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Performance of temperature and humidity independent control air-conditioning system in an office building

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ABSTRACT

The temperature and humidity independent control (THIC) system, which controls indoor temperature and moisture separately, may be an attractive alternative to existing conventional HVAC systems for its prominent improvement on the overall system performance and utilization of low grade energy resources. In order to verify the effectiveness of THIC system, a pilot project has been implemented in an office building in Shenzhen, China. In the system, liquid desiccant fresh air handling units driven by heat pumps are utilized to remove the entire latent load of outdoor air supplied for the whole building, and chilled water at the temperature of 17.5 °C from chiller is pumped and distributed into dry fan coil units and radiant panels to control indoor temperature. This paper presents the results of field test of the system, which shows that the system can provide a comfortable indoor environment even in very hot and humid weather. The COP of the entire THIC system can reach 4.0. According to the energy usage data recorded from the year 2009, the energy consumption of the THIC system in the tested office building was 32.2 kWh/(m^2 yr), which demonstrates magnificent energy-saving potential compared with the conventional air-conditioning system (around 49 kWh/(m^2 yr)).

1. Introduction

In the conventional HVAC system that removes moisture by condensation, air is cooled and dehumidified simultaneously. In most cases, sensible load of building covers the majority part of the whole cooling load while the latent load (moisture load) takes only a small part. However, as the required cooling source temperature of dehumidification is much lower than that of cooling, the chilled water temperature has to be reduced to meet the demand for condensation dehumidification. Moreover, the ratio of sensible load to latent load varies largely due to the changes of outdoor climate, number variance of indoor occupants, indoor equipments and lighting utilization mode and so on. Therefore, the indoor temperature and humidity, the two key parameters, can hardly be satisfied with condensation by the cooling coil only. In practice, the common reaction to the increased humidity is to reduce the set-point temperature and then re-condition the air after passing the cooling coil to the proper temperature, which results in a plenty of energy wastefulness [1].

To avoid the aforementioned problems, temperature and humidity independent control (THIC) air-conditioning system stands out as an appropriate pattern that temperature and humidity can be regulated independently with temperature control subsystem and humidity control subsystem respectively. Besides, the coil temperature for cooling in the temperature control subsystem can be considerably increased, e.g. from current 7 °C to 17 °C, so that improvement on the performance of chillers or even free cooling from ambient could be obtained.

Many investigations have been carried out on the hybrid desiccant dehumidification and air-conditioning system [1–4], which integrates liquid/solid desiccant units with a conventional cooling system to avoid excess cooling. Liquid desiccant units developed quickly in recent years, for its advantages of dehumidifying at a temperature higher than the air's dew-point to avoid reheat procedure in the system, and regenerating desiccant at a low temperature which can be driven by low-grade heat sources [5,6]. Many studies focusing on improving its performance with process optimization have been conducted in depth, such as Yadav [7], DryKor Ltd. [8], and Liu et al. [9]. Chen et al. [10] designed an independent dehumidification air-conditioning system with a hot water-driven liquid desiccant and a chiller that provides 18–21 °C chilled water for an office building in Beijing, which saved about 30% cooling cost compared with conventional system. The performance of a hybrid system tested by Ma et al. [11] was 44.5% higher than conventional vapor compression system at a latent load of 30% and this improving could be achieved by 73.8% at a 42% latent load. Besides, the specific research on the feasibility and performance of the hybrid system in hot and humid regions is promoted [12,13].

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Nomenclature

COP_{air}	coefficient of performance of the fresh air unit
COP_{CH}	coefficient of performance of the chiller
COP_{hum}	coefficient of performance of a set of humidity control subsystem
COP_{HUM}	coefficient of performance of the humidity control subsystem
COP_{TEMP}	coefficient of performance of the temperature control subsystem
COP_{SYS}	coefficient of performance of the THIC system
TC_{CT}	transport coefficient of the cooling tower
TC_{CTP}	transport coefficient of the cooling water pump
TC_{CWP}	transport coefficient of the chilled water pump
TC_{fan}	transport coefficient of the fans in the humidity control subsystem
TC_{FCU}	transport coefficient of indoor FCUs
P_{air}	input power of the compressors and pumps inside the fresh air units
P_{CH}	input power of the compressors of the chiller
P_{CT}	input power of the cooling tower
P_{CTP}	input power of the cooling water pump
P_{CWP}	input power of the chilled water pump
P_{fan}	input power of the fans in the humidity control subsystem
P_{FCU}	input power of the fan coil units
Q_{air}	cooling capacity of the fresh air unit
Q_{CH}	cooling capacity of the temperature control subsystem

