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Experimental research on the indoor temperature and humidity fields in radiant ceiling air-conditioning system under natural ventilation

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Experimental research on the indoor temperature and humidity fields in radiant ceiling air-conditioning system under natural ventilation

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Abstract. In this paper, the indoor temperature and humidity fields of the air in a metal ceiling radiant panel air conditioning system with fresh air under natural ventilation were researched. The temperature and humidity distributions at different height and different position were compared. Through the computation analysis of partial pressure of water vapor, the self-recovery characteristics of humidity after the natural ventilation was discussed.

1. Introduction

Radiation ceiling air-conditioning system develops rapidly in the residential and office buildings in recent years, gaining more and more attention for its comfortable indoor environment [1, 2]. All the radiation ceiling air-conditioning systems put forward a common requirement that is the doors and windows should be closed to prevent condensation when it was running. So a bottleneck caused by this requirement appears, hindering the further application of the radiation ceiling air conditioning system [3, 4]. So, the influence on the temperature and humidity fields by the opening of windows occasionally becomes the concern of users and researchers. In this paper, the indoor temperature and humidity fields for metal ceiling radiant panel with fresh air conditioning system under natural ventilation was researched [5]. The change law of temperature and humidity fields in the experimental room under natural ventilation was discussed.

2. The experimental system

In the experimental system the construction area of the room is 10.8m², the surface area of the metal radiation ceiling panel is 8.1m², the new air outlet dimension is 60 x 12cm, the new outlet is located in the west side ceiling of the experimental room. The south and west sides of the room are the glass curtain walls where the windows able to be opened. The architecture drawing is shown in fig.1. The temperature and humidity recorders were arranged at different position and different height in the room, and the temperature and humidity of the air inside the room were recorded in real time. The positions of the measuring points are shown in fig.2. The position A is near the south outer window and the position B is near the west window. The temperature and humidity recorder were arranged at different height in two locations, with 0.2m, 0.45m, 0.75m and 1.1m distance from the top.



3. Experimental research on the indoor air temperature and humidity field in radiant ceiling air conditioning system under natural ventilation

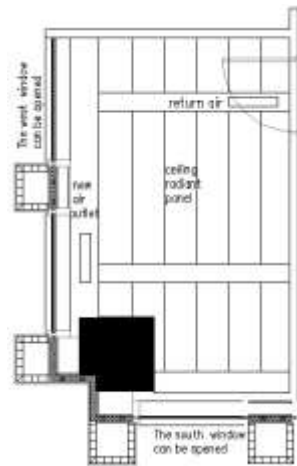


Figure 1. The architecture drawing

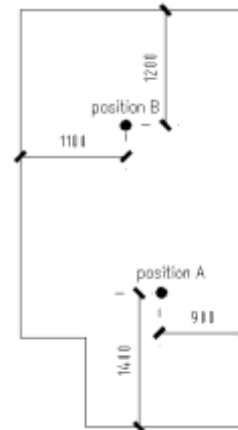


Figure 2. The position of the measuring points

The basic operating condition of the experimental system is described as follows: the surface temperature of the radiant panel is 20°C, the temperature of new air at the outlet is 19°C, the relative humidity of new air at the outlet was 70%, and the wind speed of the new air at the outlet is 0.32m/s. In the experiment, at a certain time the south window or the West window is opened to measure the wind speed of natural ventilation and closed after a period of time. And the system recovered before the windows were opened again.

The variation of the indoor temperature and humidity influenced by the opening of the south window was analyzed as a sample. In this sample, the average wind speed of the window was 0.8m/s. The south window was opened at 15:40pm and closed at 16:35pm.

