Research on Energy Saving Potential of Indoor Thermal Environment Control based on Thermal Sensation

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Abstract: Most of indoor thermal environment are controlled based on given values. Researchers have proposed a new indoor thermal environment control method based on thermal sensation, thermal sensation means human body thermal sensation to indoor thermal environment such as cold and hot. This method can not only avoid the unreasonable setting points, but also satisfies the demand of dynamic thermal comfort. At the same time, it benefits to thermal comfort and energy saving of building. This article makes a deep research on energy saving potential of this new method, which will make more energy saving.

1. Introduction
Nowadays, the temperature and humidity control of the room is usually given a set value manually, and then the air conditioning system adjusts the temperature and humidity of the room according to the set value. However, there are some problems to this control method. To this end, some scholars have proposed an indoor thermal environment control method based on thermal sensation. The indoor thermal environment is controlled by replacing the direct input of the temperature and humidity set values with the thermal sensation of the human body as an input value. In the whole system, people are equivalent to a “sensor”, which senses the indoor thermal environment and expresses it to the system. The indoor thermal environment control method based on thermal sensation will make more energy saving.

2. Control system research
By setting up an experimental platform based on thermal sensation control and recruiting volunteers to carry out experiment, the author has analyzed the behavior characteristics of room users expressing their complaints after using thermal sensation control. The layout of the experimental equipment is shown in Figure 1, and the photo of the laboratory site is shown in Figure 2. There are three stations in the room for group experiments of three people.
The thermal sensation input is the core part of the entire control system. When the user feels uncomfortable in the air conditioning environment and produces the sensation of cold, hot, too dry, too wet and excessive wind speed, it can be expressed to the human-machine interface, and the system will automatically control the set value to a reasonable range according to the user's expression. The main interface of the human-machine interface is shown in Figure 3. The control logic of indoor thermal environment based on thermal sensation is shown in Figure 4.
3. Energy consumption feedback
After the user expresses his feeling of the hotness and the coldness in the room through the human-machine interface, the system will adjust the temperature and humidity of the room according to the user's feeling. This behavior will lead to the increase in energy consumption. It was found through experiments that 225 sensation inputs were collected during the experiment, and 115 of them caused an increase in energy consumption of the air conditioning system, which indicates that hot and cold complaints are likely to lead to an increase in energy consumption. For the purpose of energy saving, this paper proposes a new energy consumption information feedback interface. Each time the user expresses the feeling of hot and cold to the human-machine interface, the user will be prompted with three indicators of the average energy consumption level, the current energy consumption level and the energy consumption level after the complaint, and let the user choose whether to continue complaining.

The energy consumption feedback information interface is shown in Figure 5. The user is reminded with the three numbers: the average energy consumption of the air conditioning system, the energy consumption of the current air conditioning system, and the energy consumption of the air conditioning system would occur by the complaint.

Figure 5. Energy consumption feedback information interface.

A simple estimate of the energy consumption of an air conditioning system is shown in Equation (1).

\[
E = \frac{K A (t_i - t_o) + H_i + H_s + G (e_i - e_o) \cdot COP}{COP}
\]  

(1)

Type:
E: Power consumption in air conditioning systems (W)
K: Average heat transfer coefficient (W/m² °C) of the enclosure structure
A: Enclosure Area(M2)
t: Air temperature(°C)
H: Calorific (W)
G: New wind volume (kg/s)
e: Air enthalpy (kJ/kg DA)
COP: Refrigeration factor for air-conditioning systems

Subscript:
o: Outdoor room
i: Indoor room
s: Solar radiation

The indoor air temperature values used are different when estimating the average energy consumption, current energy consumption, and adjusted energy consumption for complaints of the air conditioning system. Estimating the average energy consumption of the air conditioning system, \(t_i\) is 26°C. Estimating the current energy consumption of the air conditioning system, \(t_i\) is current measured
air temperature. When estimating adjusted energy consumption for complaints of the air conditioning system, $t_i$ is the new room temperature setting given by the control system.

4. Experimental results

The thermal sensation complaints and corresponding setting-point adjustments in room temperature and humidity on a typical experimental day are shown in Figure 6. The control system is aimed at the user's complaints of being too cold, too hot, too dry, too wet, too stuffy, too blowing, etc, and adjusts the thermal comfort zone and temperature and humidity settings to meet the user's comfort needs.

The number of complaints accumulated during the experiment is shown in Figure 7. The number of complaints about cold and heat is the highest (at 72.3%), reflecting user's feelings of hotness and coldness are more sensitive than other factors. In addition, women's per capita complaints are twice as high as men's, indicating that women are more sensitive than men and are glad to express their feelings.

![Figure 6. Indoor temperature, humidity curve and user's thermal complaints.](image)

![Figure 7. Number of thermal complaints during the experiment.](image)

The experimental results of energy consumption are summarized in Table 1. From table1, we can see that the volunteers canceled 17 complaints after seeing the feedback information. It is about 14.78% of the complaints that will lead to the increase of air conditioning energy consumption.

| Time of the experiment       | 2017.5.1~2017.5.15 |
|------------------------------|-------------------|
| Number of experimental units | 64                |
| Number of participants       | 15（Undergraduate and postgraduate） |
Total number of complaints 225
Total number of complaints resulting in increased energy consumption 115
Number of complaints cancelled 17
Complaint cancellation rate(number of cancellations as a percentage of complaints resulting in increased energy consumption) 14.78%

5. Conclusion
This article makes a deeper research on energy saving potential of indoor thermal environment control method based on thermal sensation, and propose human-machine interface of thermal sensation and energy consumption information. Compared with traditional way, the new mouthed will save more energy and improve comfort of indoor thermal environment.

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