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Study on Influencing Factors of Night Ventilation in Office Rooms

Zhaojun Wang
Ph.D.
Associate Professor

Xiaoli Sun
Master Student

School of Municipal & Environmental Engineering, Harbin Institute of Technology
Harbin P.R.China, 150090
wzjw02@yahoo.com.cn

Abstract: A mathematical and physical model on night ventilation is set up. The fields of indoor air temperature, air velocity and thermal comfort are simulated using Airpak software. Some main influencing factors of night ventilation in office rooms in Harbin are simulated and analyzed. The results show that the inlet velocity and area can influence the effects of night ventilation. When the inlet velocity is 2.5m/s, both indoor air temperature and air velocity meet ASHRAE standard 55-2004. Indoor environment may be improved further at the inlet velocity of 3.5m/s; however, subjects sitting near the windows feel a draft and are uncomfortable. If the inlet area is 0.15m^2, the indoor climate at 1.1m level does not satisfy thermal comfort requirements. On the other hand, it meet the ASHRAE standard when the inlet area is 0.30m^2.

Key words: office room; night ventilation; thermal environment; numerical simulation; influencing factors

1. INTRODUCTION

Building energy is about 25% of all the energy consumption in China at present. With the development of building industry, building energy increases about 15%。Thus energy saving has been the most important thing for air-conditioning design. Air distribution in the office rooms with night ventilation are simulated in Harbin in this paper. The aim is to discuss the feasibility to improve indoor thermal environment and indoor air quality, as well as to decrease energy consumption of air-conditioning system by using night ventilation technology.

There are some factors which influence the effect of night ventilation. The important ones such as inlet velocity and inlet area are simulated and analyzed here.

2. PHYSICAL MODEL

The office room model with night ventilation is seen in Fig.1. Its length, width and height are 9.0m, 3.6m and 3.6m, separately. In Fig.1, number 1 denotes openable window, numbers 2 and 3 denote fixed windows. Numbers 4 to number 10 present bookcases, fluorescence lights, person A, computers, desks, and person B. The openable window of which size is 1.2m height and 0.5m.width is inlet and outlet. It is located in the exterior wall, and 0.9m above the floor.

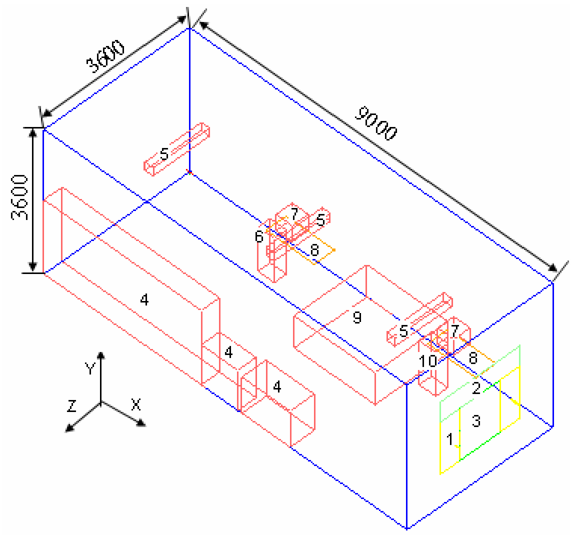

Fig.1 Physical model of night ventilation

3. PARAMETERS OF PHYSICAL MODEL

3.1 Selection on Parameters of Physical Model

(1) Two sedentary persons are in the room with the heat loss 75W/person. (2) There are three lights and the power of each light is 50W. (3) There are two computers and the power of each computer is 173W.

3.2 Boundary Conditions

The following simulation is given based on steady state. During the period of night ventilation, the environmental physical parameters were measured.

According to the tested results of August 1, 2004, the outdoor atmospheric pressure and air temperature is 101325Pa and 24.8℃ at 8:00 o'clock[1]. The third boundary condition is used for the exterior wall of which the convection heat transfer coefficient is 23W/(m^2·K). The first boundary condition is used for the exterior window of which the temperature is 30℃. The tested inlet velocity and temperature are 2.1m/s and 24.8 , separately. The surface temperatures of the other three walls are 26℃, 26.2℃ and 26.1℃ separately.

