Actual measurement and analysis of winter thermal environment of a graduate student studio in Shenyang based on Airpak numerical simulation

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Abstract. This paper takes a graduate workshop in Shenyang as the research object, and uses Airpak software to conduct numerical simulation analysis on the air distribution and thermal comfort of the fan coil side air supply mode in winter. The measured air supply temperature is 25°C, air supply speed in the x direction for 0.8 m/s, 1.5 m/s and 2.3 m/s three gears, from east to west up to back air supply 3 mode. With the increase of air supply speed, the temperature of the working area gradually increases, and the wind speed increases. PMV index and PPD index were used to evaluate the indoor comfort under the three air supply speeds. The air supply speeds of 1.5 m/s and 2.3 m/s can meet the requirements of indoor comfort. According to the distribution of personnel, 18 measuring points were set for measurement. The comparison between the simulation results and the measured results showed a consistent trend, which verified the feasibility and accuracy of Airpak for indoor thermal environment comfort analysis.

Keywords: thermal comfort, numerical simulation, airpak, thermal environment, supply air velocity

1 Introduction

Contemporary graduate students work and study in the studio for more than eight hours a day, the comfort of the indoor environment directly affects the work and study efficiency of graduate students. At present, it is very common to use CFD numerical simulation method to select appropriate environmental parameters for building healthy, comfortable and energy-saving indoor thermal environment. Zhang¹ used Airpak software to verify that the use of side air conditioning system in summer can achieve a comfortable office environment; Sun² used CFD simulation to find that the down-return air supply mode had higher indoor comfort and air quality; Zhang³ used Airpak software to concluded that changing the internal layout of the office could improve the indoor thermal environment. Tang⁴ used Airpak software to compare the effects of different air supply speeds on the indoor air environment under one supply mode and obtained the optimal air supply parameters. Hou⁵ used Airpak software to simulate and study the temperature field in the office under different air distribution in summer, it is concluded that the energy utilization of the top-to-bottom type is better.

According to previous studies, there are relatively few simulation studies on the indoor thermal environment comfort of office buildings using air conditioning systems in cold regions. In this paper, a graduate studio of a university in Shenyang was taken as the research object, and the indoor air conditioning environment was simulated in winter, and the indoor temperature field, velocity field, PMV-PPD were
analyzed, and compared with the measured results.

2 Physical model and simulation

2.1 Physical model

The geometric dimension of the room is length × width × height =11m × 7m × 4m. The east wall is connected with the corridor by an iron gate, and the west wall is connected with the outdoor environment by six Windows. The size of the Windows is in width × height =1.5m × 1.8m. The north wall is the outer wall and the south wall is the inner wall. There are 18 graduate students in the workshop, each equipped with a computer to work, hanging 6 fluorescent lamps on the roof. Airpak is used to establish the following physical model (Fig. 1). The fan coil unit is used for heating and air supply. The air outlet is set on the east wall, 0.3m from the ceiling. There are three pairs of the same air outlet, and the air outlet and the air outlet of each pair are arranged in parallel, the distance between is 0.1m.

![Fig. 1 Physical model of workshop](image)

2.2 Simulation method

2.2.1 Boundary conditions

In the heating season, air supply temperature is 25°C, and the air supply speed can be adjusted by three gears, respectively 0.8m/s, 1.5m/s and 2.3m/s. Shenyang winter outdoor average temperature is -11.5°C. See Table 1 for details.

<table>
<thead>
<tr>
<th>name</th>
<th>number</th>
<th>boundary conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>people (sit)</td>
<td>18</td>
<td>heat, 50w</td>
</tr>
<tr>
<td>lamp</td>
<td>6</td>
<td>heat, 40w</td>
</tr>
<tr>
<td>computer</td>
<td>18</td>
<td>heat, 160w</td>
</tr>
<tr>
<td>East wall</td>
<td>1</td>
<td>Fixed, 10°C</td>
</tr>
<tr>
<td>North wall</td>
<td>1</td>
<td>Fixed, -5°C</td>
</tr>
<tr>
<td>South wall</td>
<td>1</td>
<td>adiabatic</td>
</tr>
</tbody>
</table>

2.2.2 Evaluation index

There are many methods for thermal comfort in evaluation rooms, among which PMV-PPD proposed by Professor Fanger in Denmark is the most commonly used. According to Code for design of heating, ventilation and air conditioning in civil buildings, the thermal comfort is divided into two grades (І and ІІ). See Table 2 for design calculation parameters (winter) of І grade and ІІ grade air conditioning.

<table>
<thead>
<tr>
<th>level</th>
<th>PMV</th>
<th>PPD</th>
<th>temperature</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>І</td>
<td>[-0.5,0.5]</td>
<td>≤10%</td>
<td>22-24°C</td>
<td>≤0.2 m/s</td>
</tr>
<tr>
<td>ІІ</td>
<td>[-1,1]</td>
<td>≤27%</td>
<td>18-22°C</td>
<td>≤0.2 m/s</td>
</tr>
</tbody>
</table>

3 Simulation results and analysis

Students can be considered to be sitting quietly in the workshop, so we choose Y =1.2m as the research plane. 18 measuring points are set up in the studio, and the arrangement of measuring points is shown in Fig. 2.

