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Use of regenerative evaporative cooling to improve the performance of a novel one-rotor two-stage solar desiccant dehumidification unit

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ABSTRACT

Ongoing research and development works suggest that good system configurations have significant potential for improving the performance and reducing the cost and size of rotary desiccant dehumidification and air conditioning system. In this paper, a novel desiccant cooling system using regenerative evaporative cooling and a one-rotor two-stage desiccant cooling system are analyzed and compared under Air-conditioning and Refrigeration Institute (ARI) summer, ARI humid and Shanghai summer conditions. The objective of this paper is to compare the thermodynamic performance of the two systems and obtain useful data for practical application. It is found that compared with the conventional desiccant cooling system, the novel desiccant cooling system with regenerative evaporative cooling can handle air to a much lower temperature while maintaining good thermal performance. Under ARI summer, ARI humid and Shanghai summer conditions, the minimum attainable supply air temperatures are reduced from 13.5 °C to 7.9 °C, from 14.2 °C to 9.2 °C and from 18.0 °C to 13.0 °C respectively. It is suggested that the novel desiccant cooling system with regenerative evaporative cooling is beneficial to breaking the obstacle of limited temperature reduction encountered by conventional desiccant cooling system, especially in the case of extreme high humid conditions.

1. Introduction

Rotary desiccant air conditioning system, which is advantageous in being free from CFCs, using low-grade thermal energy and controlling humidity and temperature separately, has been recognized as an alternative to vapor compression refrigeration for space cooling [1–4]. The basic concept of the rotary desiccant cooling is to integrate the technologies of rotary desiccant dehumidification and evaporative cooling. Since the desiccant dehumidification process is close to an isenthalpic procedure and merely converts latent energy to sensible energy producing no useful cooling, auxiliary coolers like evaporative cooler and other air conditioning equipments must be incorporated to remove the sensible heat, thereby achieving a cooling effect [2]. When the desiccant material, wheel structure and operating condition are invariant, the performance of desiccant cooling system (DCS) is principally determined by the system configuration. Therefore, various types of rotary desiccant air conditioning systems have been proposed and studied both analytically and experimentally [5–14].

The first basic rotary desiccant cooling cycle was introduced by Pennington in 1955 [5]. The Pennington cycle, known as the ventilation cycle, adopts ambient air as process air and return air as regeneration air. In the cycle, the process air is dehumidified, sensibly cooled and evaporatively cooled in a desiccant rotor, a heat exchanger and a direct evaporative cooler in tandem. By changing the sources of process/regeneration air and rearranging the components, several other basic configurations, such as recirculation cycle [6], Dunkle cycle [7], SENS cycle [8], REVERS cycle [9] and DINC cycle [10], are formed. In practical application, these cycles are appropriate for different locations, for example, the ventilation cycle is recommended for conditioned-space with high outside air requirement, whereas the recirculation cycle is suitable for space requiring much less fresh air. On the basis of the basic system configurations, some advanced technologies, namely, staged regeneration [11], isothermal dehumidification [12], hybrid desiccant air conditioning [13], have been developed and investigated to lower the reactivation requirement (e.g., low regeneration temperature and cheap desiccant), ensure the operational stability, and improve the thermal utilization rate and energy saving potential. Among these technologies, staged regeneration reduces the consumption of high temperature heat by pre-heating and pre-regenerating the desiccant and is advantageous in reducing the size

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