Experimental study on the room temperature uniformity with air supply and back patterns

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Abstract. To study the influence of the air supply-return methods and air supply temperature on the temperature uniformity, several scaled experiments were carried. By comparing of the ceiling hole-board ventilation and diffuser air supply, it is shown that the air supply method of ceiling hole-board with air-in and floor air-back is a better airflow pattern.

Introduction

Air distribution is one of the most important segments during air conditioning system design. Air distribution design of the air conditioner room will directly affect the air conditioning result and energy consumption of air conditioning system. Among all the influencing factors to air distribution, the selection of blowing and return air type or blowing air parameter setting are the most important one. During air conditioner design, the air distribution type has important affection to whole air conditioning result of cabin. Reasonable air distribution can not only improve the air quality in the cabin, but also avoid energy lost, so as to running the air conditioner with low cost. So the prediction and analysis for cabin air distribution is the most important segment in the whole air conditioning design.

This paper talks about the experiment research of uniformity affection to room temperature field under different blowing and return air or different blowing temperature from air conditioner, by utilizing existing device and condition based on the built man-made environment chamber platform.

Experiments

Experiments Set

Full scaled experiments were carried out in a lab with several scenarios using a typical room geometry. The dimension of the room considered was 4.8 m (x) × 3.3 m (y) × 2.4 m high (z). Five thermocouple trees were located as shown in *figure 1,* with five points in each thermocouple tree. And the measured points in vertical dimension were set as shown in *figure 2*. An electric stove with 800W heat was simulated as the heat gain of the room shown in *figure 3-6*. Agilent 34970A was used to collect the data.

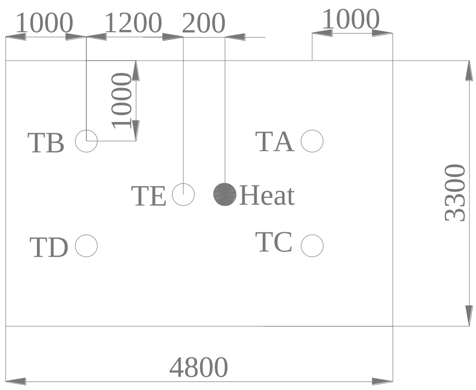

Fig. 1 Layout of the thermocouple trees location

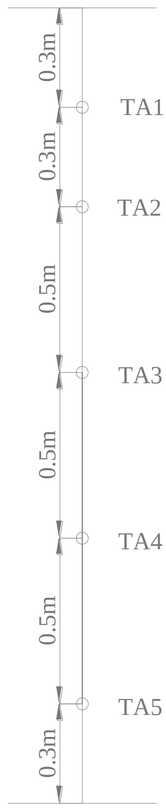

Fig. 2 Layout of the thermocouple trees in vertical direction

Cases and Results

Three working conditions were set with room temperature 19 ˚C, 17 ˚C and 18 ˚C separately, and called working condition I, working condition II and working condition III. During the experiments, the air conditioning system was started to make the environmental chamber to working condition I. After working condition I became stable, and then regulated the condition system to get working condition II. After working condition II became stable, opened the window for a while, and then closed it. After working condition II became stable again, increase the room temperature to working condition III. After the working condition III became stable, the experiment was finished. Recorded the temperature of each characteristic point, and then the temperature variation curve during experiment were achieved.

The four experimental cases of airflow patterns were shown in *figure 3-6*.