![Fig. 2 Distribution of measuring points in the workshop](image)

3.1 Supply air speed =0.8m/s

As can be seen from Fig. 3, when the air supply velocity is 0.8m/s, the average temperature of the working area is 17.4°C, the highest temperature of the 18 measuring points is 18.9°C, and the lowest temperature
Fig. 3 Distribution of temperature and wind speed

is 16.8°C. The temperature decreased from south to north, but there was no significant difference in the east-west direction. The average wind speed in the working area is 0.05m/s. There is little difference in the wind speed of the 18 measuring points. The highest is 0.08m/s and the lowest is 0.03m/s.

3.2 Supply air speed =1.5m/s

As can be seen from Fig.4, when the air supply velocity is 1.5m/s, the average temperature of the working area is 19.8°C. The highest temperature of the 18 measuring points is 20.7°C, and the lowest temperature is 18.9°C. The temperature decreased from south to north, but there was no significant difference from east to west. The average wind speed of the working area was 0.07m/s, and there was almost no sense of blowing wind. There was little difference in the wind speed of the 18 measuring points. The highest is 0.14m/s and the lowest is 0.05m/s.

Fig. 4 Distribution of temperature and wind speed

3.3 Supply air speed =2.3m/s

As can be seen from Fig.5, when the air supply velocity is 2.3m/s, the average temperature of the working area is about 21.2°C. The highest temperature of the 18 measuring points is 22.7°C, and the lowest temperature is 20.4°C. The temperature decreased from south to north. The southwest corner is warmer. The average wind speed in the working area was 0.11m/s, without obvious blowing sensation. The wind speed of the measuring points near the north was higher than that of the measuring points near the south, with the highest being 0.14m/s and the lowest being 0.08m/s.

3.4 Evaluation analysis

In order to intuitively compare the changes of thermal comfort in the workshop under different air supply speeds, the PMV index, PPD index of 18 measuring points under different air supply speeds were compared and analyzed by dot plot respectively. As can be seen from Fig. 6, when the air supply velocity is 0.8m/s, PMV of 15 measurement points in the workshop is ≤-1, and PPD of 12 measurement points is ≥27%, so it cannot meet the requirements of thermal comfort; When the air supply speed is 1.5m/s, the PMV of 18 measuring points in the workshop is within the range of -1≤PMV≤-0.5, and the PPD is within the range of 15% ≤PPD≤23%, so it can meet the requirements of thermal comfort II; When the air supply velocity is 2.3m/s, the PMV of 15 measuring points in the workshop is within the range of -0.5≤PMV≤0, and the PPD of the working area fluctuates around 10%. Thermal sensation is close to thermal neutral, which can basically meet the requirements of I level of thermal comfort.

Fig. 5 Distribution of temperature and wind speed

Fig. 6 PMV index diagram and PPD index diagram

4 Experimental study
The temperature and wind speed of 18 measuring points in the workshop were measured by instruments. Taking the supply air speed of 1.5m/s as an example, the comparison between test results and simulation results is shown in Fig.7. The simulated values of temperature and wind speed at 18 measuring points in the workshop are basically consistent with the measured values. The difference between the measured temperature and the simulated temperature is small, but the measured value is slightly less than the simulated value at most of the measurement points; The measured wind speed value is less than the simulated wind speed value, which may be caused by the fact that it is morning when the test is conducted and the staff in the workshop are not present. At the same time, the enclosure structure is set as the fixed wall temperature, which causes certain errors in the simulation results. The accuracy of the model is also verified by actual measurement.

Fig. 7 Changes of temperature and wind speed

5 Conclusion

(1) The indoor temperature distribution shows a gradual decreasing trend from south to north. At Y=1.2m, when the air supply velocity is set at 0.8m/s, the average temperature is 17.4°C. When the air supply speed is 1.5m/s, the average temperature is 19.8°C. When the supply air speed is 2.3m/s, the average temperature is 21.2°C.

(2) There is little difference in indoor wind speed distribution. Basically, the wind speed in the north is slightly larger than that in the south. At Y=1.2m, when the supply air speed is set at 0.8m/s, the average wind speed is 0.05m/s. When the supply air speed is 1.5m/s, the average wind speed is 0.07m/s. When the supply air speed is 2.3m/s, the average wind speed is 0.11m/s.

(3) PMV index and PPD index were used to evaluate the indoor comfort under the three air supply speeds. The air supply speeds of 1.5m/s and 2.3m/s can meet the requirements of indoor comfort. Therefore, considering the energy saving benefits, it is suggested to adopt the wind speed of 1.5m/s for winter heating in the workshop.

(4) The temperature and wind speed of 18 measuring points were measured under the condition of air supply velocity of 1.5m/s, and the comparison and analysis of the temperature and wind speed with the simulated value showed that the degree of agreement was higher, which verified the accuracy of the numerical simulation. The model can be used for other research in the future.

This research was supported by National Natural Science Foundation of China (Grant No. 52038009 and 52178082), Program for Liaoning Innovative Talents in University (No. SHSCXRC2017003)

References