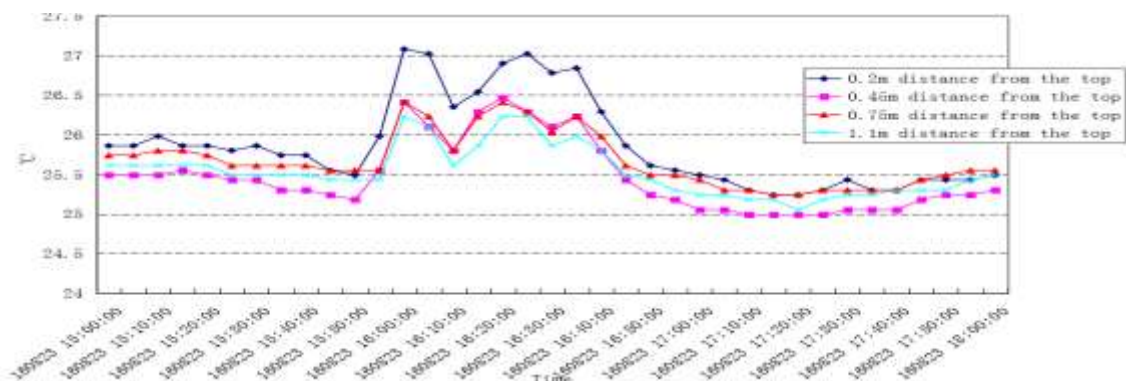


Figure 3. The distribution of temperature at different height at the position A

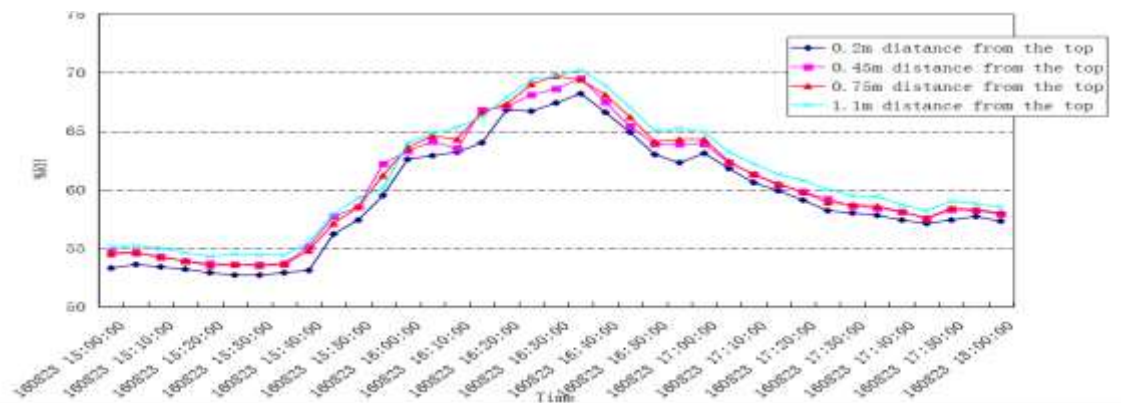


Figure 4. The distribution of humidity at different height at the position A

The changes of temperature and humidity at position A at different height are shown in Fig.3 and Fig.4, it can be seen from the figures that the changing tendencies of temperature and humidity at different height are similar, which when the south window is opened after 15:40, the indoor temperature and humidity increase obviously. The comparison between Fig. 3 and Fig. 4 shows that the increasing of humidity is a gradual process that reaches the maximum value when the window is closed, while the temperature increases rapidly and there is some fluctuation at the high point. The maximum temperature difference at different height at position A is 0.92°C and the maximum difference of humidity is 2.9%. The measuring position A is influenced greatly by the opening of the window, with the higher temperature and lower humidity at the location closer to the ceiling.