4. MATHEMATICAL MODEL

The k-ε model is used for night ventilation[1]. The hexahedron configuration grid is used to separate the calculated areas. The step of the slotted areas is no more than 1/20 of the physical model. The minimum fluid gap is 4, for solid boundary is 4, for cylinder and triangle are 4. The maximum ratio of width and height of each cell is 1.5:1. The whole grips are about 250000 of the model room.

The SIMPLE arithmetic is used to deal with the question of coupling press and velocity. The pressure coefficient is 0.7, the velocity is 0.3, the bulk force is 0.1, and the turbulent kinetic item and the dissipation energy item are 0.6. The others are 1.0.

There are two radiant models in AirPak software. They are Surface-to-surface and discrete ordinates (DO). The effect radiation of different surfaces is uneven in this paper, and there are symmetric boundary conditions, so DO model is used here.

Solar radiation may influence night ventilation; however, for the model room in the north, it is influenced by the sun only after 16:00 pm.

For night natural ventilation, the fluid is compressible because of the buoyancy of natural ventilation. The buoyancy adds a source item to the equations k and ε. The coefficients in the model are shown in Tab.1.

Tab. 1 Coefficients in the model

C_1	C_2	C_3	C_μ	σ_k	σ_ε	σ_T
1.44	1.92	1	1.44	1.00	1.30	0.90~1.00

5. ANALYSIS ON INLET VELOCITY

The norm of heating, ventilating and air conditioning suggests that the mean outdoor velocity is 3.5m/s in summer in Harbin. And the tested velocity is 2.1m/s. Two inlet velocities are simulated. One is 2.5m/s, the other one is 3.5m/s.

5.1 Air Temperature

The fields of vertical air temperature in the middle cross section along z axis with different inlet velocities are illustrated in Fig.2 and 3. We can see that the vertical temperatures are below 26.5℃ and 25.8℃, separately, which are lower than 27℃ and meet ASHRAE standard 55-2004.

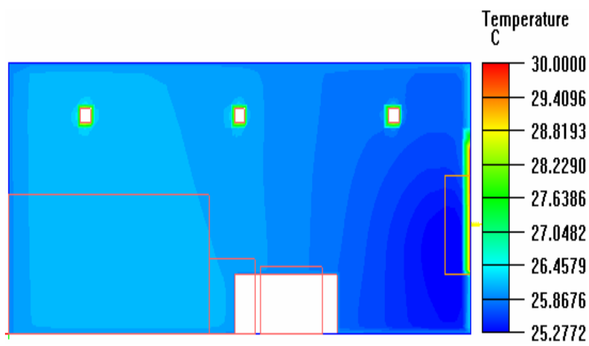

Fig. 2 Vertical air temperatures distribution in the middle cross section at velocity 2.5m/s

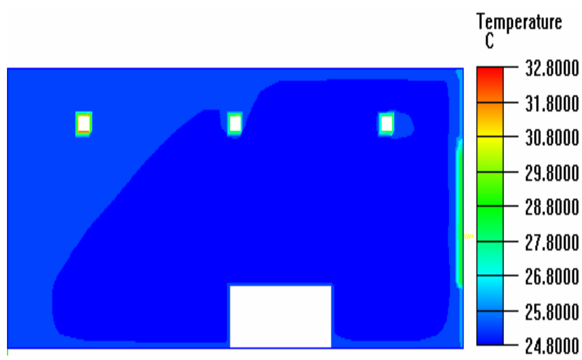

Fig. 3 Vertical air temperatures distribution in the middle cross section at velocity 3.5m/s

The fields of air temperature in 1.1m above the floor with different inlet velocities are shown in Fig.4 and 5. From Fig.4, we can see that the horizontal temperature difference is large from the exterior wall to the inner wall. The temperature near the exterior wall is 25℃, while it is 26.3℃ near the inner wall. The temperatures near two subjects are almost the same. The indoor air temperature is about 25℃ in most areas in Fig.5. The temperatures near two subjects are lower than that of Fig.4.