This paper will investigate the real operating performance of a THIC air-conditioning system operated in an office building located in Shenzhen, a modern metropolis in southern China of hot and humid climate. In this THIC system, the liquid desiccant fresh air handling units driven by heat pumps are employed to handle the outdoor air to remove the entire latent load and supply enough fresh air to the occupied spaces, and the high-temperature chiller that produces chilled water of 17.5 °C for the indoor terminal devices (radiant panels and dry fan coil units) is applied to control indoor temperature. The operating principle and performance test results of the THIC system will be shown in this paper, and suggestion for performance improvement will also be included.

Fig. 1. The tested office building in Shenzhen.

2. Description of the THIC system in an office building

The THIC system has been put into practice as a pilot project in an office building in Shenzhen, China. This system has been brought into operation in July 2008 and the basic information about the building and air-conditioning system goes as follows.

2.1. Basis information

The 5-story office building, as shown in Fig. 1, is located in Shenzhen, China, with total building area of 21,960 m^2 and the areas of 5940 m^2, 5045 m^2, 3876 m^2, 3908 m^2, 3191 m^2 for the 1st to 5th floor respectively. The main function of the 1st floor is restaurant, archive and carport, the 2nd to 4th floors are the office rooms, the 5th floor is the meeting room, and there is a vestibule vertically through up the 2nd to 4th floors in the north of the building. In the vestibule, curtain wall with ventilation shutters in the upper is applied on its north surface, as shown in Fig. 2.

The outdoor condition in Shenzhen is rather hot and humid all through the year as shown in Fig. 3. The annual outdoor air relative humidity is about 80% and humidity ratio in summer is as high as 20 g/(kg dry air). The building requires cooling and dehumidification in a long period of time, and no heating and humidification requirement in winter. Therefore, how to handle the moisture efficiently is a key issue in such a subtropical area.

2.2. THIC air-conditioning system

The THIC system serves from 1st to 4th floor with the net air-conditioning area of 13,180 m^2 (total area of 18,769 m^2), and the

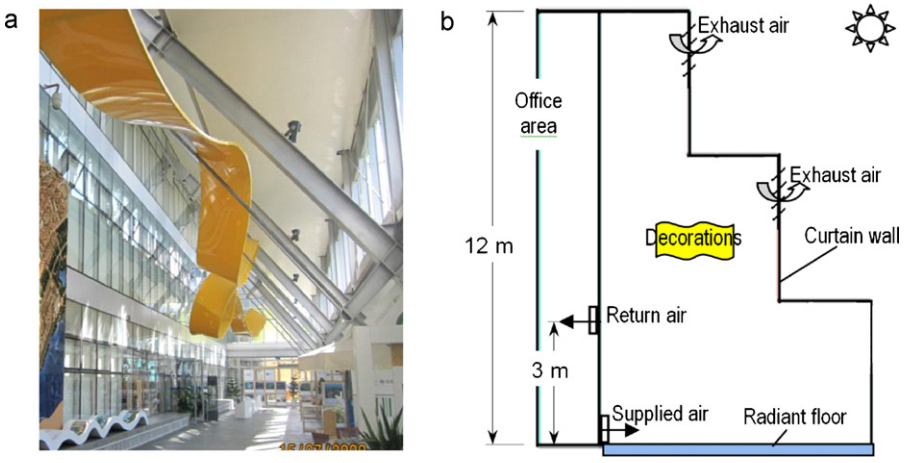

Fig. 2. The vestibule in the office building: (a) photo; and (b) schematic figure.