a great influence on the indoor humidity and humidity distribution. when the humidifier is placed beside the door, the humidifier does not improve the indoor humidity. When the humidifier is placed in the centre of the room, the humidity in the room is evenly distributed. When the humidifier is placed close to the wall, condensation occurs near the ground due to the low wall temperature.
6) From this simulation, it can be concluded that in the dry winter season, by arranging the position of the indoor vents and placing the humidifier reasonably, the humidity can reach a comfortable range while reducing the possibility of condensation.

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