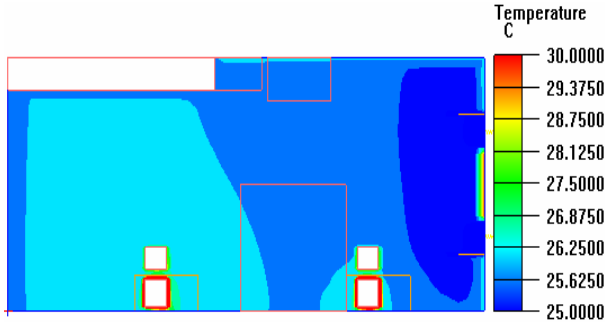

Fig. 4 Air temperatures distribution in 1.1m above the floor at inlet velocity 2.5m/s

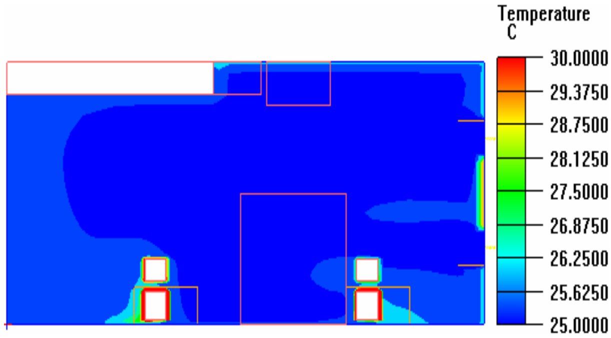

Fig. 5 Air temperatures distribution in 1.1m above the floor at inlet velocity 3.5m/s

5.2 Air Velocity

The fields of vertical air velocity in the middle cross section with different inlet velocities are illustrated in Fig.6 and 7. From Fig.6, we can see that the vertical air velocity is about 0.1m/s in most areas, which meet thermal comfort standard. The vertical air velocity is more than 0.3m/s in the area near the exterior wall in Fig.7, which does not meet thermal comfort standard. The subject will feel draft.

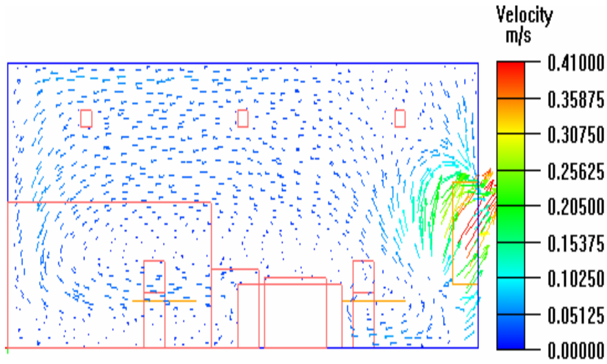

Fig. 6 Vertical air velocities distribution in the middle cross section (2.5m/s)

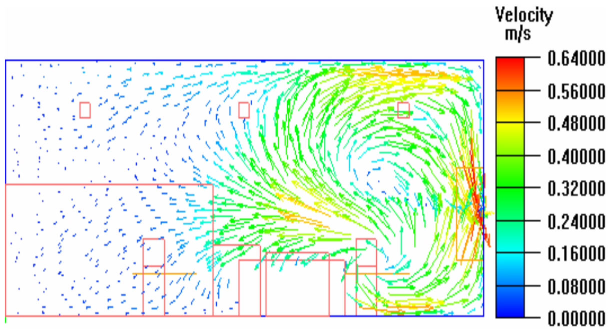

Fig. 7 Vertical air velocities distribution in the middle cross section (3.5m/s)

The fields of air velocity in 1.1m above the floor with different inlet velocities are shown in Fig.8 and 9.

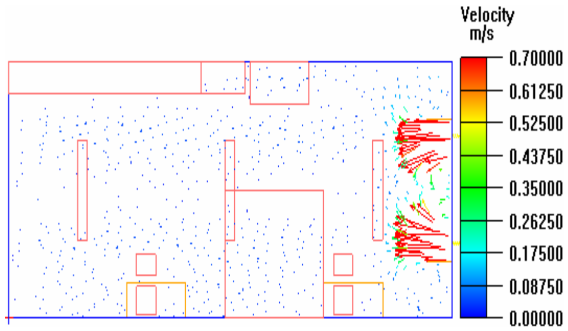

Fig. 8 Air velocities distribution in 1.1m above the floor at inlet velocity 2.5m/s

