International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 5 ǁ 2022 ǁ PP. 35-42

Research on Variable Parameter Control of Fan Coil Based On Thermal Comfort

Wang Hu Cheng, Weng Wen Bing, Hui Ze
(University of Shanghai for Science and Technology)

Abstract
To study the thermal comfort of fan coil under indoor load condition, a three-dimensional simulation model of a conference room cooled by fan coil was established. The distribution of indoor temperature, speed and PMV field value was simulated. Combined with the experiment, the influence of different setting parameters on indoor thermal comfort and energy consumption was analyzed. The results show that the fan coil cooling can meet the requirements of thermal comfort in the appropriate range of air supply parameters. Setting the best parameters has better energy saving effect.
Key words: *fan coil; Numerical simulation; Thermal comfort; Energy saving*

Date of Submission: 02-05-2022 Date of acceptance: 15-05-2022

I. INTRODUCTION

According to incomplete statistics, people's society spend about 90% of their time in buildings in nowadays[1]. A comfortable indoor environment can make people happy and improve people's work efficiency to 18% [2]. On the contrary, people who are in an uncomfortable indoor environment for a long time will increase the probability of building syndrome, absenteeism and cognitive decline [3], and whether a comfortable indoor environment can be created will determine the quality of people's life. Air conditioning system is an important way to create a comfortable indoor environment, and its air supply comfort has always attracted to people's attention. Dai et al. [4] studied the influence of fan coil installation position on indoor thermal comfort in winter; Di Yuhui et al. [5] studied the effect of wind speed of office buildings on human thermal comfort in summer; Huang Wenxiong et al. [6] studied The thermal comfort of the human body with the side-send side-return air conditioner in the conference room under the working conditions shows that the indoor temperature and wind speed have a great influence on the thermal comfort of the human body in summer.

As the number of air-conditioning systems continue to grow, so do their energy consumption. Existing energy consumption survey data show that in 2018, the whole energy consumption of buildings in my country accounted for about 22% of the whole energy consumption in the country [7], and the energy consumption of air conditioning systems is the main component of building energy consumption, accounting for about 22% of the whole building energy consumption. Therefore, improving the energy efficiency of the air conditioning systems is an effective way to achieve building energy conservation.

Fan coil unit is a common terminal equipment in air-conditioning system and widely used in various buildings. When the system is designed and calculated to output the same cooling capacity, there are various combinations of supply air temperature and air volume. Under the condition of satisfying thermal comfort, increasing the chilled water temperature of the fan coil can significantly improve the operating efficiency of the chiller and achieve system energy saving. Zhou Cong et al. [9] studied the variable chilled water temperature control of the air-conditioning system, and the results show that changing the chilled water supply temperature according to the room load changes has a better energy-saving effect; Thu [10] et al. Through experimental research, it has been proved that the temperature of frozen water supply increases by 1℃, the COP of the chiller is increased by about 3.5%, and the cooling capacity is increased by about 4%.

This paper takes a conference room in Shanghai as the research object, establishes a simulation model through Airpak software, and obtains the temperature field, velocity field, velocity field, etc. The distribution of PMV values is analyzed, the range of air supply parameters for the comfort of the fan coil unit and the combination of air supply parameters with the best energy saving effect are analyzed, and the accuracy of the simulation results is verified by experiments. The research results can provide a reference for the research on variable parameter control of comfortable air supply of fan coil units under different load conditions.

