Numerical Simulation of a Rotary Desiccant Wheel

G. Diglio, P. Bareschino, G. Angrisani, M. Sasso, F. Pepe
Università degli Studi del Sannio, Dipartimento di Ingegneria,
Piazza Roma 21, 82100 Benevento, Italy.

Introduction: Interest towards desiccant-based dehumidification systems has recently increased due to their great potential for reduction of both primary energy consumption and greenhouse gas emission with respect to conventional systems. Performances of these devices, in terms of humidity reduction of inlet air, depend on several design and operational parameters. Objectives of this study are the development of a general predictive model of the behaviour of the wheel and the analysis of the performance of the desiccant wheel under various design and operational parameters.

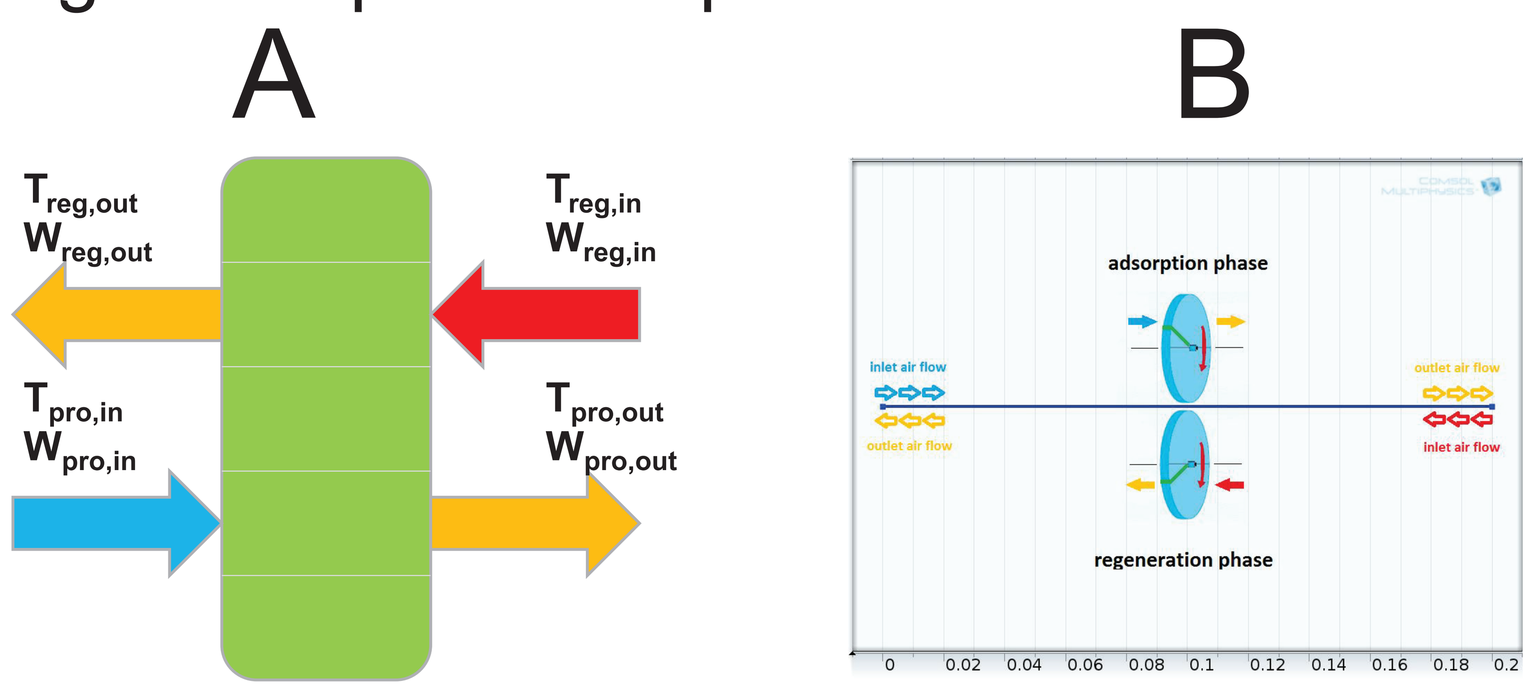

Figure 1. (A) Schematic and (B) COMSOL one dimensional model of a counter-current rotary desiccant wheel.

Computational Methods: A one dimensional coupled heat and mass transfer based on [1], combined with classical Linear Driving Force approximation, was solved in COMSOL:

$$\text{gas phase mass transfer} \rightarrow \rho \frac{\partial w_i}{\partial t} + \nabla \cdot j_i + \rho (u \cdot \nabla) w_i = R_i$$

$$\text{global energy balance} \rightarrow (\rho c_p)_{eq} \frac{\partial T}{\partial t} + \rho c_p u \cdot \nabla T = \nabla \cdot (k_{eq} \nabla T) * Q$$

$$\text{solid phase mass transfer} \rightarrow d_a \frac{\partial M}{\partial t} + \nabla \cdot (-c \nabla M) + \beta \cdot \nabla M = f$$

Moreover, the dependence of thermodynamic properties of moist air on temperature has been taken into account. "Base-case" values of design and operational parameters were reported in Table 1. Changing one parameter at a time, computations are carried on for a sufficiently large number of cycles in order to approach a cyclic steady state profile in both adsorption and regeneration process.

