Numerical Simulation of a Rotary Desiccant Wheel

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Abstract

In recent years the interest towards desiccant-based dehumidification systems has increased, due to their great potential for reduction of both primary energy consumption and greenhouse gas emission with respect to conventional systems. Desiccant cooling systems can be powered by low grade thermal energy sources such as solar energy, geothermal energy and "waste" heat. Furthermore, these systems are attractive since they use a natural working fluid such as water as refrigerant, and also since the desiccant materials usually used (silica-gel or zeolites) are environmental friendly.

The main component of desiccant-based dehumidification systems is the desiccant wheel. It consists of a cylindrical rotating wheel obtained rolling up sheets of a supporting material coated with an adsorbent substance, commonly silica gel, as shown in Figs. 1 and 2. Two air streams pass through the cross-sectional area of the device: the process air, which has to be dehumidified, and the regeneration air, which removes water from the adsorbent material. The two streams are always arranged as counter current flows, as shown in Fig. 3.

Performance of this device, in terms of humidity reduction of process air, depends on several design and operational parameters, such as adsorption characteristics of the adsorbent material, desiccant wheel thickness, rotational speed, air regeneration temperature and so on.

Objectives of this paper are to develop a general predictive model of the behaviour of the wheel and to analyse the performance of the desiccant wheel under various design and operational parameters. Previous works have always assumed that the thermodynamic properties of air were constant and equal to those of dry air, while here, exploiting the potential of COMSOL Multiphysics®, the dependence of thermodynamic properties of moist air with temperature has been taken into account.

To predict the steady periodic performance of the rotary desiccant wheel, a one dimensional coupled heat and mass transfer model, based on [1], combined with the classical Linear Driving Force (LDF) approximation, was implemented in COMSOL Multiphysics®. In particular, the Transport of Concentrated Species interface to solve mass balances and the Heat Transfer in Porous Media interface to solve energy balance were used. Moreover, the Classical PDEs Convection-Diffusion Equation interface was employed to implement the adsorption isotherm in the model.

Based on the simulation, temperature and humidity profiles at the exit of the wheel during both the dehumidification and the regeneration process (as shown in Fig. 4) were obtained and analysed under different design conditions and input variables values, namely process and regeneration time, temperature and moisture content of regeneration air, process air flow.

Reference

[1] MH Ahmed, NM Kattab, et al., Evaluation and optimization of solar desiccant wheel performance, Renew Energy, 30, 305-25 (2005).

Figures used in the abstract

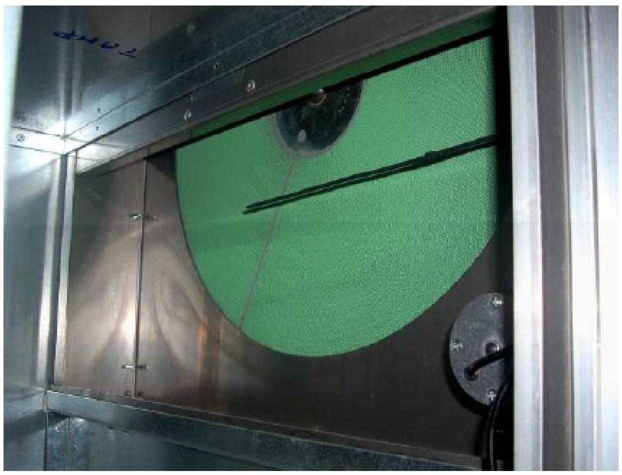

Figure 1: rotary desiccant wheel

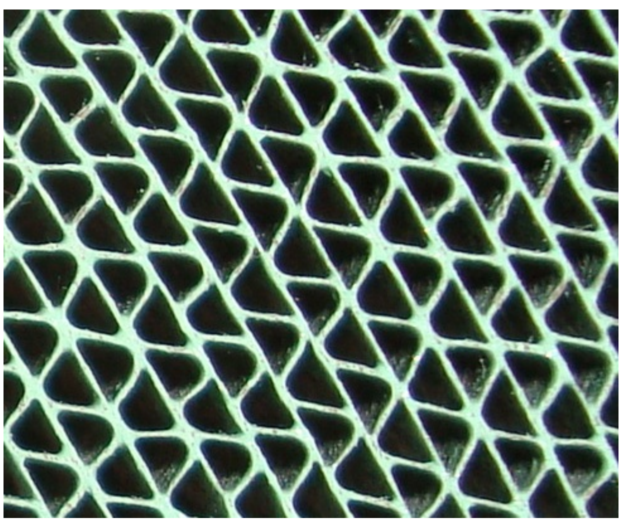

Figure 2: matrix of the wheel

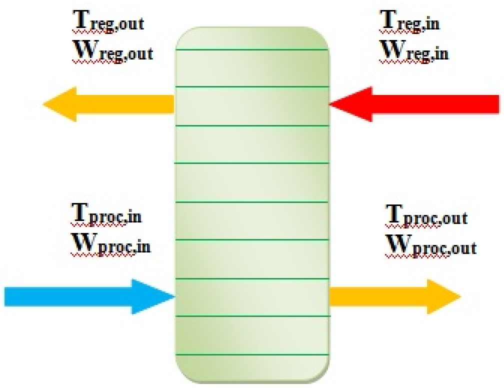

Figure 3: process and regeneration air flow

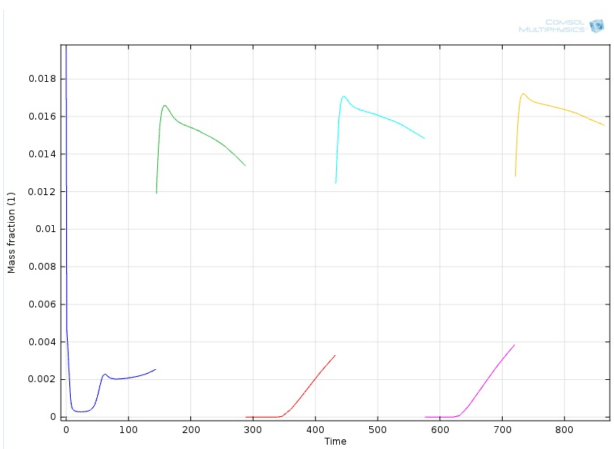

Figure 4: temperature profile at the exit of the wheel during both dehumidification and the regeneration process