Simulation of BHE fresh air air conditioning system based on TRNSYS-CFD Hybrid Simulation

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Abstract: In order to solve the problem of input fresh air overheating (cooling) in the cold supply (heating) season in severe cold regions, a soil source (BHE) combined with fresh air preheating (cooling) air conditioning system was studied in a net-zero energy building in Shenyang. Firstly, a hybrid TRNSYS-CFD simulation model based on TRNSYS and Fluent simulation software was established to simulate the operation and indoor temperature distribution of the air conditioning system in the building during a typical day in the summer (winter) season. The TRNSYS-CFD hybrid simulation allows simultaneous analysis of the operating characteristics of the air conditioning system and the real-time indoor temperature distribution. The results show that the accuracy of the hybrid simulation is compared with that of the TRNSYS stand-alone simulation by monitoring the temperature changes in each room. The room temperature from the TRNSYS stand-alone simulation is the average temperature of the room return air, while the room temperature from the hybrid simulation has a stratification effect and the simulation data is more valuable for reference.

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0 Introduction

At present, the world's energy problems are becoming increasingly severe, and the coupled use of renewable energy is a new solution to the new era of energy problem scarcity and efficient energy supply and utilisation coordination. WeiHua Lu proposes a new fresh air pre-treatment system that makes full use of shallow energy to preheat fresh air. A model of a typical whole-air system with a pre-treatment system was developed on the TRNSYS platform. The energy saving potential of this fresh air pre-treatment system was simulated according to different climatic conditions. The results show that the ratio of the cumulative heat transfer capacity of the fresh air pre-treatment system to the total annual cooling and heating load is 35-45% , and that the fresh air pre-treatment system with shallow geothermal energy has good prospects for application in most climatic zones[1]. In this paper, the proposed form of air conditioning with Independent Fresh Air combined with Soil Source Energy Pile is a promising form of air conditioning. It uses a Soil Source Energy Pile to pre-treat the fresh air to meet indoor sanitary requirements and to take up the entire latent and most of the sensible heat load in the room, with the fan coil system taking up the remaining sensible heat load. Compared to traditional forms of air conditioning, the IFA+SSEP air conditioning system has a great potential for energy saving, as the fresh air is pre-treated with energy piles to greatly increase its ability to take on the sensible heat load, thus reducing the energy consumption of the air conditioning system.

As the IFA+SSEP air conditioning system causes uneven temperature distribution in the rooms, the use of building energy simulation software (TRNSYS) alone can cause large deviations to the simulation results. This type of software assumes a homogeneous air mixture in the room, i.e. the entire air-conditioned room is considered as a gas node. The output from such simulation assumptions is not accurate and does not allow for an accurate analysis of indoor comfort. On the other hand, the CFD simulation software package Fluent can make reasonable predictions on factors such as indoor temperature distribution, indoor airflow distribution and indoor thermal comfort, and obtain detailed distributions of various physical quantities in the room, etc. However, Fluent does not enable simulation and analysis of the energy consumption and control of air conditioning systems. b.l. Goweresunker uses TRNSYS - Goweresunker used TRNSYS to build a simulation platform for the air conditioning system and PID control system, and CFD to build a two-dimensional model of the airport and a phase change heat exchanger model. The results show that the use of phase change heat exchangers can reduce reheat energy consumption in the transition season and summer months by up to 34% [2].

Therefore, this paper compensates for the shortcomings of TRNSYS, which cannot perform indoor single-point control, by using a hybrid simulation approach combining TRNSYS and Fluent, i.e. on the basis of the dynamic simulation of the air conditioning system built on TRNSYS, combined with Fluent's simulation of the air conditioning room temperature field, through the hybrid simulation approach of the two simultaneously and analyse the IFA+SSEP air conditioning system's The simulation results are more accurate and have more practical application value.

1 Research subjects

1.1 Study subjects

The research object of this paper is a net zero-energy consumption office demonstration building located in Shenyang. The office area on the second floor is selected for simulation. The layout type of the room is shown in Figure 1. The total area of the room is 124 m², 3.6m high and composed of an office, toilet and public office area. The office building adopts the air supply form of fan coil and independent fresh air. The number and dimensions of fan coil and fresh air are shown in Table 1.

Fig. 1. Schematic diagram of the building layout.

Table 1 Selection of feng shui heat exchanger

<table>
<thead>
<tr>
<th>room type</th>
<th>room area m²</th>
<th>Air outlet diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public office area</td>
<td>120</td>
<td>40</td>
</tr>
<tr>
<td>office</td>
<td>13</td>
<td>40</td>
</tr>
</tbody>
</table>

1.2 System overview

The IFA + SSEP system combined with the soil source energy pile, through the use of geothermal heat for preheating treatment of the general fresh air, so that the fresh air has the ability to bear some indoor heat display and all the wet load, so as to reduce the energy consumption of the air conditioning system to achieve the purpose of energy saving.

The principle of the system is: general fresh air can be recovered with indoor return air in full heat exchanger after heat exchange, so winter fresh air can bear indoor latent heat load and partial heat load, reduce air conditioning system and reduce investment in initial cost. General fresh air can be precooled through the air source, realize soil heating and precooling and heat filling, improve the energy efficiency of the system and meet the building cooling and heating requirements.
Fig. 2. System schematic diagram.

