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Review on solar powered rotary desiccant wheel cooling system

T.S. Ge *, Y.J. Dai, R.Z. Wang

Institute of Refrigeration and Cryogenics, Shanghai Jiao Tong University, Key Laboratory of Power Mechanical Engineering, MOE China, Shanghai 200240, PR China

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ABSTRACT

Rotary desiccant wheel cooling system operates on the principle of adsorption dehumidification and evaporative cooling. The system adopts natural substance as working fluid and can be driven by low grade thermal energy such as solar energy. Due to these merits, solar powered rotary desiccant wheel cooling system has recognized as one of good alternatives to conventional vapor compression air conditioning system and has obtained increasing interests in the past years. This paper aims to summarize recent research developments related to solar powered rotary desiccant wheel cooling system and to provide information for potential application. Based on whether auxiliary refrigeration system is adopted, the systems are divided in to two categories: separate solar powered rotary desiccant wheel cooling systems and hybrid solar powered rotary desiccant wheel cooling systems. Within the first category, separate solar powered rotary desiccant wheel cooling systems are reviewed according to different types of solar collector. It can be found that these researches mainly focus on feasibility study of such system under different climates. Results show that separate solar powered rotary desiccant wheel cooling systems can be adopted in several representative cities in Europe, Asia, Australia and Africa. However, system performance in terms of solar fraction and thermal coefficient of performance varies greatly with respect to different operation conditions. For the second category, works related to hybrid solar powered rotary desiccant wheel cooling systems are grouped by types of auxiliary refrigeration systems. It can be found that vapor compression system is widely adopted in these hybrid systems. Also, due to both solar energy and electricity are consumed in hybrid systems, primary energy consumption is an important performance index. Results show that hybrid solar powered rotary desiccant wheel cooling system can obtain significant energy saving compared with conventional vapor compression system.

Contents

* Corresponding author. Tel./fax: +86 21 34206335.
E-mail address: baby_wo@sjtu.edu.cn (T.S. Ge).

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1. Introduction

Nowadays, there is still a big amount of needs in air conditioning systems with environmental change and improvement of living standards. However, air conditioning systems have already accounted for a large part of energy consumption in the whole society, and then how to effectively increase the energy utilization ratio of air conditioning system is crucial for sustainable development. Traditional air conditioning system operate on vapor compression (VC) cycle, although theoretical COP (coefficient of performance) of the system can reach to about 30, due to the existence of heat transfer difference and other irreversible loss, actual COP only can reach to 3.5. Besides, such systems rely on electricity and the adopted refrigerant still make contributions to greenhouse emission. Rotary desiccant wheel air conditioning system, which operates on the principle of adsorption dehumidification and evaporative cooling, becomes one of the good alternatives to conventional VC systems. In rotary wheel desiccant cooling system, desiccant material (solid adsorbent) is impregnated into rotary desiccant wheel, process air is pumped into desiccant wheel to contact with desiccant material, due to the vapor concentration difference between process air and desiccant material, water vapor within process air can be adsorbed by solid desiccant material, thus latent load of process air is removed and humidity ratio of the air is always extremely low. After that, an evaporative cooling is adopted to handle the sensible load. With use of a dehumidification component and evaporative cooler, comfort air with decreased humidity ratio as well as temperature can be supplied to conditioned space in cooling season. In order to make desiccant material reuse, a regeneration process in which air with high temperature is adopted to desorb water vapor from desiccant material operates in parallel with dehumidification process. On the other hand, if regeneration air is adopted as the supply air to the conditioned space, the system realizes function of heating and humidification for heating season. Compared with conventional VC system in heat pump mode, rotary desiccant wheel cooling system not only can control the temperature but also can realize humidification. It also can be found that thermal energy is the main power to drive solid desiccant cooling system and the adopted refrigerant is natural working fluid. In other words, solid desiccant system is an energy-saving and environmentally friendly air conditioning method. Based on these reasons, numerous researches have been conducted in this field in terms of desiccant material, cycle mode and so on as concluded in previous works [1–4].

A brief review on previous work shows that available researches mainly focus on how to increase the energy utilization ratio or air quality of rotary desiccant wheel system, and electricity or gas burning is adopted to simulate the low grade heat source, mainly due to the merits of easy operation and maintenance. Solar energy with the advantages of cleanness and sustainability is widely acknowledged as a promising low grade thermal energy. Meanwhile, the obtained solar energy consists with required cooling load in cooing season, which means that when solar radiation is abundant, there is always a great need in cooling power. Also, solar technology has achieved remarkable progress with increasing attention on energy crisis in past decades. Based on these, solar powered solid desiccant air conditioning system especially solar powered solid desiccant cooling system gets more and more attention, and several actual systems have been built up. To the authors' knowledge, there is not yet a work that summarizes recent works done on solar powered rotary desiccant wheel air conditioning system. Hence, the objective of this article is to examine the progress in this area and to provide guidelines for designers. Emphasis should be placed on the fact that most of solid desiccant air conditioning system is developed to provide cooling power and then this paper focuses on summarize the development of solar powered rotary desiccant wheel cooling system. However, available results in heating season are also included although it is account for only a small part. The paper is categorized by whether auxiliary refrigeration system is installed. Within the first category it is ordered according to types of solar collector. For the second category, works are grouped by types of auxiliary refrigeration systems. For each system reviewed, attempt has been made to gather up the specifications of solar system, desiccant cooling system and overall performance of whole system.

2. Solar powered separate rotary desiccant wheel cooling system

2.1. Introduction of solar powered separate rotary desiccant wheel cooling system

2.1.1. Basic mode

Solar powered Desiccant wheel Evaporative Cooling System (SDECS) as shown in Fig. 1 is the widely adopted basic type of solar rotary desiccant wheel cooling system. This system is mainly consists of two subsystems: solar subsystem and desiccant cooling subsystem. In the solar subsystem, solar collector, auxiliary heater and water tank are the main components similar to conventional solar hot water system. Solar collector (1) is adopted to absorb solar radiation and heat up the water which is utilized in air heater (3) to heat up regeneration air. Water tank (2) acts like a heat storage unit which also helps to adjust the flux of water. The desiccant cooling subsystem operates on basic ventilation mode: process air from ambient condition is dehumidified and heated in desiccant wheel (4), then is cooled in sensible heat exchanger (5), heat exchanger wheel or plate type heat exchanger) and is further cooled in evaporative cooler (6), at last the air is supplied to conditioned space. Regeneration air from indoor condition flows through evaporative cooler (7), sensible heat exchanger (5), air heater (3) and desiccant wheel (4) in series. It can be seen that these two subsystems are connected by air heater (3), in which hot water from solar subsystem is utilized to heat up regeneration air in desiccant cooling subsystem.

Emphasis should be placed on the fact that auxiliary heat source (8) such as gas heater or electricity is adopted in some systems to ensure the continuous operation when solar energy is lack. Auxiliary heater can be installed in solar subsystem (mode 1) or installed directly in regeneration air side (mode 2).

2.1.2. Performance indicators

There exist several indices in different literatures to evaluate performance of solar solid desiccant cooling system. These indices are summarized and categorized in this part to make the following review more clear.