Experimental study on two-stage evaporative cooling air conditioning system with inner cooling desiccant bed

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Introduction

The energy consumption of cooling and heating accounts for more than half of the total energy consumption of buildings and continues to grow rigidly. Building energy saving will become the key field of "carbon emission reduction" and "carbon neutralization". At present, the problem of high energy consumption exists in steam compression refrigeration. Evaporative cooling is an energy-saving and environmentally friendly cooling method. When combined with a dehumidification bed, the cooling range of evaporative cooling system is improved [1].

The driving force of heat and humidity transport in the evaporative cooling device is the temperature difference between cooling water and air and the partial pressure difference of water vapour [2]. Therefore, the researchers evaluate the thermal performance and environment of the evaporative cooling system. It is found that the energy consumption of the evaporative cooling system is reduced by 75%, and the carbon dioxide emission is reduced by 78% compared with the traditional steam compression system [3].

Since evaporative cooling reduces the air temperature through the heat and moisture transfer between water and air, the efficiency of the evaporative cooler has great limitations [4]. Dehumidification of one-stage evaporative cooling outlet air through dehumidification equipment and evaporative cooling can effectively improve the cooling range [5-6]. The inner cooling desiccant bed can realize isothermal dehumidification, and combined with evaporative cooling can improve the cooling effect of evaporative cooling.

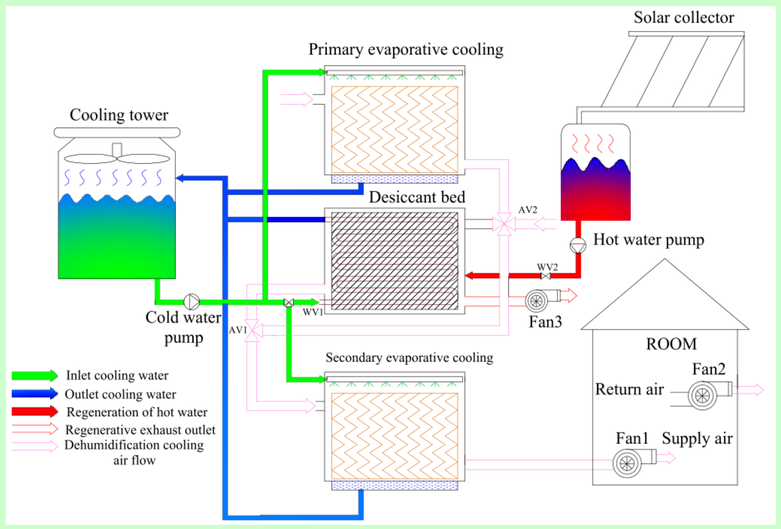

Fig. 1. Scheme of the experimental installation.

Experimental setup

The two-stage evaporative cooling air conditioning system is composed of primary evaporative cooling unit, secondary evaporative cooling unit, inner cooling desiccant bed, cooling tower and a solar heating unit, as shown in Fig1. The specific components include fan, water pump, solar collector, hot water tank, cooling tower, inner cooling desiccant bed and cooling pad fibre wet curtain. The physical diagram of the experimental system is shown in Fig2. It is composed of 600 mm x 500 mm x 300 mm cooling pad fibre wet in two 700 mm x 600 mm x 400 mm stainless steel air ducts and 400 mm x 300 mm x 200 mm desiccant bed in series.

The operating state of the desiccant bed can be divided into dehumidification and regeneration state. When the copper pipe in the desiccant bed is fed with cooling water and operates in the middle of two evaporative cooling systems, it is in the dehumidification state. When the copper tube is connected with the regenerative hot water from the solar collector and operates independently, it is regenerative state. In the two-stage evaporative air conditioning, the air passes through primary evaporative cooling device, and the water in the cooling pad evaporates to absorb the heat in the air to achieve cooling. Then the outlet air of the primary evaporation cooling device enters the desiccant bed to dehumidification, which makes the temperature difference of air dry and wet sphere increase, and the driving force of energy and quality transfer of secondary evaporation cooling device is enhanced, and the overall cooling range of the system is improved.

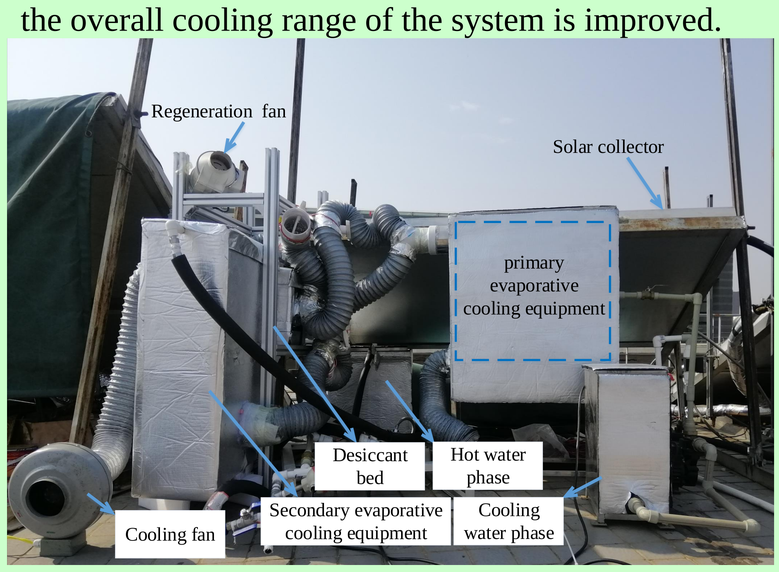

Fig. 2. View of the insulated installation.