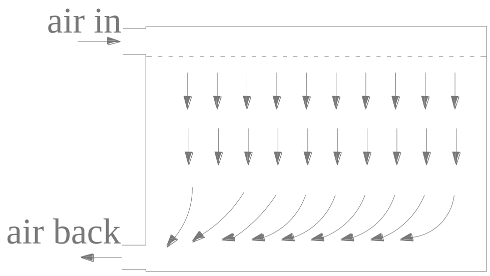

Fig. 3 Case 1- Ceiling hole-board ventilation with ceiling-in and side-back

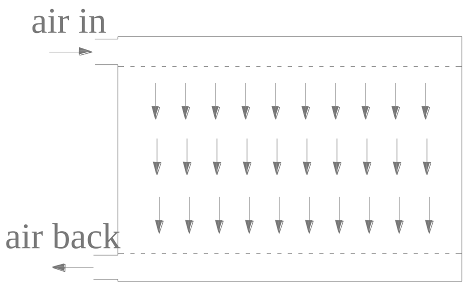

Fig. 4 Case 2- Ceiling hole-board ventilation with ceiling-in and floor-back

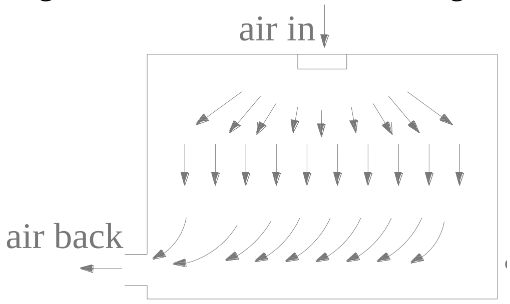

Fig. 5 Case 3- Diffuser air supply with ceiling-in and side-back

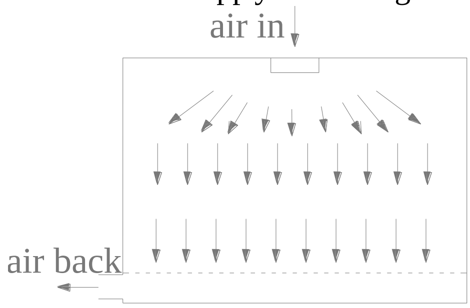

Fig. 6 Case 4- Diffuser air supply with ceiling-in and floor-back

To show the analysis, only the results with *case 1* in working condition III were listed in *table 1*.

Table 1 Results with case 1 in working condition III

Number	Temperature [˚C]	Number	Temperature [˚C]
TA1	18.70	TB1	18.48
TA2	18.52	TB2	18.59
TA3	18.39	TB3	18.73
TA4	18.45	TB4	19.22
TA5	18.45	TB5	18.37
TC1	18.38	TD1	18.44
TC2	18.37	TD2	18.54
TC3	18.24	TD3	18.89
TC4	18.11	TD4	19.11
TC5	18.32	TD5	18.63
TE1	18.41		
TE1	18.37		
TE3	18.71		
TE4	19.55		
TE5	29.59		

Analysis

In the room, temperature differences appear in different locations. And the differences could be evaluated by using the temperature nonuniform coefficient. Several measured points are selected to get the temperature, and then arithmetic mean value is defined in equation 1:

$$\bar{t} = \frac{\sum t_i}{n} \quad (1)$$

Where t_i = the temperature value, n = the number;

The root mean square deviation is defined in equation 2:

$$\sigma_{\mathrm{t}} = \sqrt{\frac{\sum \left(t_i - \bar{t}\right)^2}{n}} \quad (2)$$

Then, the temperature nonuniform coefficient k_{t} is obtained in equation 3:

$$k_{\mathrm{t}} = \frac{\sigma_{\mathrm{t}}}{\bar{t}} \quad (3)$$

Where k_{t} is a dimensionless number, a smaller value indicates a better air uniformity.

According to the results in *table 1*, the nonuniform coefficient k_{t} was gained with *case 1* in working condition III. In the same way, the results of other cases in different working conditions were gained in *tables 2-4*.

Table 2 k_t in working condition I

Cases	Working condition I	
	Temperature difference [˚C]	k_{t}
Case 1	0.70	0.0166
Case 2	0.36	0.0141
Case 3	0.15	0.0163
Case 4	-0.12	0.0146

Table 3 k_{t} in working condition II

Cases	Working condition II	
	Temperature difference [˚C]	k_{t}
Case 1	0.47	0.0179
Case 2	0.32	0.0173
Case 3	0.38	0.0218
Case 4	0.14	0.0209

Table 4 k_{t} in working condition III

Cases	Working condition III	
	Temperature difference [˚C]	k_{t}
Case 1	0.58	0.0174
Case 2	0.34	0.0158
Case 3	0.37	0.0175
Case 4	-0.08	0.0173

Now, the difference of the measured temperature and the set temperature in specific working condition was varied with the set temperature in *figure 7*. The comparisons could be obviously illustrated in *figure 8*.