II. Airpak simulation

2.1 physical model

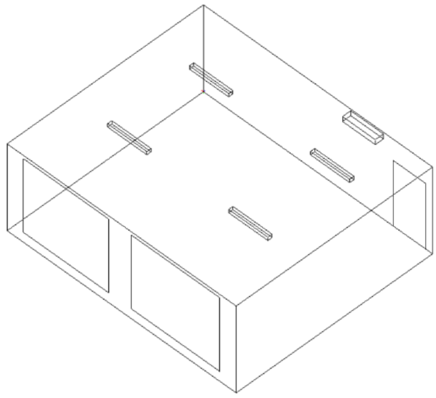


Figure 1. Conference room model

The conference room is 7m (length) × 6m (width) × 2.65m (height) located in Shanghai, the south wall is the outer wall, the heat transfer coefficient is 1.5W/(㎡ • K), and the rest are inner walls; the south outer wall is installed with Two external windows, the dimensions are 2.6m (width) × 2.25m (height), 2.7m (width) × 2.25m (height), the heat transfer coefficient of the external window is 3W/(㎡ • K), and the shading coefficient is 0.3 ; Solar radiation heat and indoor lighting, equipment, and personnel cooling load are regarded as internal heat sources; the upper and lower floors do not exchange heat with the outside world. The summer design cooling load of the conference room is calculated to be about 3400W. In this paper, the fan coil unit is used to cool the room. The fan coil unit can change the air supply parameters by adjusting the water supply water volume and temperature. The fan coil unit is installed in the middle and upper part of the north wall, 1.5m away from the east wall. The three-dimensional mathematical model of the conference room is established based on Airpak software. The specific model is shown in Figure 1. The negative direction of the Z axis is the north direction.

2.2mathematical model

The establishment of the mathematical model is based on the following assumptions: the indoor air velocity is a low-velocity incompressible Newtonian fluid; considering the influence of buoyancy, it conforms to the Boussinesq assumption; the indoor air is a radiation-transparent medium. The simulation uses the k-ε turbulence model as an additional equation for turbulence. Its governing equation is:

1.Continuity equation

$$\frac{\partial u_i}{\partial x_i} = 0$$

u_i——velocity vector

2.momentum conservation equation

$$\frac{\partial}{\partial x_j}(\rho u_i u_j) = \frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} + \rho g_i + F_i$$

$$\tau_{ij} = \nu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \frac{2}{3}\nu\frac{\partial u_i}{\partial x_j}\delta_{ij}$$

ρ ——velocity vector

p——static pressure

τ_{ij}——Stress tensor

ρg_i——Unit volume gravity

ν ——Kinematic viscosity

δ_{ij}——Unit tensor

3.Energy conservation equation

$$\frac{\partial}{\partial x_i}(\rho u_i h) = \frac{\partial}{\partial x_i}(k + k_i)\frac{\partial T}{\partial x_i} + S_h$$

k——Molecular thermal conductivity

k_i——Turbulent diffusion thermal conductivity

S——Volumetric heat source

2.3 boundary condition

This paper uses SDCR series energy-saving DC fan coil units (model 600) to conduct simulation experiments. The cooling capacity is fixed at 3400W, the three simulated working conditions are shown in Table 1, and the fan coil unit is set to horizontal air outlet.

Table 1. Numerical simulation conditions

working condition	Air supply temperature（℃）	Supply air volume（m³/h）
1	12	533
2	16	832
3	18	1400

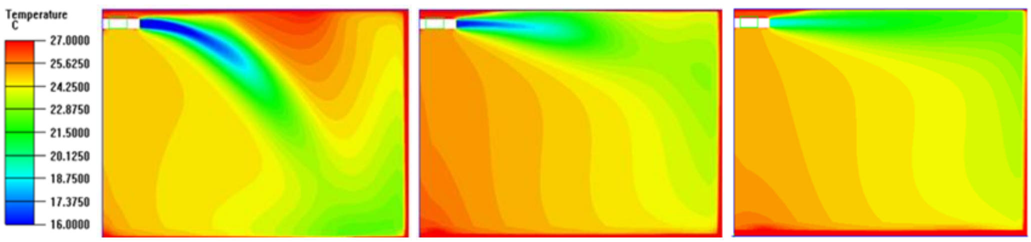
The indoor design temperature is 26° C and the relative humidity is 75%; the outdoor design temperature adopts the average summer temperature of 36° C in Shanghai, and the average relative humidity is 90%; the exterior walls, roofs, doors and windows are set according to the heat transfer coefficient of the materials. There is no heat exchange between the inner wall and the outside, so it is set as an adiabatic wall; the heat dissipation power of the electric lamp is 40W.

2.4 Analysis of simulation results

The simulated cloud image selects the elevation of the air supply outlet of the fan coil unit for analysis. This elevation is the elevation that the human body is more sensitive to the indoor environment. The temperature, speed and PMV cloud images of the elevation are intercepted for analysis.

