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Characterization of desiccant wheels with alternative materials at low regeneration temperatures

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ABSTRACT

A number of new desiccant materials have been proposed which have the potential to improve the performance of desiccant wheels being regenerated at low temperature. Desiccant wheels containing two such desiccant materials (zeolite and superadsorbent polymer) were compared with a conventional silica gel desiccant wheel. The superadsorbent polymer desiccant wheel achieved greater dehumidification than the silica gel wheel when dehumidifying high relative humidity air with low temperature (50 °C) regeneration air. The temperature of dehumidified air exiting the polymer wheel was also lower. The zeolite desiccant wheel was generally less effective at dehumidifying air and had a higher pressure drop.

Caractérisation des roues déshydratantes utilisant des matériaux innovants à des basses températures de régénération

Mots clés : Roue déshydratante ; Déshumidification ; Gel de silice ; Polymère ; Zéolite

1. Introduction

Solid desiccant cooling has been proposed as an alternative to vapour compression refrigeration for space cooling. It is an environmentally attractive solution, which does not require ozone depleting refrigerants and can be run off low temperature waste heat or solar heat.

At the heart of the process, a desiccant wheel is used for dehumidifying building supply air, prior to an evaporative cooling step. Silica gel is widely used as a desiccant material

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in the desiccant wheel, although there is an ongoing desire to develop new improved desiccant materials (Jia et al., 2007; Tokarev et al., 2002; Cui et al., 2007).

Ideally an improved desiccant material would (i) lower the humidity of dehumidified air exiting the desiccant wheel (thereby increasing the efficiency of the desiccant cooling process) and (ii) increase the rate of dehumidification (thereby reducing desiccant wheel size and cost). This would be achieved with minimum pressure drop over the axial length of the desiccant wheel. Materials that enable the desiccant wheel to be regenerated with lower temperature heat are also attractive for a number of waste heat and solar thermal applications.

Three desiccant wheels with alternative low temperature desiccant materials are investigated in this study. The three materials are (i) a ferroaluminophosphate (FAM-Z01) zeolite material with 7.3 Å pore size, (ii) a superadsorbent polymer and (iii) silica gel for comparison with conventional practice.

Kakiuchi et al. (2005), Oshima et al. (2006) and Cho et al. (2007) presented results from the testing of desiccant wheels with the FAM-Z01 zeolite material. They found that the zeolite desiccant wheel gave improved performance over a silica gel wheel when regenerating at very low temperatures (~50 °C). Shim et al. (2008) compared the performance of a new superadsorbent polymer desiccant material with that of silica gel in a batch dehumidification/regeneration desiccant process. They reported an increase in the dehumidification rate of around 20% with the superadsorbent polymer at a regeneration temperature of 60 °C.

2. Experimental description

Experimental testing of candidate desiccant wheels was performed using the Controlled Climate Test Facility at the CSIRO Energy Centre in Newcastle, Australia. The facility (Fig. 1) is designed to provide two streams of air at controlled temperature and humidity conditions. One stream of simulated fresh "supply" air is dehumidified by the test desiccant wheel. The second stream of air, at temperatures up to 90 °C, is used for regenerating the desiccant wheel.

Each air stream is first dehumidified over a refrigerated coil before being heated and then re-humidified, by steam injection, to the desired level. A final trim heater is used to achieve the desired temperature. The two conditioned air streams are supplied to the desiccant wheel inlet faces. The dehumidified supply air and spent moist regeneration air streams exiting the desiccant wheel are removed and exhausted out of the laboratory.

The temperature of each of the inlet and outlet air streams was sampled at four positions across the duct cross-section to obtain a representative measurement of the bulk air stream conditions. Temperature was measured with class B RTD temperature sensors. Sensor error was small compared with the variation of temperature across the duct cross-section (around ±1.2 K). This temperature variation across the duct cross-section is due to stratification and uneven heating/humidification across the duct.

The humidity of each of the inlet and outlet air streams was measured from respective air samples taken uniformly across each duct cross-section. Sampling lines were heated to prevent moisture condensation on surfaces. Relative humidity was measured with capacitive humidity sensors (Vaisala HMW40/50) accurate to ±1.5% RH. Each sensor was calibrated at operating conditions, for each test point, by comparison with measurements from a precision dewpoint analyser (General Eastern Optica) with dewpoint accurate to ±0.2 K.

The velocity of dehumidified supply air and spent moist regeneration air downstream of the desiccant wheel was calculated from the pressure drop measured over respective Venturi nozzles according to ASHRAE Standard 41.2 (1992). The pressure drop was measured with a Dwyer Series MS-121 differential pressure transmitter with an accuracy of ±1% of full scale corresponding to an accuracy of ±0.16 m s^{-1} for the velocity.

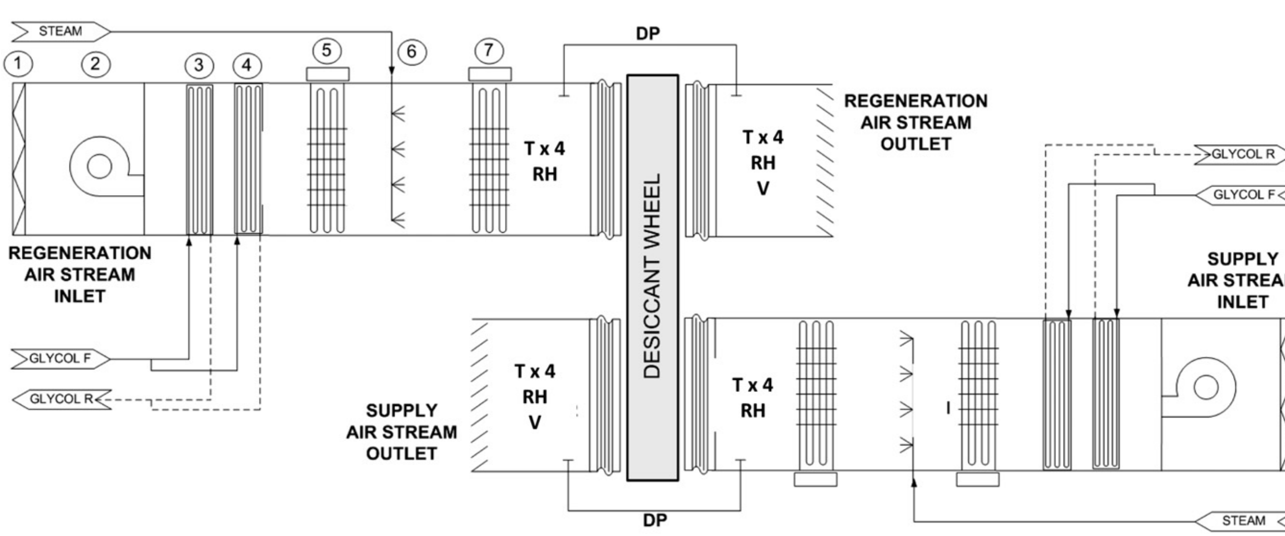

Fig. 1 – Schematic of the Controlled Climate Test Facility. (1) Intake filter, (2) Fan, (3) Medium temperature coil, (4) Low temperature coil, (5) Primary heater bank, (6) Steam injection humidifier, (7) Secondary heater bank, (T) Temperature sensor, (RH) Relative humidity sensor, (V) Velocity sensor, (DP) Differential pressure sensor.