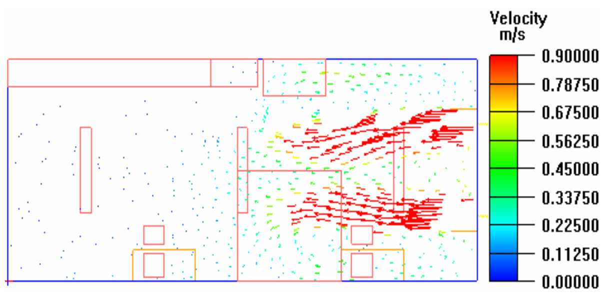

Fig. 9 Air velocities distribution in 1.1m above the floor at inlet velocity 3.5m/s

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The air velocity is less than 0.1m/s in Fig.8, which meets thermal comfort standard. While it is more than 0.3m/s in the area near the exterior wall in Fig.9, which does not meet thermal comfort standard. The subject will feel draft.

5.3 Predicted Percentage of Dissatisfied (PPD)

The fields of vertical PPD in the middle cross section with different inlet velocities are shown in Fig.10 and 11. We know that the vertical PPD is less than 20% in most areas, which meet thermal comfort standard.

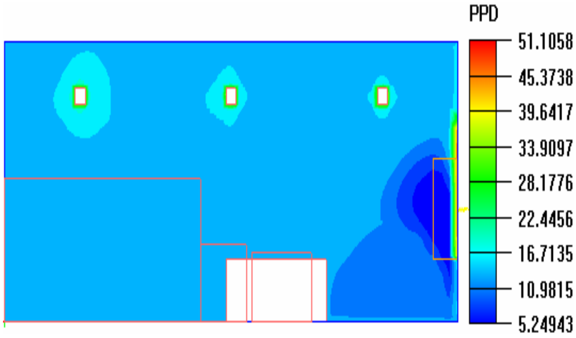

Fig. 10 Vertical PPD distribution in the middle cross section at velocity 2.5m/s

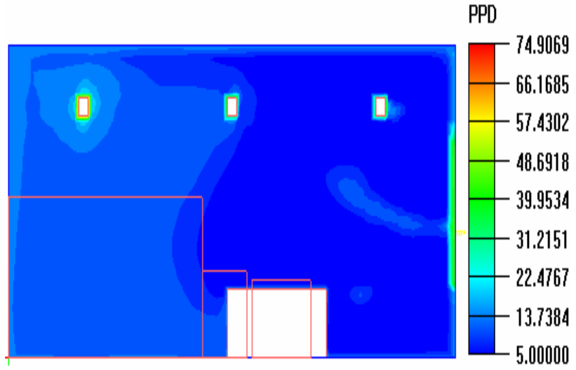

Fig. 11 Vertical PPD distribution in the middle cross section at velocity 3.5m/s

The fields of PPD in 1.1m above the floor with different inlet velocities are seen in Fig.12 and 13. From Fig.12, we know that PPD is about 15% in most areas, while PPD is more than 20% near two subjects, which does not meet thermal comfort standard. PPD is about 10% in most areas in Fig.13, the subject near the inner wall feel uncomfortable because its PPD is more than 20%.