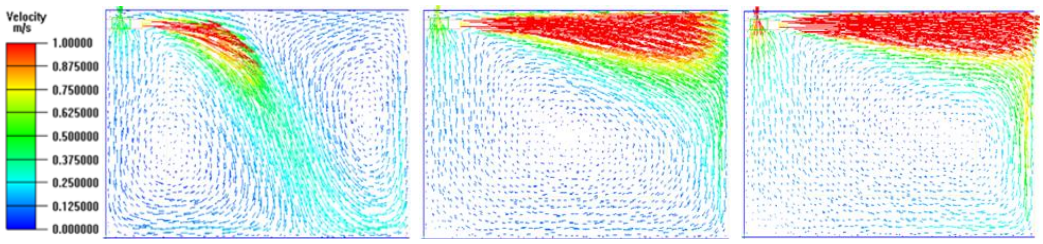
2.4.1 temperature distribution

Figure 2 shows the temperature distribution of the X=5.1m section under the three working conditions. Figure 2(a) The supply air temperature is low and the supply air volume is small. Seriously heavy, resulting in uneven temperature distribution in the room, the average temperature of the working area is lower than 23 ° C, and the human body feels cold; Figure 2(b) and Figure 2(c) The air supply volume is large, and the air is attached to the top of the room and sent out in the room. The area near the south wall sinks, the average temperature of the working area can be maintained at about 24℃, the temperature distribution is uniform, and the human body feels comfortable.



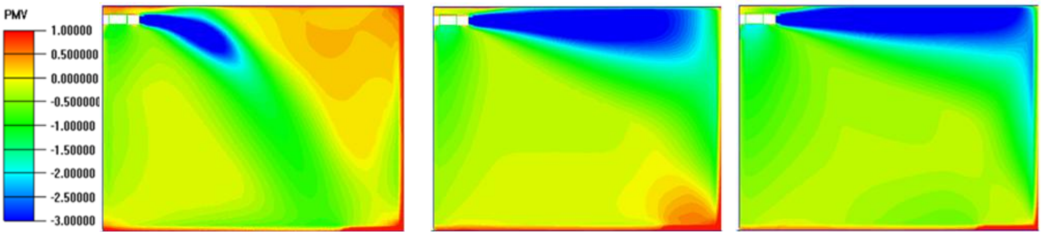
（a）working condition1　（b）working condition2　（c）working condition3

Fig. 2 Temperature distribution of air supply section



（a）working condition1　（b）working condition2（c）working condition3

Fig. 3 Velocity distribution of the supply air section



（a）working condition1　（b）working condition2　（c）working condition3

Fig. 4 PMV distribution of air supply section

2.4.2velocity distribution

Figure 3 shows the wind speed distribution of the X=5.1m section under the three working conditions. Figure 2(a) The air supply wind speed is small, the air flow begins to sink in the middle of the room, and the wind speed in the working area can reach 0.5m/s. Strong sense of drying. As the air supply volume increases, the air supply in Fig. 2(b) and Fig. 2(c) forms an attached jet, and the air flow sinks near the south wall of the room. The top and bottom of the room have higher wind speeds than the middle of the room, but generally relatively Condition 1, the wind speed in the air supply work area is smaller, the distribution is more reasonable, and the human body feels more comfortable.

2.4.3 PMV distribution

Figure 4 shows the distribution of PMV values of the X=5.1m section under three working conditions. Combined with the temperature field and velocity field analysis of the section, working condition 1 has low temperature and high wind speed in the working area, as shown in Figure 4(a) PMV Values below -1, the body feels cooler. The PMV values of most of the work areas in Figure 2(b) and Figure 2(c) are between -0.5 and 0, and the human body feels comfortable.

III. Experimental Verification

In this paper, the simulation results are verified by experiments. In order to ensure the accuracy of the experiment, the installation position of the fan coil unit is consistent with the position in the simulation model and the cooling source equipment is connected. During the experiment, the inlet water temperature and water volume of the fan coil unit are adjusted, Make its air supply parameters reach the analog set value. The water supply and return pipes are covered with thermal insulation materials to minimize the heat exchange between the supply and return water and the outside world. During the test, the outdoor relative humidity is about 90%, and the indoor relative humidity is 70%~80%.

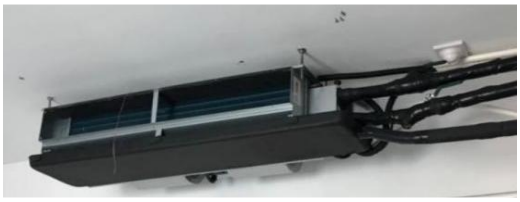


Fig. 5 Experimental fan coil

In the experiment, three vertical survey lines were arranged on the X=5.1m section, and the distances from the north outer wall were 1.5m, 3m, and 4.5m, respectively. It is 0.3m, 0.6m, 1.1m, 1.6m, 1.8m, 2m, and the temperature of each measuring point is read by the Agilent data acquisition instrument through the NTC temperature measuring resistance installed on the bracket. In order to more comprehensively analyze the thermal comfort state of the entire air-conditioned room, combined with the simulation, three non-air outlet elevation measurements of X=1.2m, X=2.6m, and X=3.9m were selected for comparative analysis. The specific location of each elevation is shown in Figure 6 below.