2 Model establishment

This paper uses the TRNSYS software to model the various system components of the IFA + SSEP air conditioning system, while the building model of the case building is built by the CFD software.

2.1 System model

According to the DOAS + CRCP air conditioning system shown in Figure 2, the air conditioning system simulator is established based on TRNSYS software, and the load calculation of the whole building is time by time indoor load and wall heat flow density, along with the parameters obtained by air supply temperature, air supply temperature and air outlet discharge temperature are sent to the CFD model as the TRNSYS-CFD.

The three operating conditions listed in Table 2 are simulated. In order to maintain a constant variation of the external boundary input conditions for each room, the ratio of the air supply to the air supply in the two rooms is kept constant for each condition, subject to the variation of the air supply, as shown in Table 3.

<table>
<thead>
<tr>
<th>Working condition</th>
<th>Air supply temperature °C</th>
<th>air output kg/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>400</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>500</td>
</tr>
</tbody>
</table>

Table 2 simulated condition

2.2 Building model

As shown in Figure 3, the residential three-dimensional model, to simplify the calculation, furniture and personnel are simplified to the cuboid model. GAMBIT was used to generate the grid, which encrypted the large temperature gradient and speed gradient such as air outlet and heat source, and a total of 9,247 grids were divided. In this paper, the RNG k-turbulence model is adopted, the air convection heat dissipation model is calculated, and the SIMPLEC algorithm of pressure-velocity coupling is solved in discrete. Among them, the momentum equation, the energy equation, the k-equation, and the equation are all solved in the second-order windward scheme. Calculations need to calculate from The real-time boundary conditions obtained by the TRNSYS are respectively: ceiling air supply wind speed, air supply temperature, square radiator heat dissipation temperature, ceiling and room temperature, load, and solar radiation heat, etc.

Fig. 3. Building 3D model

2.3 The TRNSYS-CFD hybrid simulation platform

The air conditioning system model established by TRNSYS software and the building model built by CFD software describe different objects. In order to establish the whole building and air conditioning system, the two must be combined to simulate, that is, TRNSYS-CFD hybrid simulation. In the hybrid simulation, the TRNSYS performs the dynamic simulation simulation for each time step, and then the TRNSYS outputs the boundary conditions required for the CFD calculation (such as air supply temperature and humidity, etc.), and the CFD updates the relevant indoor data (such as return air temperature and humidity, etc., after completing the steady-state calculation), and these data are returned to TRNSYS for the next time-step simulation, realizing the quasi-dynamic binding of TRNSYS and CFD. Figure 4 shows the systematic diagram of the TRNSYS hybrid CFD simulations. The key problem in the hybrid simulation is the data exchange between TRNSYS software and CFD software. In this paper, we use TRNSYS as the main program of hybrid simulation to create a subprogram calling CFD. The quasi-dynamic signal feedback program was used to achieve timing and quantification between CFD and TRNSYS data exchange as described in Figure 5.

Fig. 4. TRNSYS-CFD system diagram.

Table 3 Room air supply ratio

<table>
<thead>
<tr>
<th>Room type</th>
<th>Air supply ratio%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public office area</td>
<td>80</td>
</tr>
<tr>
<td>Office</td>
<td>20</td>
</tr>
</tbody>
</table>

Fig. 5. Systematic diagram.
Control the temperature change of room by TRNSYS, the operation time of fresh air system and air conditioning system is 8:00-18:00. TRNSYS outputs the simulated operation time of air conditioning system and sets the 10 minute temperature fluctuation data of the temperature interval point as the external boundary input of Fluent and then feedback to TRNSYS for control, using the control strategy of pre-feedback-negative feedback mechanism.

There are two models for the case building room, including hybrid simulation and TRNSYS separate system simulation, where the maximum temperature in the living room is close to 24°C. In only TRNSYS simulation, the return temperature is the average temperature of the four rooms, but the air conditioning system of IFA + SSEP mainly bears the load of the personnel activity area, and the temperature stratification phenomenon will appear in the room. Therefore, the return temperature should not be the average temperature of the four rooms, and the result of the return temperature in the hybrid simulation is more practical.

4 Conclusion
Since IFA + SSEP air conditioning system will cause indoor temperature stratification, the TRNSYS-CFD hybrid simulation platform established in this paper can add the influence of temperature field homogeneity in the simulation, synchronous real-time analysis of system operation and the analysis of indoor comfort. The results show that:

1) The air supply volume of the independent fresh air system has a great impact on the indoor temperature and humidity. The air conditioning system of IFA + SSEP makes the vertical temperature gradient in the room small, so that the temperature distribution of cold head and foot heating meets the requirements of human comfort.

2) Because the air conditioning system will make the indoor temperature distribution is uneven, the vertical temperature stratification phenomenon appears. Only the single-node simulation using TRNSYS software, the results differ greatly from the actual situation, while the hybrid simulation can be closer to the actual operation situation.

Therefore, the TRNSYS-CFD hybrid simulation platform can be used for the optimization and control of the IFA + SSEP air conditioning system. By changing the air supply parameters and the radiation ceiling water supply parameters, the indoor temperature and humidity are controlled within the required range, to ensure the safe operation of the system, and to make the indoor airflow distribution more uniform, and to meet the requirements of personnel comfort.

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