

Numerical and Experimental Study on Indoor Air Distribution and Quality

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Abstract. To optimize and control the indoor air distribution and quality, the indoor temperature and humidity were measured based on indoor fresh air system. The one measurement was indoor temperature and humidity in both cases of return air and without return air in winter respectively. The other was indoor temperature and humidity in both cases of return air and without return air in summer respectively. In addition, the test room environment was simulated using the finite element analysis software of ANSYS. Through setting a variety of air organization operating modes, the best solution of indoor air flow could be obtained.

Introduction

China has experienced rapid economic growth and urbanization in the past three decades^[1]. Along with this process, a large number of buildings have been built. Improvement of indoor air quality and protection of human health are important goals for contemporary architectural environments^[2]. Indoor air distribution and quality is important for architectural environments. It has been reported that the over-standard rate of formaldehyde and TVOC in underground buildings has reached 66.7 % and 77.8 % respectively in Xi'an^[3]. Emissions of formaldehyde and TVOC are influenced by many environment factors^[4-6], such as temperature, humidity, air velocity and merchandise materials.

To investigate the optimal control method of indoor air distribution and quality, indoor fresh air quantity is first obtained, and it is a key factor for indoor air quality. Fresh air can help wipe off indoor pollutants, which is diluted to the allowed range. The investigation on indoor air quality plays significant role in the field of controlling indoor air pollution. To control the indoor thermal environment effectively, furthermore, the return fan is being added to acquire the formation of organized exhaust. However, there are less quantitative researches on the effects of fresh air on the improvement of the thermal environment so far.

Measurement methods

The reception room on the third floor was selected for the test room. Testing equipment was installed. The acquired and heat pump data were collected in the data collection system. Based on the computational fluid dynamics (CFD) software of ANSYS, the numerical model of the indoor environment was established. After the model validation, ventilation scheme are optimized by the different working conditions.

Test scheme The methods of indoor and outdoor temperature and humidity test are described as followed. Two blowers were equipped in the system. And they were connected with two supplied outlets of fresh air respectively, as shown in Fig. 1. The rated volume flow of fresh air was 135 m³/h, and the volume flow could be adjusted. The measurement contents of fresh air system were indoor temperature and humidity conditions in winter and summer with and without return air. During the debugging period, six sets of indoor temperature and humidity measuring instrument were placed in three different place, two of the same plane position instrument settings in different heights, be away

from the floor one meter and two meters respectively. According to the requirement of external temperature conditions, the operation was carried out in the coldest and hottest month. Therefore, in our work, the winter and summer were selected, and each phase test kept for two weeks. Two stages arranged before and after the New Year's Day in 2015 and before and after July in 2015 respectively. Apparatus in different places included six sets of indoor temperature and humidity testing instrument, two of the same plane position instrument settings in different heights. The distances between the apparatus and floor were 1 m and 2 m, respectively. And an outdoor temperature and humidity meter was decorated on the outdoors wall of the testing room. Two weeks of each phase testing time specific arrangement was as followed. The one was that testing indoor and outdoor temperature and humidity conditions in the case of indoor fan back closure in the measurement of the first week. The other was the testing indoor and outdoor temperature and humidity in the case of open the indoor fan back in the first week.

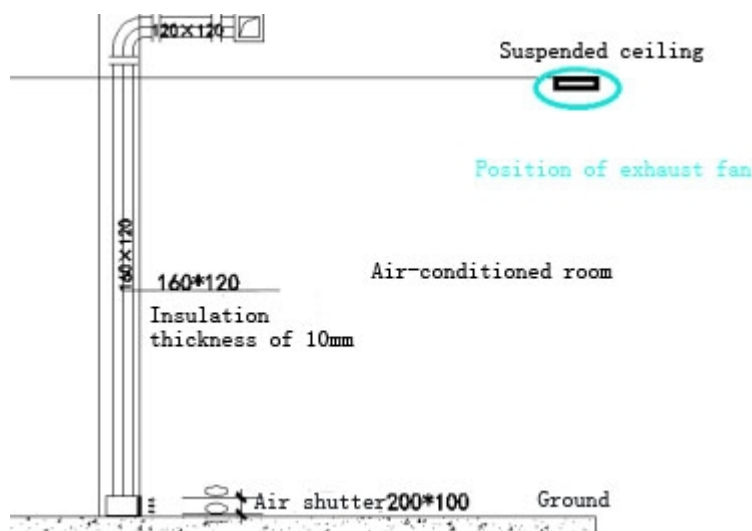


Fig.1 Schematic of blower installation and indoor temperature and humidity test in winter and summer