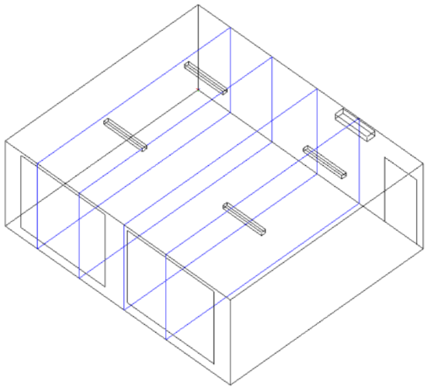


Fig. 6 Location distribution of each section

3.2Analysis of experimental results

The experiment records the water side parameters and air supply side parameters of the fan coil unit corresponding to the three working conditions. The results are shown in Table 2 below:

Fan coil parameters	working condition1	working condition2	working condition3
Air supply temperature（℃）	13.51	16.1	18.4
Air supply volume（m^3/h）	530	828	1387
Inlet water temperature(℃)	8.7	7	12.4
Water volume(kg/s)	0.18	0.12	0.3

Table 2. Numerical simulation conditions

3.2.1Temperature distribution

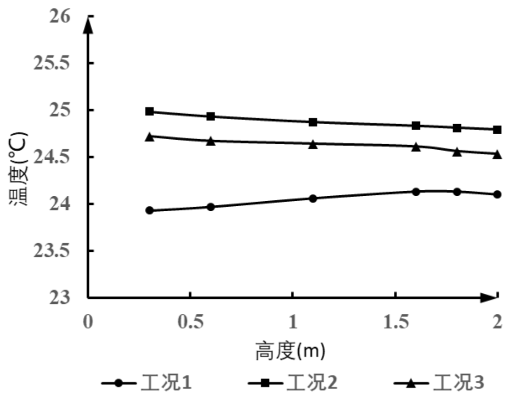


Fig. 7 Temperature distribution on survey line 1

At measuring line 1, the air supply of each working condition has not yet begun to sink, and the temperature of each measuring point of the air supply in working condition 1 is about 24 ° C; The temperature of each measuring point of the supply air is about 25 ℃. The human body feels more comfortable in all three working conditions.

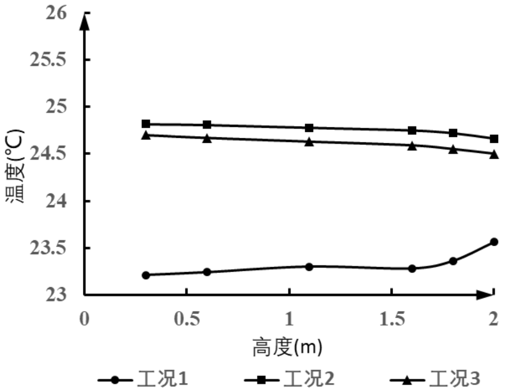


Fig. 8 Temperature distribution on survey line 2

At 2 measuring lines, in working condition 1, the low-temperature airflow of the supply air sinks seriously. The temperatures of each measuring point are 23.21, 23.24, 23.3, 23.28, 23.36, and 23.56 ° C, all of which are lower than 24 ° C, and the human body feels colder; working condition 2 And working condition 3, the temperature of each measuring point of air supply is between 24.5 and 25 ℃, and the human body feels comfortable.

