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International Journal of Refrigeration 30 (2007) 345–353
REVUE INTERNATIONALE DU FROID
INTERNATIONAL JOURNAL OF
refrigeration
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Use of compound desiccant to develop high performance desiccant cooling system

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Received 16 June 2005; received in revised form 24 March 2006; accepted 5 April 2006
Available online 12 June 2006

Abstract

The paper is aimed to develop a high performance rotary solid desiccant cooling system using a novel compound desiccant wheel (DW). The unique feature of the desiccant wheel is that it can work well under a lower regeneration temperature and have a higher dehumidification capacity due to the contribution of the new compound desiccant materials. Experimental results indicate that the novel desiccant wheel under practical operation can remove more moisture from the process air by about 20–40% over the desiccant wheel employing regular silica gel. A mathematical model that is used to predict the system performance has been validated with the test results. By integrating the desiccant wheel with evaporative cooling, heat recovery and heating for regeneration sections, a solid desiccant cooling system can be formed. Simulation results show that because of the use of the new compound desiccant, the desiccant cooling system can work under much lower regeneration temperature and have a relative high COP, thus low grade thermal energy resources, such as solar energy, waste heat, etc., can be efficiently utilized to drive such a cooling cycle.

Keywords: Air conditioning; Desiccant wheel; Adsorption; Enhancement; Desiccant; Experiment; Modelling; Performance

Utilisation d'un composé déshydratant afin de développer un système à déshydratant très performant

Mots clés : Conditionnement d'air ; Roue déshydratante ; Adsorption ; Amélioration ; Déshydratant ; Expérimentation ; Modélisation ; Performance

1. Introduction

Desiccant cooling systems work on the principles of desiccant dehumidification and evaporative cooling. The unique merit they have is that the sensible and the latent heat can be processed separately. Also, they are advantageous particularly for use in hot and humid climates, and can have access to various low grade thermal energy resources, such as solar energy, waste heat, etc. During the past decades, many efforts have been made to develop such kind of cooling device [1–3]. It is found that desiccant systems are quite efficient in dealing with the latent load, but considerably less so with regard to the sensible load [4]. There are two solutions to overcome such defect. One

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0140-7007/$35.00 © 2006 Elsevier Ltd and IIR. All rights reserved.
doi:10.1016/j.ijrefrig.2006.04.001

Nomenclature

T	Dry-bulb temperature (°C)
RH	Relative humidity
m	Mass flow rate of air (kg/s)
Y	Humidity ration of air (kg/kg)
h	Enthalpy of air (kJ/kg)
COP	Coefficient of performance
Q_c	Refrigerating output (kW)
Nu	Nusselt number
Sh	Sherwood number
ω	Rotation speed (r/h)
c_p	Specific heat (J/kg K)
a	Half height of desiccant channel (m)
b	Half width of desiccant channel (m)
f_d	Mass of desiccant unit length (kg/m)
f_m	Mass of matrix unit length (kg/m)
r	Radius (m)
L	Latent heat of water vapor (kJ/kg)

Subscripts

r	Regeneration air and rejected air
p	Process air side
a	Ambient air
s	Supply air

is for the desiccant cooling system to deal with the latent heat while an electric-powered heat pump deals with the remaining sensible heat. The other is to improve the performance of the desiccant wheel and make the process air sufficient dry so that the sensible heat can be removed entirely by means of evaporative cooling. Nevertheless, one has to face the fact that the size of the desiccant wheel must be big enough if the conventional desiccant rotors are utilized, or other high performance desiccant wheel should be developed by identifying new desiccant materials in order to make the system compact and lower the initial and operating costs.

It is known that the advanced desiccant materials may give improved sorption capacity, better moisture and heat diffusion rates, as well as favorable equilibrium isotherms, of which an ideal Type 1M isotherm shape (Modified Langmuir Type 1) was proposed by Collier et al. [5] as early as 1986. In general, the chosen adsorbent used in desiccant wheel should have both high hygroscopic capacity and saturated adsorption rate. At present, commercially available desiccants include silica gel, activated alumina, natural and synthetic zeolites, titanium silicate, lithium chloride, and synthetic polymers. Such kinds of devices are widely utilized in industrial and commercial application for dehumidification operation. Since Pennington [6] has patented the first desiccant cooling system (DCS), there have been many reports on desiccant cooling performance so far. Parameters optimization on desiccant cooling systems was one of important works [7–9]. Refs. [10–12] report the open cycle systems experimentally. However, to date, coefficient of performance (COP) for DCS has been usually about 0.5–1.0 [13]. It is the key for improvement in COP of DCS to develop novel desiccant wheels with advanced desiccant materials.

In this paper, a novel desiccant wheel fabricated with a new kind of composite desiccant is developed and utilized in a desiccant cooling system. The main objectives are to report the relevant work and analyze the performance of the DCS for the purpose of obtaining a better COP through both numerical calculation and experimental analysis.

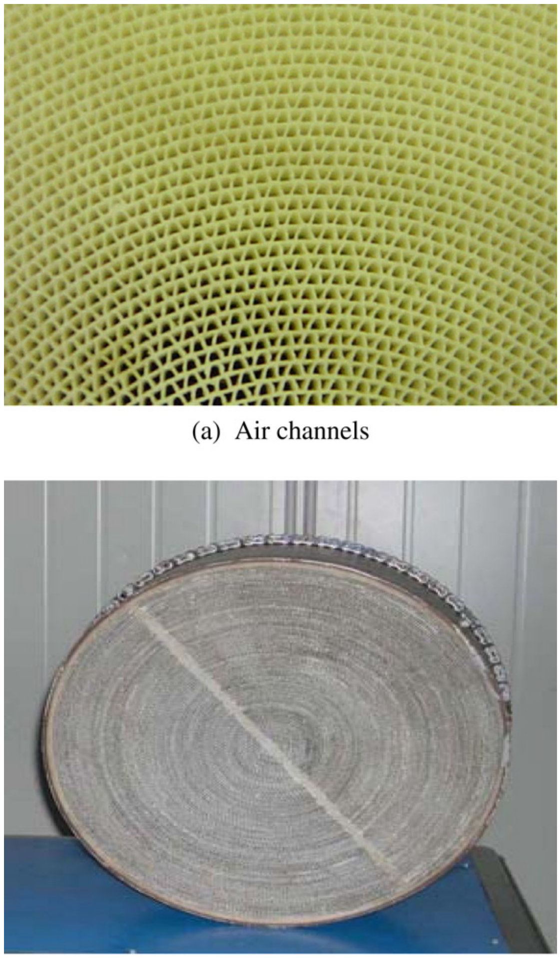

Fig. 1. The experimental desiccant wheel.