From *figure 7* and *figure 8*, it is observed that in hole-board ventilation, the temperature difference increased with the increasing of the room temperature. However, under the condition of air diffuser blowing, the temperature difference decreased with the increasing of the room temperature.

For each case, the nonuniform coefficient was increasing with the decreasing of the room temperature. It is because that the heat convection between the hot air in the room and the cold air from outside makes the temperature field unbalanced when the door was opened at 17˚C.

The nonuniform coefficient in Case 2 is less than other cases at different situations. A conclusion was drawn that a good temperature uniform was made with the ceiling hole-board air in and the floor air back. It could be explained that the blowing speed of hole-board is well-distributed and quick-decayed; also the airflow is blown from top to bottom in a straight-line way, which will not cause irregular turbulence. So the temperature field is well distributed when the airflow is blown from the holeboard at top and returned from the floor at bottom. Overall, the temperature filed uniformity of hole-board ventilation is better than air diffuser blowing, and the temperature filed uniformity of floor return mode is better than side return mode.

Air supply temperature is another factor to affect the temperature field uniform. Several comparisons were done as seen in *table 5*.

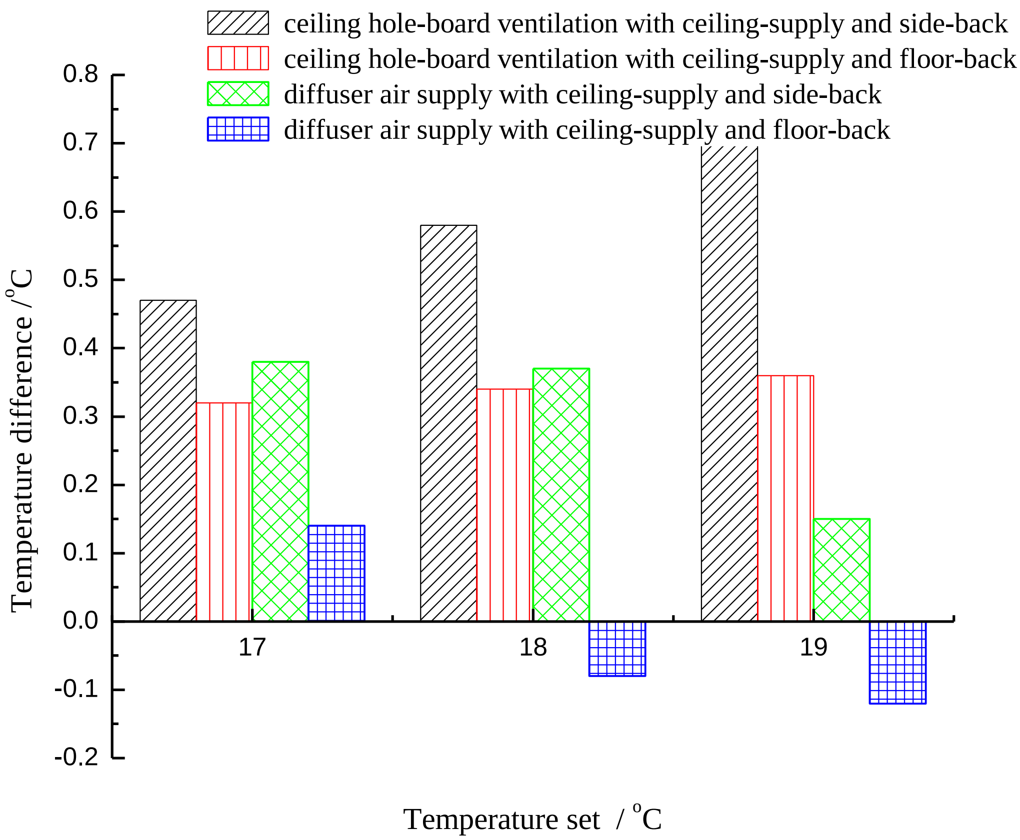

Fig. 7 Temperature difference in cases 1-4

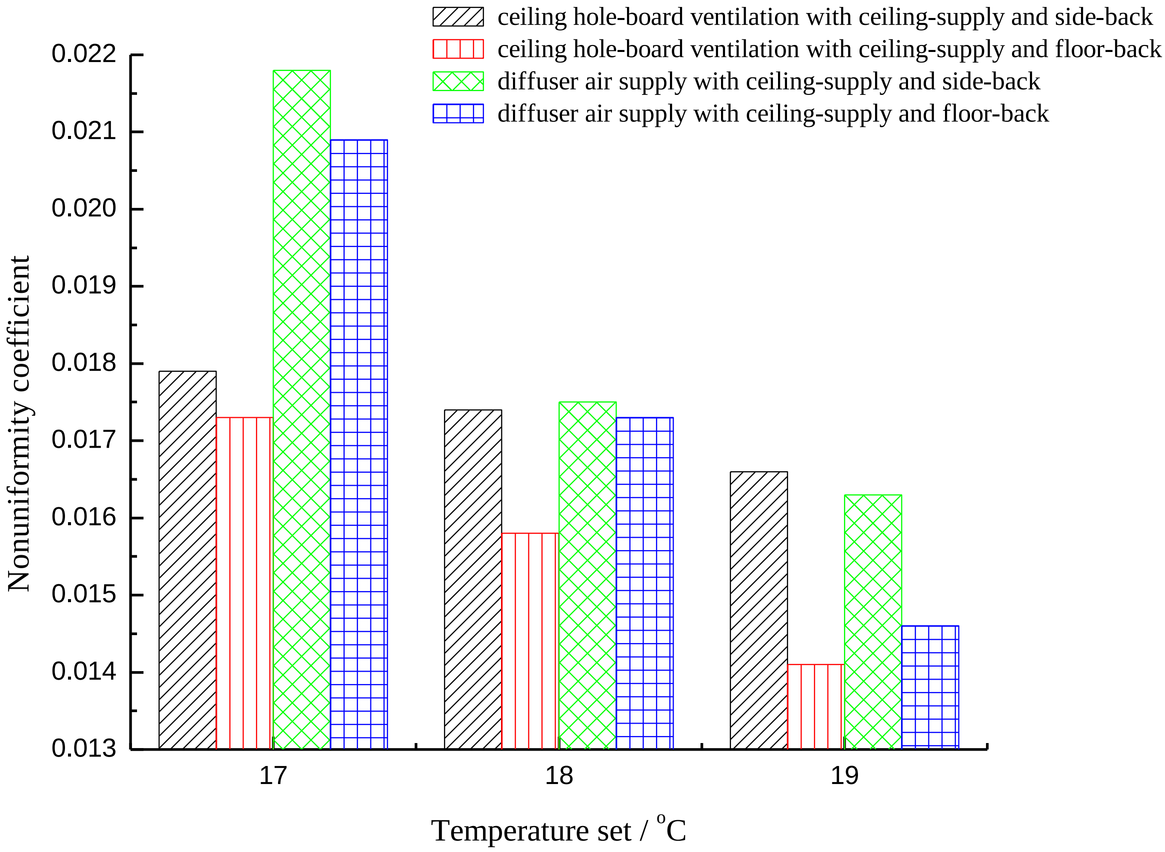

Fig. 8 Nonuniform coefficient in cases 1-4

Table 5 k_t in different air supply temperature

Case	Air supply temperature		
	12[˚C]	14[˚C]	16[˚C]
Case 1	0.0123	0.0116	0.0095
Case 2	0.0121	0.0115	0.0091
Case 3	0.0136	0.0124	0.0114
Case 4	0.0129	0.0118	0.0109

From *figure 9* it was demonstrated obviously that the temperature nonuniform coefficient with hole-board ventilation is less than air diffuser blowing at the same air supply temperature. And the airflow with ceiling-supply and floor-back is much better than the ceiling-supply and side-back due to a smaller nonuniform coefficient. This result also expresses the temperature field of hole-board is better distributed than air diffuser blowing. In view of air distribution, the temperature filed of supply in the top and return from the bottom mode is better distributed than the ventilation from the top and return from the bottom.