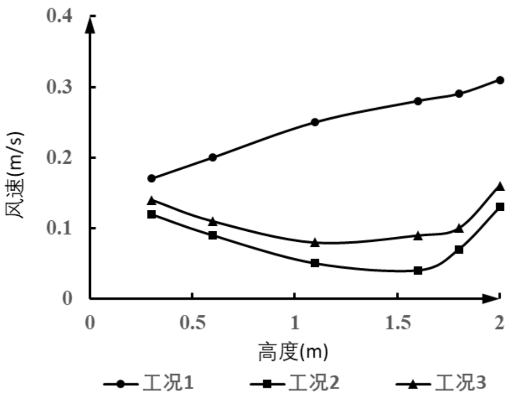


Fig. 9 Temperature distribution on survey line 3

At measuring line 3, the air flow in working condition 1 has sunk, so the bottom temperature is low, and the temperature gradually increases with the increase of height. In working conditions 2 and 3, the airflow is attached to the top of the room and sent out. As the height of the measuring point increases, the temperature decreases, and the temperature at the three higher measuring points is lower than 24 ° C. The low-temperature airflow in working condition 2 sinks faster than that in working condition 3, and the temperature is lower at the measuring points of 1.8m and 2m, which is consistent with the simulation results. The temperature of the working area is between 24 and 24.5 ° C, which meets the thermal comfort requirements of the human body.

	working condition1	working condition2	working condition3
facade1	24.25	24.15	24.32
facade2	24.35	24.23	24.45
facade3	24.46	24.27	24.78

Table 3 Average temperature of three facades

The temperature at multiple locations on the facade of the three non-air supply outlets was measured, and the average value was obtained. The results are shown in Table 3. The temperature is all around 24 ° C, and the farther away from the air supply section, the higher the average temperature.

3.2.2Wind speed distribution

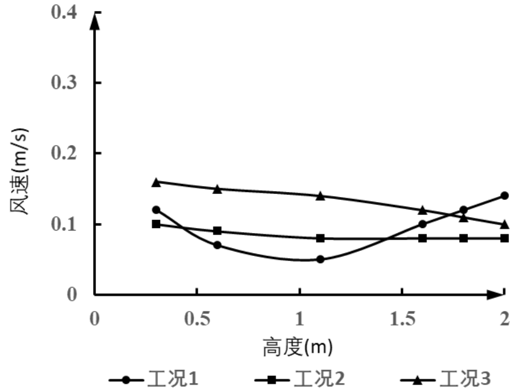


Fig. 10 Wind speed distribution on survey line 1

At measuring line 1, the supply air volume of working condition 1 is small, the measuring point of Y=2m is near the supply air flow, and the air flow sinks in the middle of the room, the air reaches the floor and flows to both sides, and the air velocity at the top and bottom of the room is relatively high. high. In working conditions 2 and 3, due to the large air supply air volume, the airflow has not yet sunk, the wind speed at the top is small, and the human body in the working area is not strong enough to meet the thermal comfort requirements of the human body.

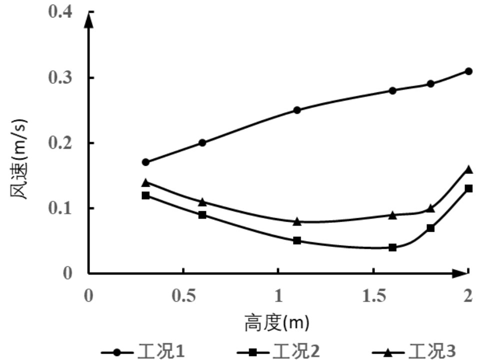


Fig. 11 Wind speed distribution on survey line 2

At measuring line 2, the wind speeds of each measuring point of the air supply in working condition 1 are 0.17, 0.2, 0.25, 0.28, 0.29, and 0.31m/s, respectively. The wind speed in the working area is relatively large, and the human body has a strong sense of blowing. Condition 2 and Condition 3 due to the large air supply air volume, the airflow is attached to the top and sent out, and flows downward after reaching the south wall. Therefore, the wind speed is higher at the measuring points of Y=0.3m and Y=2m, but the overall working area is The wind speed is low, and the human body feels comfortable.

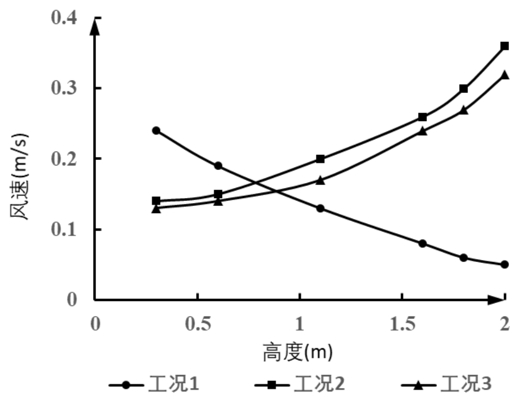


图 12 测线 3 风速分布

Fig. 12 Wind speed distribution on survey line 3

At survey line 3, the air supply air in working condition 1 sinks and reaches the floor and flows to both sides, so the air velocity at the measuring point at the bottom of the survey line is relatively high. In working conditions 2 and 3, the supply air flow reaches the south wall and flows downward. The maximum wind speed reaches 0.36m/s and 0.32m/s respectively, and the blowing feeling is strong.