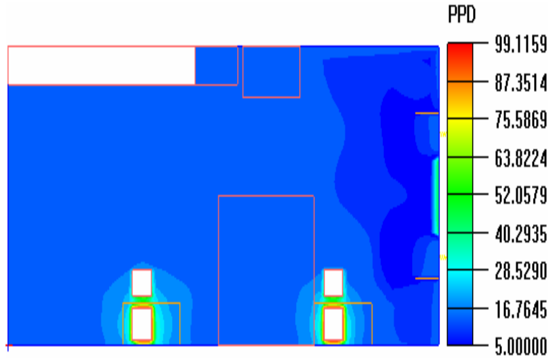

Fig. 12 PPD distribution in 1.1m above the floor at inlet velocity 2.5m/s

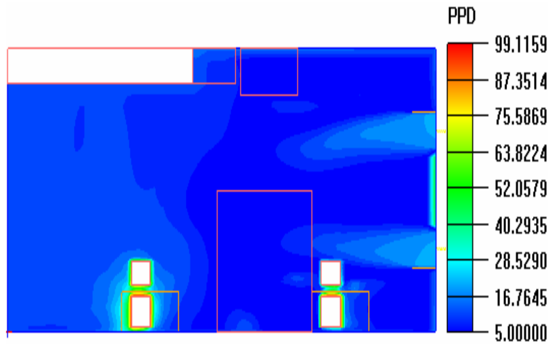

Fig. 13 PPD distribution in 1.1m above the floor at inlet velocity 3.5m/s

6. ANALYSIS ON INLET AREA

Two inlet areas are simulated. One is 0.15m^2, the other one is 0.3m^2. The sizes of two inlets are 0.3m× 0.5m and 0.6m×0.5m, separately.

6.1 Air Temperature

The fields of vertical air temperature in the middle cross section with different inlet areas are illustrated in Fig.14 and 15. The vertical temperature is below 26.5℃ and 26.2℃, separately, which are lower than 27℃ and meet thermal comfort standard.

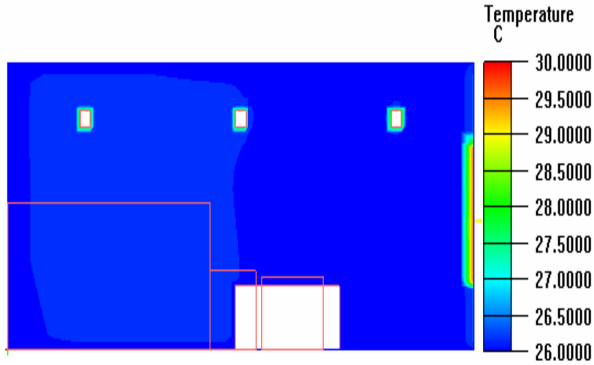

Fig. 14 Vertical air temperatures distribution in the middle cross section (0.15m^2)

Fig. 15 Vertical air temperatures distribution in the middle cross section (0.30m^2)

The fields of air temperature in 1.1m above the floor with different inlet areas are shown in Fig.16 and 17. The vertical temperature is below 26.5℃ and 26.3℃, separately, which are lower than 27℃ and meet thermal comfort standard.

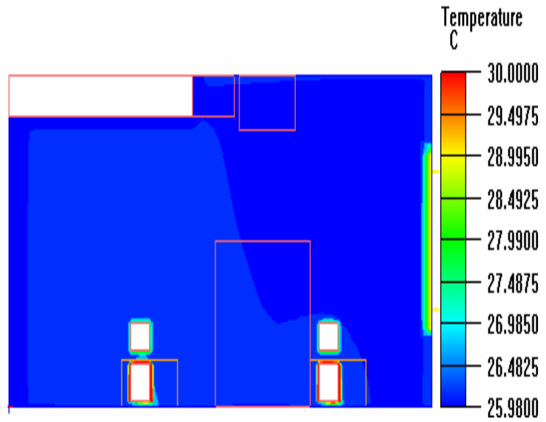

Fig. 16 Air temperatures distribution in 1.1m above the floor at inlet area 0.15m^2

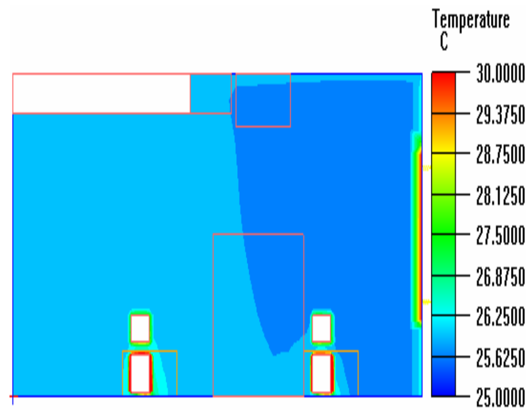

Fig. 17 Air temperatures distribution in 1.1m above the floor at inlet area 0.30m^2

6.2 Air Velocity

The fields of vertical air velocity in the middle cross section with different inlet areas are seen in Fig.18 and 19. The vertical air velocity is about 0.1m/s in most areas, which meet thermal comfort standard.