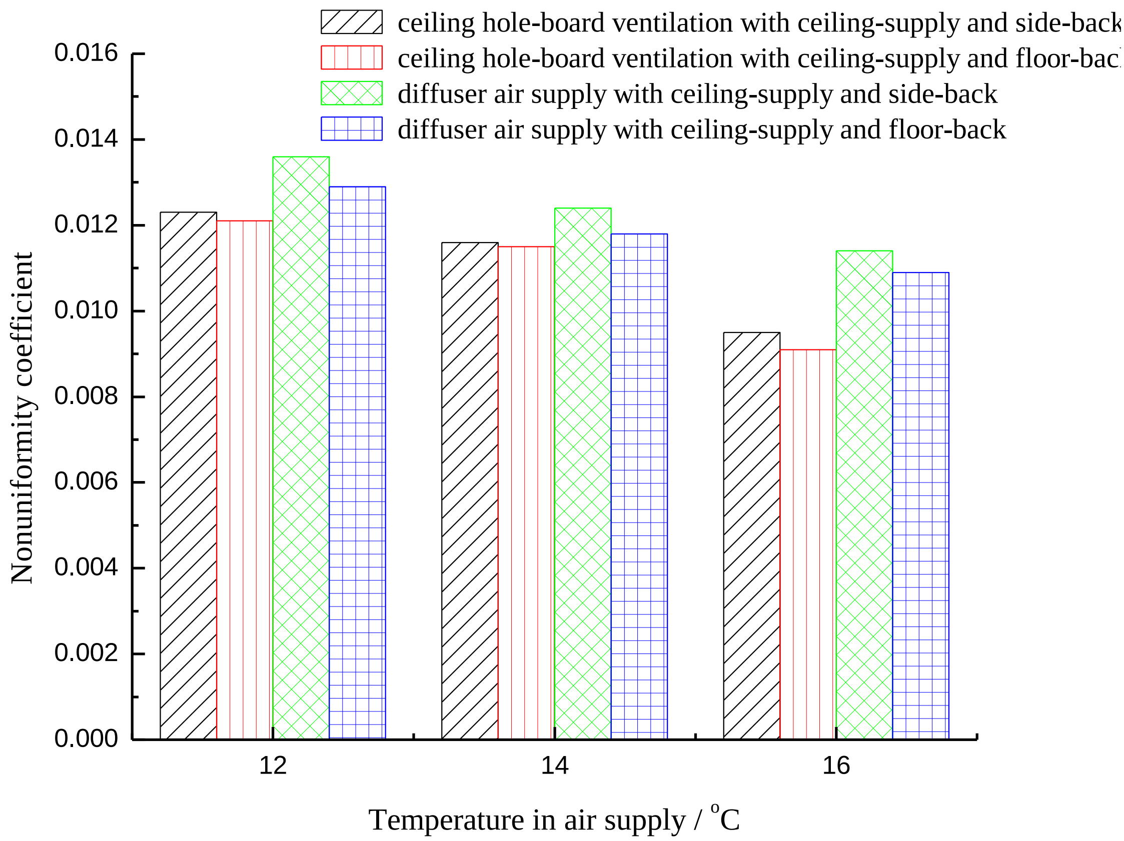

Fig. 9 Nonuniform coefficient with the temperature in air supply in cases 1-4

Conclusions

In this study, experiments were carried out to research the effects of the air in-back method and the air supply temperature on the temperature field in the air-conditioned room. In conclusions, there are two aspects as following:

[1] In the temperature field uniform experiments, by analyzing the temperature nonuniform coefficient, the method of hole-board ventilation with ceiling air-in and floor air-back can make a more uniformed temperature field. And, with the hole-board ventilation the uniform temperature field had an advantage over the diffuser ventilation. In addition, the more uniformed temperature is obtained with air floor-back method.

[2] In the different air supply temperatures, it is still the hole-board ventilation which can get a more uniformed temperature field. Also, the airflow pattern of the ceiling air-in and floor air-back has a smaller nonuniform coefficient, which means this pattern is suggested in the air conditioning design. Furthermore, with the increasing air supply temperature, the nonuniform coefficient decreases, which shows the temperature field is more uniformed.

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