The wind speeds at multiple locations on the facade of the three non-air supply outlets were measured, and the average value was obtained. The results are shown in Table 4. Most of the wind speeds were lower than 0.15m/s, and the farther away from the air supply section, the lower the average wind speed.

	$533m^3/h$	$832m^3/h$	$1400\ m^3/h$
facade1	0.09	0.09	0.12
facade2	0.1	0.12	0.14
facade3	0.13	0.13	0.16

Table 4 Average Wind Speed of Three facades

After experimental verification, the air supply in working condition 1 cannot meet the requirements of indoor thermal comfort, while the air supply in working conditions 2 and 3 can meet the thermal comfort requirements. When the load of the conference room is 3400w, the parameter range of the fan coil unit for comfortable air supply is shown in Table 5.

Air supply parameters	Range
Air supply temperature（℃）	16~18
Supply air volume（m^3/h）	832~1400

Table 5 Comfortable air supply parameter range

In the case of meeting the indoor load, increasing the water supply temperature of the fan coil unit has a good energy saving effect [10]. Nowadays, the energy saving of variable water temperature is less studied in combination with indoor thermal comfort. Provide a reference for the research on the comfort air supply control method of the fan coil unit with the best energy saving effect.

IV. Conclusion

(1) This paper shows that the use of fan-coil cooling in summer can meet the requirements of indoor thermal comfort within the appropriate parameter range.

(2) This paper shows that when the load of the conference room is 3400w, the air supply parameter combination for the fan coil to meet the thermal comfort and the best energy saving effect is the air supply temperature of 18 °C and the air supply air volume of 1400 m^3/h.

(3) This paper shows that while increasing the energy saving of the fan coil water supply temperature, in order to meet the indoor load, it is necessary to increase the air supply air volume, which will inevitably affect the indoor thermal comfort, but when the air supply parameters are selected properly, it can still meet the Indoor thermal comfort requirements.

REFERENCES

[1]. Peter Höppe. Different aspects of assessing indoor and outdoor thermal comfort[J]. Energy & Buildings,2002,34(6).

[2]. Fisk W J . How IEQ affects health, productivity[J]. Ashrae Journal, 2002, 44(5):p.56.

[3]. R. J. Dear,T. Akimoto,E. A. Arens,G. Brager,C. Candido,K. W. D. Cheong,B. Li,N. Nishihara,S. C. Sekhar,S. Tanabe,J. Toftum,H. Zhang,Y. Zhu. Progress in thermal comfort research over the last twenty years[J]. Indoor Air,2013,23(6).

[4]. Dai Wei, Cao Xiaolin, Zhang Qixiong. Thermal comfort research based on the heating of existing farm houses with fan coil units[J].Fluid Machinery,2018,46(05):73-77.

[5]. Di Yuhui, Yin Hui, Wang Lijuan, Chong Ding. An experimental study on the effect of wind speed on human thermal comfort in office buildings in summer[J]. HVAC,2018,48(06):103-109.

[6]. Huang Wenxiong, Fu Haiming. Simulation of human thermal comfort with side-delivery and side-return air conditioners in conference rooms in summer [J]. HVAC,2018,48(06):120-126+16.

[7]. Tsinghua University Building Energy Conservation Research Center. 2020 China Building Energy Efficiency Annual Development Research Report [M]. Beijing: China Building Industry Press,2020.

[8]. Lin C M，Liu H Y，Tseng K Y，et al．Heating，ventilation，and air conditioning system optimization control strategy involving fan coil unit temperature control[J]. Applied Sciences，20199(11) : 2391．DOI:10．3390/ app9112391．

[9]. Zhou Cong, Zou Hong, Chen Jianbo. Characteristics experiment and energy saving research of variable water temperature DDC control of air-conditioning system[J].Fluid Machinery,2008(05):6-9.

[10]. Kyaw Thu,Jayaprakash Saththasivam,Bidyut Baran Saha,Kian Jon Chua,S. Srinivasa Murthy,Kim Choon Ng. Experimental investigation of a mechanical vapour compression chiller at elevated chilled water temperatures[J]. Applied Thermal Engineering,2017,123.