

Dynamic Simulation of Desiccant Cooling System with Simultaneously Using Solar and Ground Renewable Energies in Hot-Humid Regions

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ABSTRACT: This paper presents the dynamic operation of a desiccant cooling system combined with solar and ground source energies. Solar energy is used for providing the required energy for regenerating the desiccant wheel, and the ground source heat exchanger is exploited as an air pre-cooling component. The potential of the system in providing thermal comfort is assessed in hot-humid regions. Results reveal that this system is capable of providing thermal comfort in these regions with low-grade regeneration temperatures (lower than 75 °C). As a new perspective, the maximum value of the desiccant wheel regeneration temperature is controlled. The effect of the desiccant wheel performance and its maximum regeneration temperature is evaluated on the behavior of the system. With results, high performance desiccant wheel increases the provided thermal comfort up to 40% and the contribution of solar energy up to 14% compared with its low performance. Reducing the maximum regeneration temperature to 50 °C, decreases the achieved thermal comfort to lower than 30%. Ground source heat exchanger enhances the thermal comfort and a specified level of that can be provided with lower regeneration temperatures. The economical assessment shows that in entirely provided thermal comfort conditions by the system, the payback period is calculated to be 8.2 years.

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1. Introduction

Around 40% of consumed energy in the world is used in buildings, and approximately 50-60% of energy in buildings is devoted to Heating, Ventilation and Air Conditioning (HVAC) systems [1,2]. Cooling systems composed of compressors are commonly employed in hot and humid regions [3]. These systems consume a high level of electricity and have damaged the environment in recent years. Therefore, conventional cooling systems are significantly recommended to be substituted by systems with lower energy demands.

Desiccant cooling systems have been shown to have a high usage potential in hot and humid regions and can be a favorable alternative for the conventional cooling systems that are commonly used in these regions [4,5]. Desiccant cooling systems consume much lower energy compared to conventional cooling systems and are able to be integrated with renewable energies successfully [6]. Several previous pieces of research integrated the desiccant cooling system with ground source energy and eventually concluded that the cooling potential of the system was enhanced dramatically [7,8].

The main goal of this study is to introduce a novel configuration of a desiccant cooling system where solar and ground cycles are implemented simultaneously. The base configuration of the system presented here was first introduced by Uçkan et al. [9]. In this system, solar energy is used as an auxiliary source to provide required energy for the regeneration of the desiccant wheel while ground source

energy is employed as a pre-cooling component to assist the main cooling component in the system, Direct Evaporative Cooler (DEC).

2. Methodology

The cooling system studied here is shown in Fig. 1.

As is seen in Fig. 1, the cooling system is divided into the process section and the regeneration section. In the process section, the process air humidity reduces in the Desiccant Wheel (DW) and then enters the cooling equipment. Cooling types of equipment are Ground Source Heat Exchanger

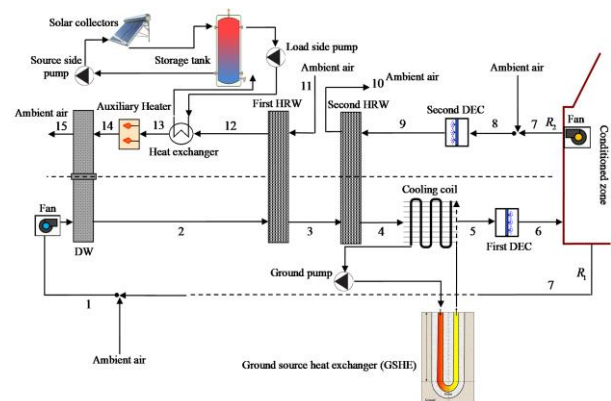


Fig. 1. The proposed desiccant cooling system studied in this research

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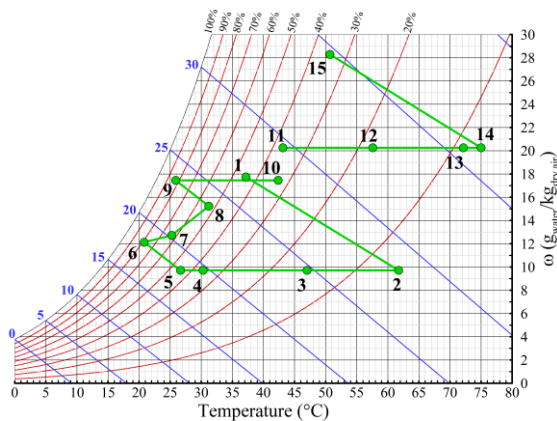


Fig. 2. The cooling system state points on a psychrometric chart

(GSHE), cooling coil, and direct DEC. In the regeneration section, the ambient air is warmed up to get to the required temperature to regenerate the DW. Solar loop and auxiliary heater are used to provide the energy required for regeneration process.

