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Construction and initial operation of the combined solar thermal and electric desiccant cooling system

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Abstract

This paper reports the constructed combined solar thermal and electric desiccant cooling system – its initial operation and operational procedures. The system, as designed, can be operated during nighttime and daytime. The nighttime operation is for thermal energy storage using the auxiliary electric heater, while the daytime operation is for solar energy collection and desiccant cooling. Ongoing experimental evaluation is being undertaken to observe and determine the long-term performance of the system.

Keywords: Solar thermal; Desiccant cooling; Thermal energy storage; Auxiliary electric heating

1. Introduction

Development of green technologies solves the problem of ozone-layer depleting substances (Berry and Jaccard, 2001). Moreover, problems associated with the burning of carbon-based energy sources are eliminated (Aldy and Stavins, 2008). Several green technologies are being eyed as alternatives to the current technologies. The most promising alternatives are the thermally activated technologies (DOE, 2003). Nevertheless, coupling of the green technologies with green energy sources enhances the solution of the problems (Enteria et al., 2008a).

Desiccant-based cooling system is a green technology utilizing the capability of sorbent material in controlling air moisture content (ASHRAE, 1989). The system is a promising alternative to the vapor compression system (Waugaman et al., 1993; Mazzei et al., 2005; Daou et al., 2006; Afonso, 2006). The process of the desiccant dehumidification can either be done through changing of pressure or temperature (Yang, 1987). However, for commercial applications, operation through temperature is the most common and economical way.

Several studies had been conducted on the operation of the desiccant dehumidification employing evaporative cooling processes (Waugaman et al., 1993; Mazzei et al., 2005; Daou et al., 2006). Collier et al. (1982) presented several designs of the desiccant cooling system with some variation of air flows for recirculation and optimization purposes. Sheridan and Mitchell (1985) conducted simulation of the hybrid desiccant cooling system for possible applications in the Australian different climatic conditions. Joudi and Madhi (1987) fabricated an experimental desiccant-based cooling system utilizing solar energy to

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Nomenclature

A	area (m^2)
C_P	specific heat (kJ/kg-K)
COP	coefficient of performance
E	electric power (W)
h	latent heat (kJ/kg), enthalpy (kJ/kg)
I	radiation (W/m^2), current (A)
LER	Latent Energy Ratio
m	mass flow (kg/s)
Q	thermal power (W)
RPH	revolution per minute
SER	Sensible Energy Ratio
T	temperature (°C)
t	time (s)
V	voltage (V)

Greek symbol

ε	efficiency

Subscripts

Aux	auxiliary
Coi	coil
Col	collector
Cur	current
DB	dry bulb
DEC	direct evaporative cooler
DW	desiccant wheel
Ele	electric
$Evap$	evaporation
F	Fan
HA	hot air
Hea	heater
HEX	heat exchanger
I	inlet, instantaneous
LE	latent energy
MIN	minimum
O	outlet
OA	outdoor air
P	pump
PA	processed air
Rad	radiation
Reg	regeneration
$RegA$	regeneration air
SA	supply air
SE	sensible energy
Sol	solar
Vol	volt
WB	wet bulb

heat-up the regeneration air passing the collector. It is intended for Middle East climatic conditions. Smith et al. (1994) made TRNSYS simulation study of the desiccant cooling system using solar energy for application in the United States climatic conditions. Moreover, Davanagere et al. (1999) made further studies using numerical evaluation with building load. The investigation focused on the United States climatic conditions.

Additional researches were carried-out. Henning et al. (2001) made evaluation of the system when applied in European climatic conditions. Dhar and Singh (2001) made study of different desiccant cooling cycles, some of which include hybrid systems. Halliday et al. (2002) reported the feasibility studies of the desiccant cooling system when applied in the United Kingdom climatic conditions. Moreover, Mavroudaki et al. (2002) evaluated the possible application of the desiccant cooling system under Mediterranean climatic conditions. Ando et al. (2005) conducted experimental evaluation of different desiccant cooling cycles for application in Japanese climatic conditions. In addition to this, Kodama et al. (2005) conducted experimental evaluation utilizing solar energy as a sole source of thermal energy.

Recent researches on the desiccant-based cooling system such as of Li et al. (2006) evaluated the hybrid system. The system is the same as the numerical set-up made by Sheridan and Mitchell (1985). Moreover, Henning et al. (2007) made further study on the system for possible application in the Mediterranean climate. The study investigates different desiccant cooling system designs. In addition to this, further investigation was done for the desiccant-based cooling system for possible application in different climatic conditions (Henning, 2007). Jia et al. (2007) investigates the application of high performance desiccant material for application on the desiccant cooling system. The purpose is to increase the cooling load with the same thermal energy input. Latest research on the combined solar thermal and electric desiccant cooling system is presented by Bourdoukan et al. (2008). The system employed auxiliary heater in case solar energy is not high enough its operation. In addition to this, Khalid et al. (2009) made numerical investigation about the application of the solar thermal and desiccant cooling system with different variations intended for Pakistan climatic conditions.

Based on these previous researches, mentioned above, the desiccant-based cooling cycles need further development to increase its cooling performance such as during the early-hour of the day operation and to reduce the supply air humidity content even with evaporative cooler. The solar thermal design needs new concepts for optimized operation of the system with possibility for other applications. This paper presents the developed new desiccant cooling system employing double cross-flow heat exchangers to increase the dehumidification performance at lower thermal energy requirement and to maintain the supply air humidity content at the same level as that of the pro-