Data analysis During the test, the temperatures of indoor six regions and outdoor were obtained by temperature sensors. The results of temperatures in a day and in the entire measurement period were given in Table 1, Fig. 2 and Fig. 3 respectively. From the measurements, we could find that the outdoor temperature had a great influence on the indoor temperature. Similarly, the measurements results of humidity were listed in Table 2, Fig.4 and Fig.5. Through comparative analysis, the change trend of temperature and humidity were almost identical.

Table 1 Change of temperatures in a day

Time	Temperature of region 1 (°C)	Temperature of region 2 (°C)	Temperature of region 3 (°C)	Temperature of region 4 (°C)	Temperature of region 5 (°C)	Temperature of region 6 (°C)	Outdoor temperature (°C)
0:00	22.1	23.2	22.3	22.2	23.2	24.2	21.9
1:00	22	22.9	22.1	22	22.9	24	21.7
2:00	21.7	22.7	21.9	21.7	22.8	23.8	21.3
3:00	21.5	22.4	21.7	21.5	22.4	23.5	21.3
4:00	21.3	22.2	21.4	21.2	22.3	23.4	21.2
5:00	21	22	21.3	21.1	22	23.1	21.2
6:00	20.9	21.9	21.1	20.9	21.9	23	21.2
7:00	20.8	21.8	20.9	20.9	21.9	23	21.1
8:00	20.7	21.8	20.9	20.8	21.7	22.8	20.9
9:00	22	23.5	24	23.3	23.5	23.6	22
10:00	24.3	26.5	26.7	26.4	26.4	25.9	22.6
11:00	25	27.2	27.7	27.1	27.1	26.6	23.2
12:00	25.4	27.4	27.6	27.1	27.2	27	23.1
13:00	25.9	28.2	28.5	28	28	27.6	22.7
14:00	25.7	27.6	27.7	27.4	27.5	27.4	21.7
15:00	26.1	28.1	28	27.8	28	27.8	21.3
16:00	26.3	28.3	28.2	28	28.2	28	21
17:00	26.5	28.4	28.4	28.2	28.4	28.3	20.2
18:00	26	27.9	28	27.5	27.7	27.7	19.5
19:00	25.9	28	27.9	27.6	28	28.1	18.9
20:00	24.5	25.6	25.3	24.7	25.8	26.3	18.6
21:00	23.8	24.7	24.3	23.8	24.4	25.5	18.5
22:00	23.3	24.2	23.9	23.4	24.1	25	18.2
23:00	22.8	23.9	22.7	22.8	23.3	24.8	18.4