The primary responsibility of the GSHE in the system is to reduce the process air wet-bulb temperature before entering the DEC, thereby increasing the cooling potential of the DEC and eventually the cooling potential of the system. Fig. 2 clearly illustrates the cooling system state points on a psychrometric chart.

TRNSYS software is used to conduct dynamic simulations. As a case study, the weather condition of Bushehr (a city located in the south of Iran with a hot and humid climate) is employed in simulations.

3. Results and Discussion

Simulations are performed during July because this month is the hottest month of Bushehr. So if the system was successful, it could be concluded that the system is applicable through a cooling season. Fig. 3 shows the variation in the indoor temperature and relative humidity during July.

As it is observable, the system is able to establish thermal comfort during the worst month. It is essential to investigate the contribution of solar energy to the regeneration process, called Solar Fraction (SF). Fig. 4 illustrates the daily-averaged SF during the month. Around a half portion of the energy

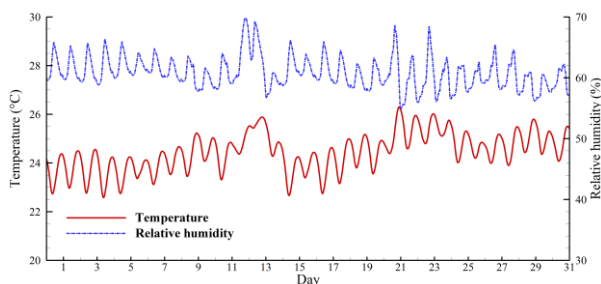


Fig. 3. Indoor temperature and relative humidity during July

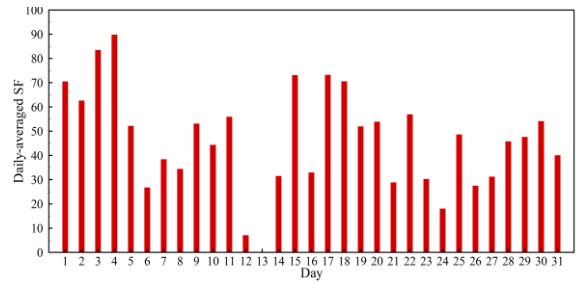


Fig. 4. Daily-averaged SF during the month

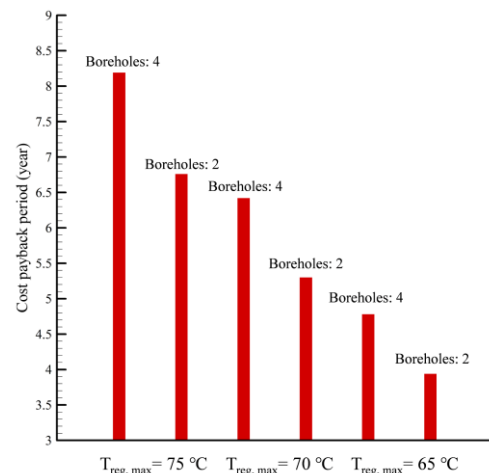


Fig. 5. Daily-averaged SF during the month

required for the regeneration can be supplied by solar energy.

The economic assessment of the system is done to prove that the system is economically reasonable. This analysis is performed based on using different numbers of the ground borehole and the maximum value of the required regeneration temperature to obtain the payback period. Fig. 5 shows the calculated payback period versus different number of ground boreholes and maximum regeneration temperature. Based on the figure, the system is economically applicable.

4. Conclusions

The main conclusions are listed below:

- The cooling system successfully provides thermal comfort in hot and humid regions.
- The GSHE dramatically improves the level of thermal comfort provided.
- A significant portion of the energy required for the regeneration process can be supplied by solar energy.
- This system is an interesting alternative for conventional cooling systems.

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