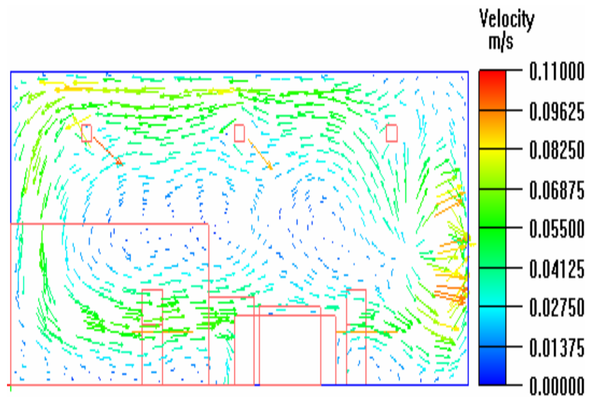

Fig. 18 Vertical Air velocities distribution in the middle cross section (0.15m^2)

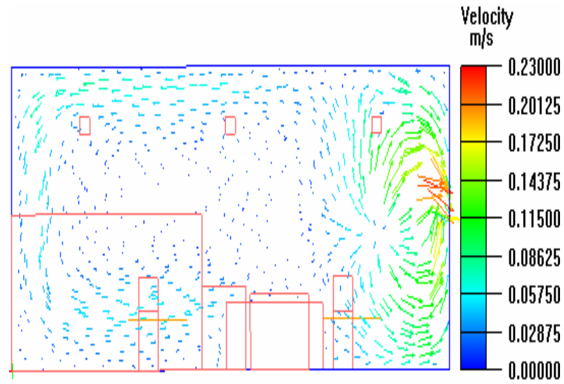

Fig. 19 Vertical Air velocities distribution in the middle cross section (0.30m^2)

The fields of air velocity in 1.1m above the floor with different inlet areas are shown in Fig.20 and 21. The air velocity is less than 0.1m/s, which meets thermal comfort standard.

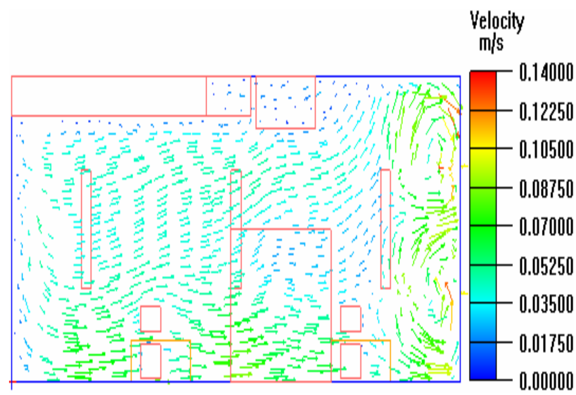

Fig. 20 Air velocities in 1.1m above the floor at inlet area of 0.15m^2

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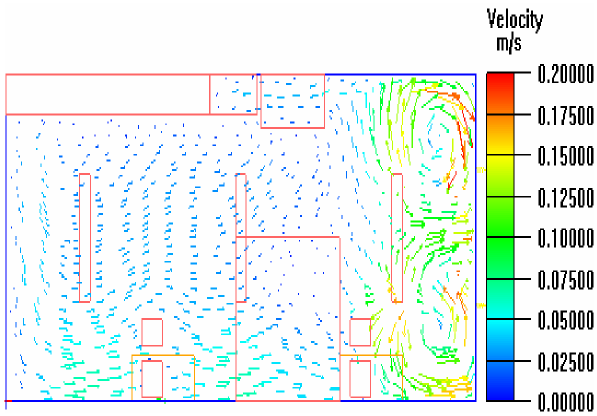

Fig. 21 Air velocities in 1.1m above the floor at inlet area of 0.30m^2

6.3 PPD

The fields of vertical PPD in the middle cross section with different inlet areas are given in Fig.22 and 23. The vertical PPD is less than 20% in most areas, which meet thermal comfort standard.