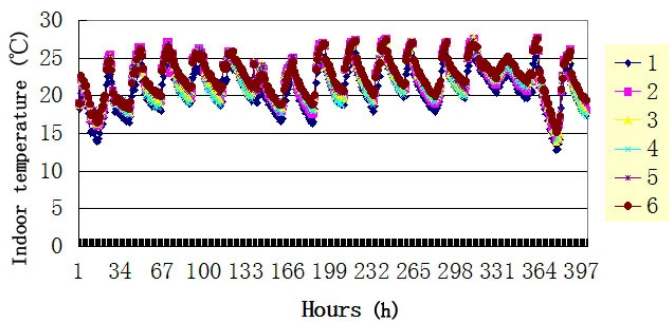


Fig.2 Measurements of indoor temperatures

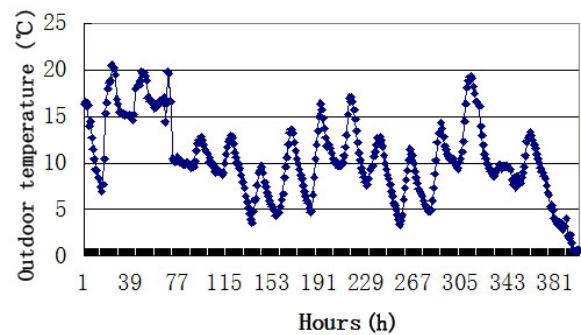


Fig. 3 Measurements of outdoor temperature

Table 2 Change of humidity in a day

Time	Humidity of region 1 (%)	Humidity of region 2 (%)	Humidity of region 3 (%)	Humidity of region 4 (%)	Humidity of region 5 (%)	Humidity of region 6 (%)	Outdoor humidity (%)
0:00	25.2	24.5	24.9	24.8	23.8	22.2	27.4
1:00	25.6	24.9	25.6	25.2	24.2	22.7	27.8
2:00	25.7	25	25.5	25.2	24.1	22.8	27.8
3:00	25.7	25	25.6	25.2	24.4	22.7	27.8
4:00	25.9	25.1	25.7	25.5	24.5	22.8	27.9
5:00	26.1	25.3	25.8	25.5	25.1	23	27.8
6:00	26.4	25.5	26.1	26	25.1	23.3	27.9
7:00	26.5	25.8	26.4	26.3	25.1	23.4	28.1
8:00	26.9	26.2	26.6	26.4	25.5	23.9	28.4
9:00	26.3	24.9	23.4	24	24.3	23.7	28
10:00	24.2	22	20.9	20.9	21.5	22	27.9
11:00	23.7	21.7	20.3	20.6	21.2	21.8	28.4
12:00	23.6	21.8	20.7	21	21.2	21.6	29.2
13:00	23.7	21.7	20.5	20.6	21.2	21.6	31
14:00	24.5	22.8	21.8	21.7	22	22.2	33.6
15:00	23.8	22.1	21.3	21.3	21.5	21.8	34.7
16:00	23.7	22.1	21.4	21.1	21.5	21.6	35.1
17:00	23.5	22	21.2	21.1	21.4	21.6	36.6
18:00	25.5	23.8	22.9	23.1	23.2	23.5	44.4
19:00	26.6	24.2	23.4	23.5	23.4	23.6	45.5
20:00	28.2	27.3	26.8	27.2	26.1	25.8	46.1
21:00	29.4	28.8	28.4	28.8	28.1	26.6	45.6
22:00	29.9	29.4	28.8	29.2	28.5	27.2	45.7
23:00	30.6	29.9	30.9	30.1	29.6	27.4	43.5

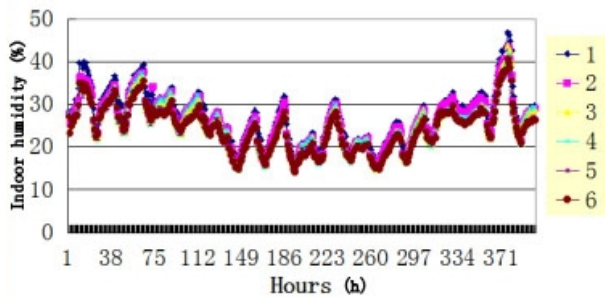


Fig.4 Measurements of indoor humidity

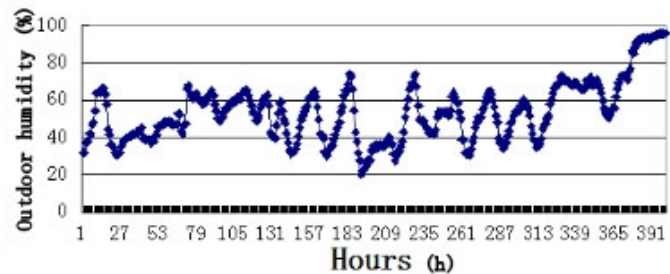


Fig.5 Measurements of outdoor humidity

Finite element simulation of CFD for scheme optimization

The computational fluid dynamics software of ANSYS was employed to simulate the air flow performance in the testing room. Test room finite element model is shown in Fig. 6. And the setting parameters during simulations are listed in Table 3. The air velocities and temperature of air were 0.2 m/s, 0.3 m/s, 294.7 K and 298 K respectively. Firstly, according to the measured data, the accuracy of finite element model was validated. And then a variety of operating cases were set to optimize the indoor air flow organization scheme.