The changes of temperature and humidity at position B at different height are shown in Fig.5 and Fig.6, it can be seen that the changing tendencies of temperature and humidity at position B are similar to them at the position A after the opening of window. The maximum temperature difference at different height at position B is 0.8°C and the maximum difference of humidity is 2.6%. The distributions of temperature and humidity at position B is different from those at position A, with the lower temperature and higher humidity at the locations closer to the ceiling. This is because the measuring position B is far from the south window, which is mainly influenced by the top of radiation plate and fresh air. The temperature at the top of the radiation plate and the temperature of new air at the outlet are both lower than the indoor air temperature, leading to the air temperatures in top section of the room are lower than those in the bottom section

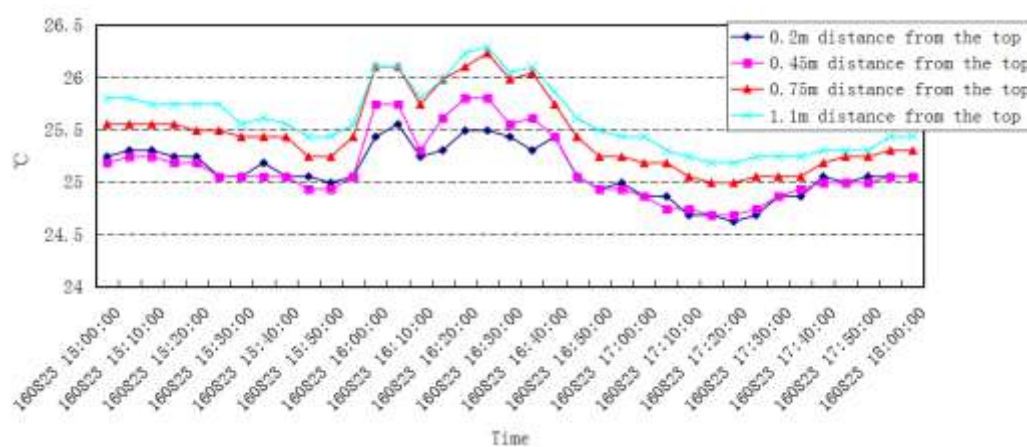


Figure 5. The distribution of temperature at different height at the position B

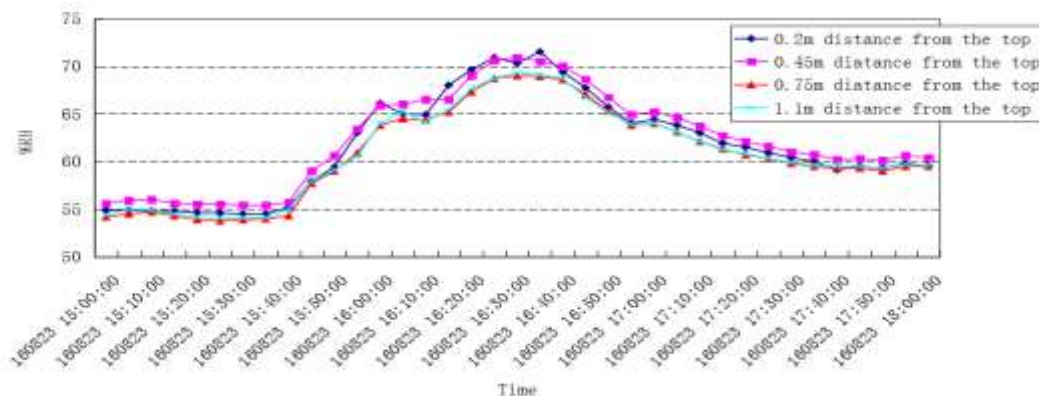


Figure 6. The distribution of humidity at different height at the position B

The data between position A and position B at different height was compared, and it was found that the difference of humidity is small, and the temperature difference is slightly big, with the higher air temperature nearby the opened window. It is indicated that the diffusion of humidity is better than that of the temperature, and the humidity field of the room is more uniform.

4. Study on the self-recovery characteristics of humidity after the natural ventilation

The indoor temperature and humidity field are mainly determined by the outdoor air, indoor fresh air and radiant cooling plate under natural ventilation. Indoor temperature and humidity will change when the window is opened, due to outdoor high temperature and high humidity air flows into the room. After the window is closed, the indoor humidity will be recovered slowly by the fresh air dehumidification system. The diffusion of water molecules in the air is determined by the partial pressure of water vapor, and the partial pressure of water vapor represents the absolute moisture content in the air. So, the self-recovery ability of indoor humidity was studied through analyzing the change rule of average partial pressure of water vapor in this paper.

