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Energy-saving operation and optimization of thermal comfort in thermal radiative cooling/heating system

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Abstract

The energy-saving operation in the thermal radiative cooling/heating system has been verified. The coefficient of performance (COP) has been experimentally evaluated by changing the water temperature and the flow rate to control the heat amount. The energy-saving operation has been achieved by increasing the flow rate for the same heat amount. The thermal comfort has also been evaluated by calculating the predicted mean vote (PMV). In the case of the energy-saving operation, it is expected that the heat amount by radiation is reduced and impair the thermal comfort. However, it is found that its reduction has a small effect on the thermal comfort.

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Keywords: energy-saving; thermal comfort; heat pump; thermal radiative cooling/heating system

1. Introduction

In the recent year, energy consumption around the world has been continuously increasing and the problems of global warming and depletion of fossil fuel has been a major concern. Therefore, the introduction of renewable energy such as solar and wind power generation and energy-saving measures have attracted a great deal of interest. As energy-saving measures in the demand side, the cooling and heating systems have been focused, because they account for one quarter of the energy consumption in the residential sector in Japan [1]. The thermal radiation type heating and cooling systems have been studied for the concern about energy conservation and energy management

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in buildings [2-5]. Therefore, the thermal radiative cooling/heating system which has an active use of radiative heat transfer and heat pump technology for the thermal energy supply has been investigated in our research by evaluating the performance of the energy efficiency, thermal radiation and thermal comfort [6-9]. This system has been expected to be available to power control in the demand side such as demand response during tight supply, because this system has the heat exchange and transfer by using water as a medium and it is controllable load equipment such as air conditioners and heat pump water heater [10, 11]. Then, the heat transfer mechanisms and the operation for efficient heating and cooling have been studied in detail in order to accommodate a variety of power control.

In this research, in order to verify the energy-saving operation in the thermal radiative cooling/heating system, the coefficient of performance (COP) in cooling and heating have been evaluated experimentally when the radiation amount is controlled by changing water temperature and the flow rate. The thermal comfort has also been evaluated in these case by estimation of predicted mean vote (PMV) based on the heat radiation model.

2. Experiment outlines

2.1. Thermal radiative cooling/heating system characteristics

The proposed thermal radiative cooling/heating system used in this work is composed of the indoor units of heat sinking radiators and the outdoor unit which contains the heat pump and the heat exchanger. Figure 1 shows the block diagram of the proposed system. In the case of heating, the heat is absorbed from the atmosphere by the heat pump. Hot water is produced by transferring the heat in the heat exchanger. The room is warmed by circulating the hot water inside the radiator. For transferring the heat in the room, the heat transfer by radiation has been actively utilized. On the other hand, in the case of cooling, which is the reverse process of heating, cold water is produced in the heat exchanger by releasing heat into the atmosphere using the heat pump. The circulation of the cold water into the radiator brings a cooling effect in the room. Moreover, a ceramic material coating with high emissivity in far-infrared region applied to the room walls, ceiling and the surface of the radiators. This coating is expected to increase the radiant heat transfer effect. The characteristics of the thermal radiative cooling/heating system are indicated as follows: It is comfortable because there is no feeling of air flow which is usually caused by warm or cold air. In addition to that, the temperature variations in the room are small. Also, it is safer for health because it prevents dust whirling up in the room. There is no mechanical noise other than water circulation in the radiator. Dehumidification effect can be expected during cooling process. Thus, this system can provide comfortable and healthy living environments.

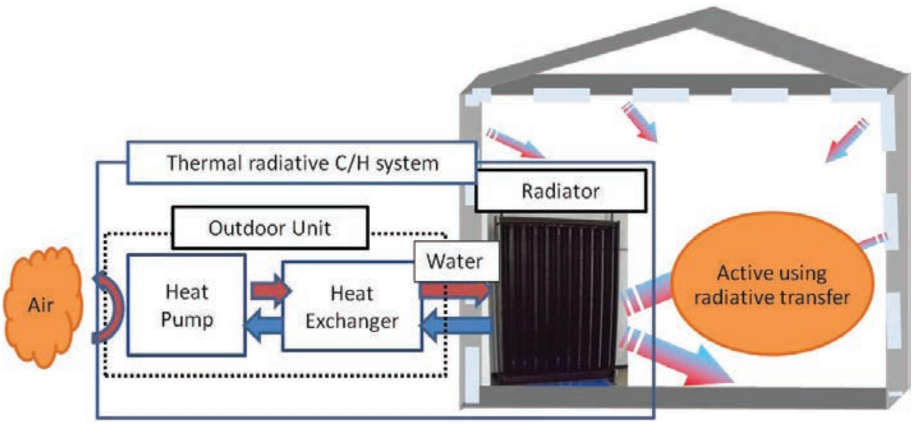

Fig. 1. Block diagram of the thermal radiative cooling/heating system.