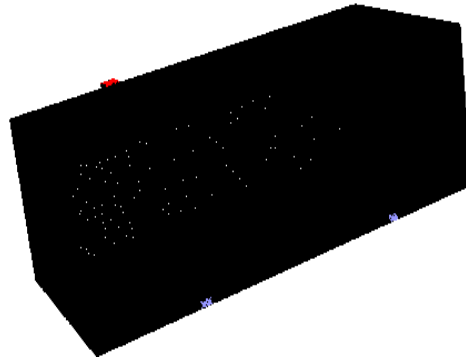


Fig. 6 Test room finite element model

Table 3 Setting parameters of simulations

Item	Air velocity (m/s)	Temperature (K)
Case 1	0.2	294.7
Case 2	0.3	298
Case 3	0.2	298
Case 4	0.3	294.7

The task of air flow organization was organizing the indoor air flow reasonably. The adjusted temperature, humidity and velocity of the indoor air could meet the requirement of health and comfort. Four main factors of affecting the human thermal comfort were the type of air supply inlet, the distance between the body and air supply inlet, the air velocity and temperature. Based on the comfort requirement and the importance of various factors, the indoor air distribution could be optimized. For the different calculation conditions, the numerical simulations were carried out. And the simulation results of temperature and velocity distributions were shown in Figs. 7 - 10.