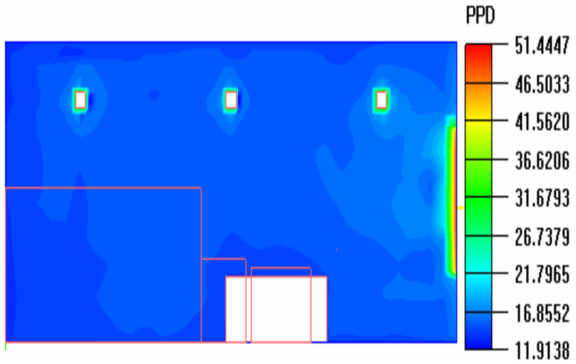

Fig. 22 Vertical PPD distribution in the middle cross section (0.15m^2)

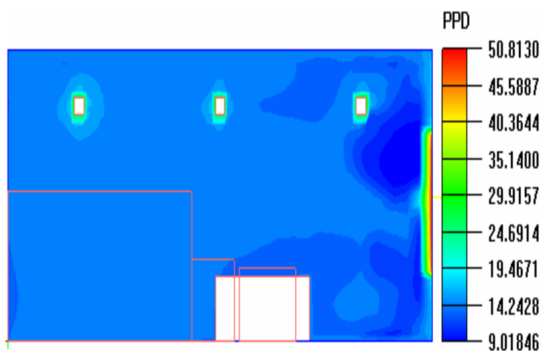

Fig. 23 Vertical PPD distribution in the middle cross section (0.30m^2)

The fields of PPD in 1.1m above the floor with different inlet areas are seen in Fig.24 and 25. From Fig.24, we know that PPD is about 21.9% in most areas, while PPD is more than 20% near two subjects, which does not meet thermal comfort standard. PPD is about 19.3% in most areas in Fig.25, and it is less than 20% near two subjects.

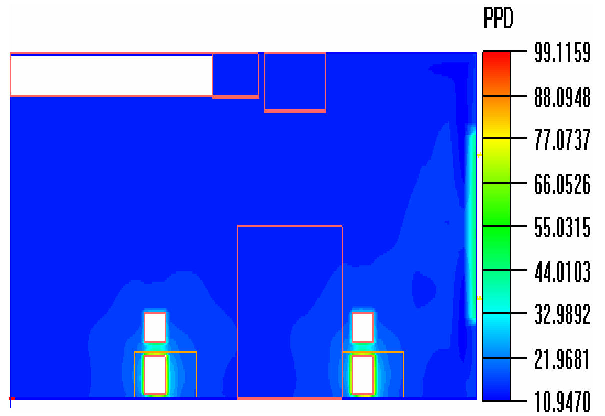

Fig. 24 PPD distribution in 1.1m above the floor at inlet area 0.15m^2

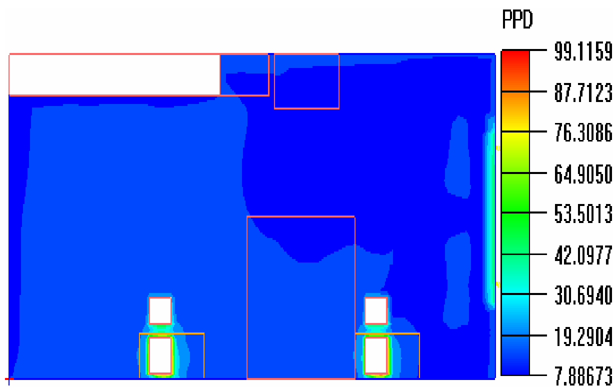

Fig. 25 PPD distribution in 1.1m above the floor at inlet area 0.30m^2

7. CONCLUSIONS

The results show that the air velocity and area of inlet can influence the effect of night ventilation. When the inlet velocity is 2.5m/s, both indoor air temperature and velocity meet ASHRAE standard 55-2004. And indoor environment may be improved further at the inlet velocity of 3.5m/s, however, subjects near the open windows feel draft and uncomfortable. If the area of inlet is 0.15m^2, the indoor climate at 1.1m level does not satisfy thermal comfort requirements. On the other hand, it meet ASHRAE standard at the inlet area of 0.30m^2.

It is applicable to use night ventilation technology in cold area to improve indoor thermal environment and indoor air quality, as well as to decrease energy consumption of air-conditioning system.

ACKNOWLEDGMENTS

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[1] Xiaoli Sun. Study on night ventilation to improve indoor thermal environment in office rooms in cold area[D]. Harbin: Harbin Institute of Technology, 2006.23~30. (In Chinese)