Applied Thermal Engineering 44 (2012) 21–28

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Limiting performance mechanisms in desiccant wheel dehumidification

M. Goldsworthy*, S.D. White

CSIRO Energy Technology, Mayfield West, PO Box 330, Newcastle, NSW, Australia

ARTICLE INFO

Article history:
Received 24 November 2011
Accepted 31 March 2012
Available online 12 April 2012

Keywords:
Desiccant wheel
Dehumidification
Adsorption
Isotherm

ABSTRACT

Desiccant cooling is an environmentally attractive alternative to conventional mechanical air-conditioning. The heart of the process is the rotary desiccant wheel which is used to dehumidify air. Recent experimental measurements of wheels with proposed alternative materials at low regeneration temperatures (<80C) have shown fewer benefits than anticipated based on the material adsorption characteristics.

Here a numerical model of a desiccant wheel was used to investigate the specific influence of the desiccant equilibrium adsorption isotherm on the overall wheel performance. The heat of adsorption, moisture diffusion rate, desiccant specific heat capacity and density were varied to provide further insight into the limiting heat and mass transfer mechanisms for low temperature regeneration. In addition, an optimization analysis of the desiccant adsorption isotherm shape was performed for a range of process conditions.

The results show that the extent of dehumidification is limited primarily by a combination of thermal affects caused by both the exothermic adsorption process and the carryover of heat from the regeneration stream. Braunuer Type 1 isotherms increase supply air dehumidification over a linear shape, though this is mostly due to the air inlet conditions which are more typically in the lower relative humidity range. The tendency toward Type 1 behaviour is greater when the heat of adsorption is a stronger function of the adsorbed moisture content. At moderate to high face velocities desiccant layer moisture diffusion kinetics also become important. Critically, the absolute moisture capacity has very limited influence on the performance. These findings have important implications for the design of desiccant wheels.

1. Introduction

Desiccant cooling is an environmentally attractive alternative to conventional mechanical air-conditioning. It does not require ozone depleting refrigerants and it can be run off low temperature waste or solar heat. The heart of the process is the rotary desiccant wheel which is used to dehumidify air. The viability of desiccant cooling is dependent on the degree to which the supply air stream can be dehumidified for a given quantity of regeneration heat and for specific air conditions and flow rates.

A number of alternative desiccant materials have been proposed to improve desiccant wheel performance at low regeneration temperatures (see references in [1]). The apparently favourable moisture adsorption characteristics of these materials is claimed to improve the wheel dehumidification performance. However, recent experimental results [2] comparing desiccant wheels using silica gel, a superadsorbent polymer and a ferroaluminophosphate (FAM-Z01) zeolite material, showed that the silica gel material actually performed as well, and sometimes better, than the alternative materials over a range of conditions. It is not clear whether this performance difference is attributed to differences in the desiccant adsorption isotherms or to other material properties.

The most appropriate method of isolating and testing the influence of specific wheel parameters on the dehumidification performance is to use a simulation model. While a number of desiccant wheel models have been developed (see for example the review by Ge *et al.* [3]), there has been little published work which systematically identifies the relative importance of the physical mechanisms at play, and the manner in which they limit the performance of a desiccant wheel. Collier *et al.* [4] considered the influence of material properties, including the moisture isotherm, using simulations of adsorption in a desiccant bed. However, they considered a parallel flow rather than a conventional counter-flow arrangement. The influence of a range of parameters was investigated and results described in terms of the propagation of wave-

* Corresponding author. Tel.: +61 2 49606112; fax: +61 2 49606021.
E-mail addresses: mark.goldsworthy@csiro.au (M. Goldsworthy), stephen.d.white@csiro.au (S.D. White).

1359-4311/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2012.03.046