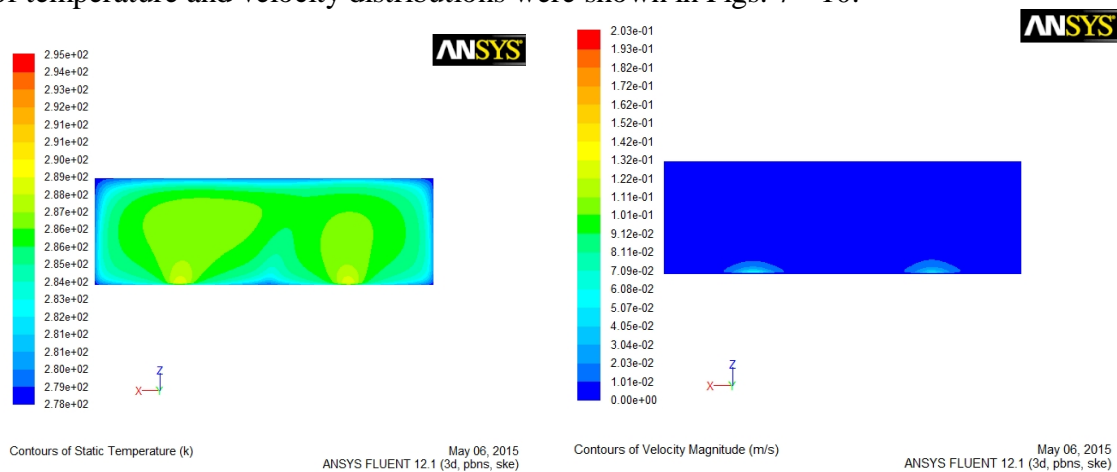


Fig. 7 Simulation results of temperature and velocity distributions under case 1

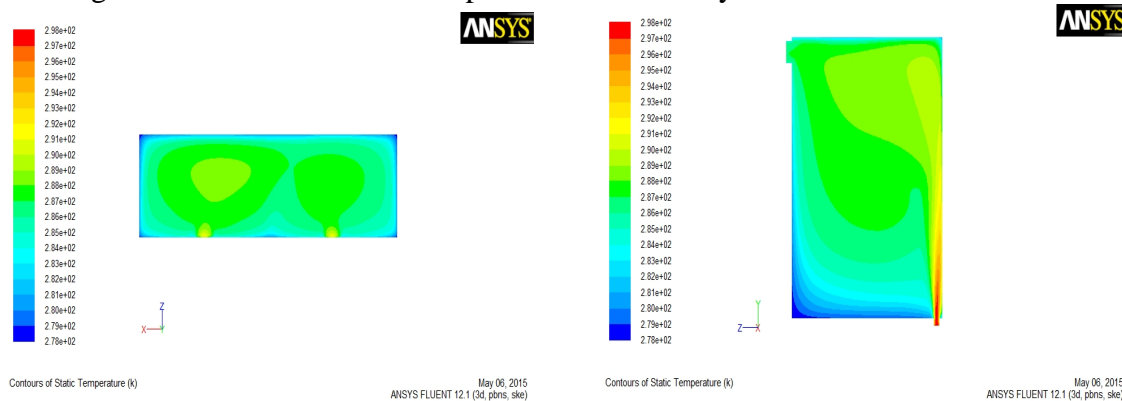


Fig. 8 Simulation results of temperature and velocity distributions under case 2

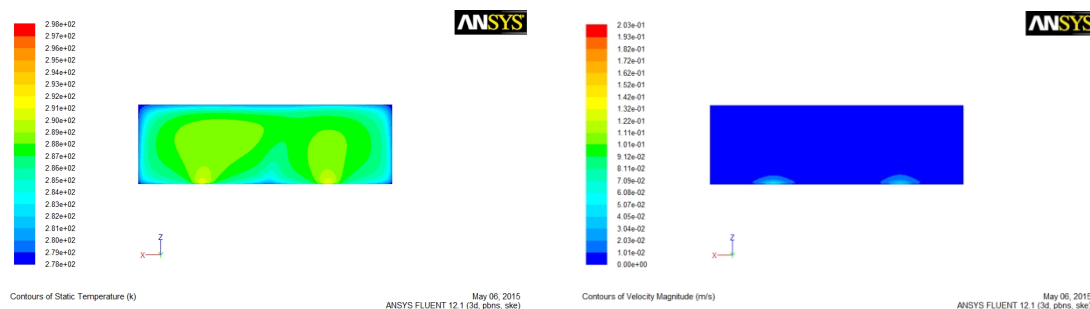


Fig. 9 Simulation results of temperature and velocity distributions under case 3

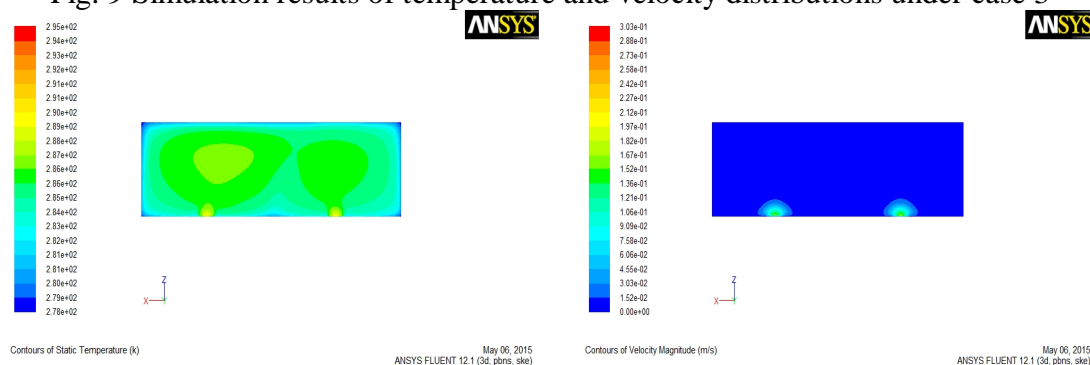


Fig. 10 Simulation results of temperature and velocity distributions under case 4

Results and Discussion

Through the results of experiment and numerical simulation, the primary and secondary order of four factors that affected the comfort of human body in the indoor air distribution was the distance between the body and air supply inlet, the air temperature, the air velocity and the type of air supply inlet. Due to the factor of the type of air supply inlet with little impact, it could be ignored.

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