Experiment

Experiments studied the effects of inlet air temperature, relative humidity, the air volume and cooling water temperature on COP of the system, and the changes of cooling ratio, cooling capacity Q_C and COP of the system were observed in one day. The temperature and humidity transmitters are placed at the inlet and outlet of the two evaporative cooling devices and the desiccant bed and connected to the paperless recorder (RX9600) to record the air temperature and humidity changes. The temperature probe is placed at the water inlet and outlet of the cooling tower and the water inlet and outlet of hot water tank and connected to the paperless recorder to record the water temperature at different positions. The thermal anemometer is used to measure the air velocity during the operation of the system. To ensure the accuracy of experimental data, the measurement time interval of different data is 2S.

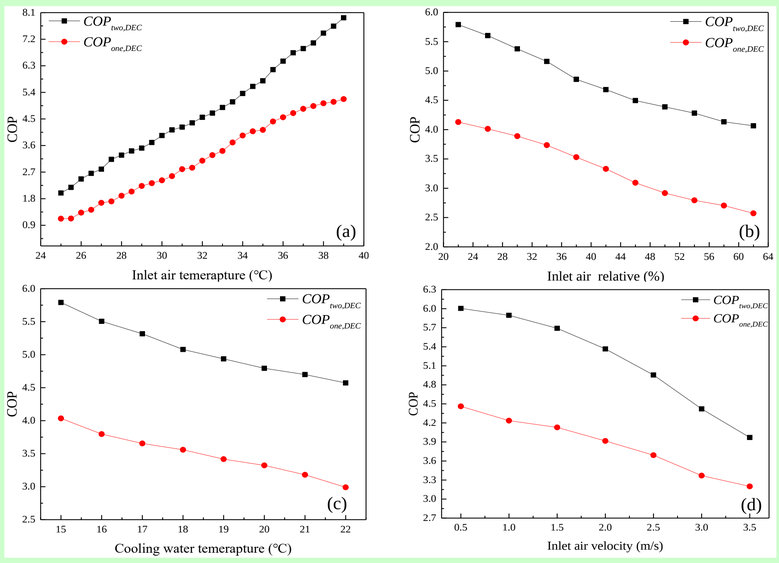

Fig. 3. System COP under different conditions.

Results

The COP is defined as the ratio of power consumption and cooling capacity of fans and pumps. Fig.3 shows the influence of inlet air temperature, humidity, cooling water temperature and air velocity on COP. According to Fig.3, with the increase of inlet air temperature, cooling water temperature and wind speed, COP decreases and increases.

According to Fig4, the outlet air temperature of the two-stage evaporative cooling system is 22.1-24.1 ℃, which is 2-2.8 ℃ lower than that of the one-stage evaporative cooling system. The maximum cooling range, cooling capacity and COP are 10.9 ℃, 631.54w and 5.8. At the same time, we can see that the cooling ratio of the two-stage evaporative cooling air conditioning system is greater than 1 during the operation of one day.

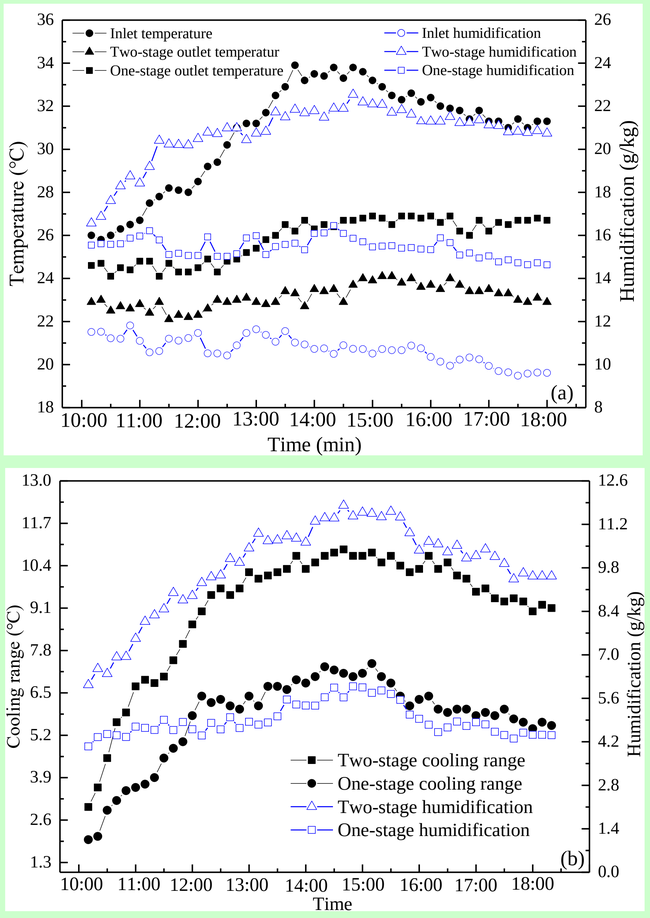

Fig. 4. Performance of one-stage and two-stage evaporative cooling system within day time.

Conclusions

The main conclusions drawn from all these work are:

- The two-stage evaporative cooling air conditioning system with inner cooling desiccant bed has higher cooling range, Q_C, COP and η_{DEC} than the one-stage cooling system;
- With the increase of inlet air temperature, inlet air humidity, cooling water temperature and wind speed decrease and increase;
- The desiccant bed approximately achieves isothermal dehumidification and does not increase the cooling load of the evaporative cooling process.

References

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