The partial pressure of water vapor calculation formula is defined as

$$\lg P = 8.10765 - \frac{1750.286}{(t + 235.0)} \quad (1)$$

$$P_s = 133.3 \times P \times \phi \quad (2)$$

Where P is water vapor saturation pressure, P_s is partial pressure of water vapor, ϕ is relative humidity and t is air temperature.

The changes of partial pressure of water vapor in the experimental room before and after the natural ventilation are shown in Fig.7. It can be seen that change of outdoor partial pressure of water vapor was small, keeping at 2400~2600Pa during the experiment. The indoor partial pressure of water vapor was 1780Pa before the nature ventilation, and half an hour later the indoor partial pressure of water vapor increased to 2130Pa after the opening of the window, for the outdoor pressure is higher than the indoor pressure, resulting in outdoor water vapor flow into the room. The indoor partial pressure of water vapor was 2347Pa and the outdoor partial pressure of water vapor was 2425Pa at the same time after nature ventilation, the partial pressure of water vapor in the indoor air were very close to those in the outdoor air. The ventilation lasted 55 minutes, when the window was closed the indoor water partial pressure of water vapor decreased gradually with self-recovery for the same time. The last indoor partial pressure of water vapor was 1898Pa, which was slightly higher than the pressure before the window opened. It was indicated that under the experiment condition the indoor partial pressure of water vapor cannot completely return to the state before the natural ventilation, and it must take longer time to remove the increasing of indoor humidity caused by the natural ventilation.

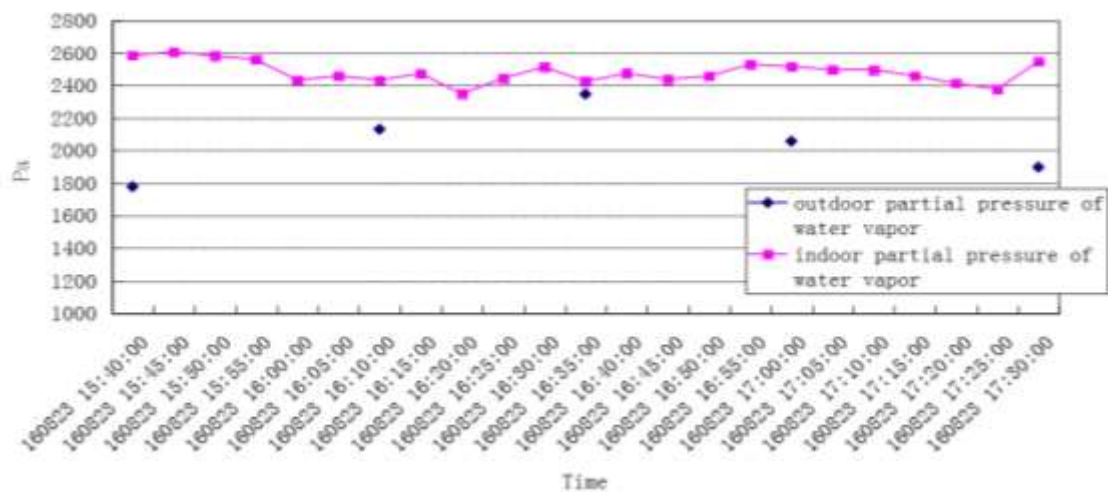


Figure 7. The change of partial pressure of water vapor

5. Conclusion

Indoor temperature and humidity field of radiation ceiling air conditioning system changed obviously under natural ventilation. The temperature near the opened window changed greater than the other. The diffusion of indoor humidity is better than the temperature and humidity changes at different positions in the room evenly. The higher the temperature is, the higher the temperature is, the smaller the humidity is; the other is the contrary. Under natural ventilation, the partial pressure of water vapor in the room increases gradually, until the partial pressure is close to the outside. When the natural ventilation is stopped, the indoor water vapor pressure will gradually restore.

Acknowledgments

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