Results: Figures 2 and 3 report air humidity (H) and temperature (T) time profiles at the exit of the wheel during a "base-case" dehumidification-regeneration cycle obtained from a COMSOL simulation.

Figure 4 and 5 show, as a sample of the results reported in the paper, time-averaged value of H and T at the exit of the wheel as a function of the process/regeneration time ratio.

Variable	Value
Process time	144 s
Regeneration time	144 s
Process air temperature	293 K
Process air humidity	20 g/kg
Regeneration air humidity	0 g/kg
Regeneration air temperature	353 K
Process and Regeneration air flow	3 m/s

Table 1. "Base-case" design and operational parameter values.

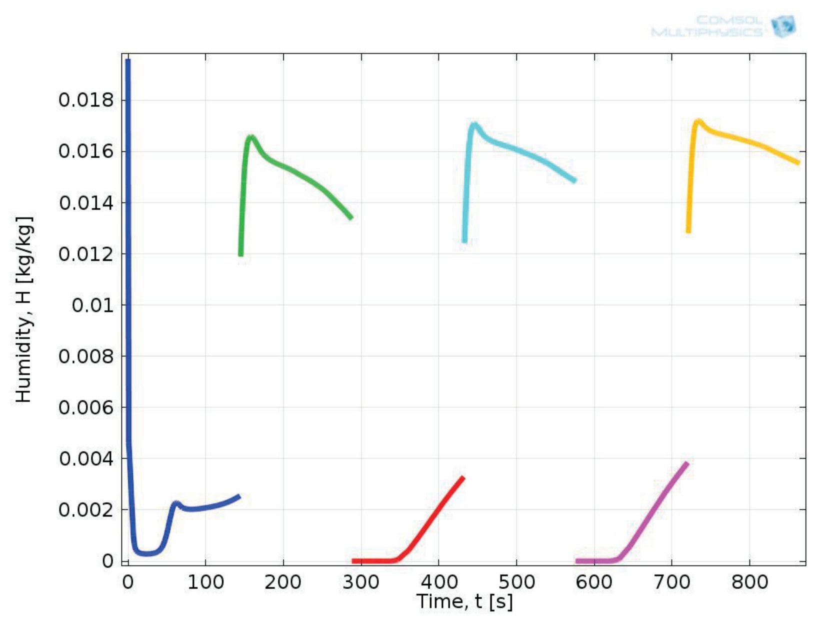

Figure 2. Air humidity time profiles at the exit of the wheel, "base-case".

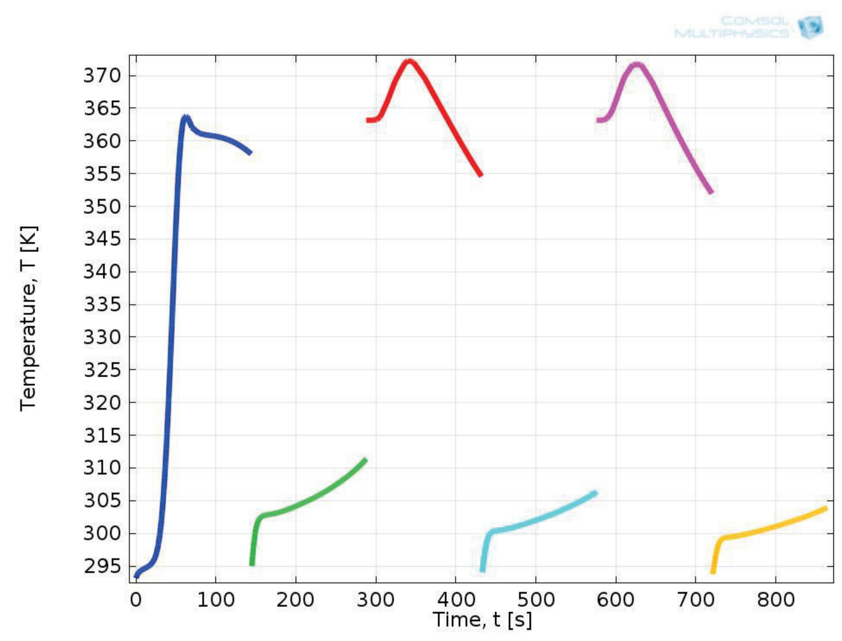

Figure 3. Air temperature time profiles at the exit of the wheel, "base-case".

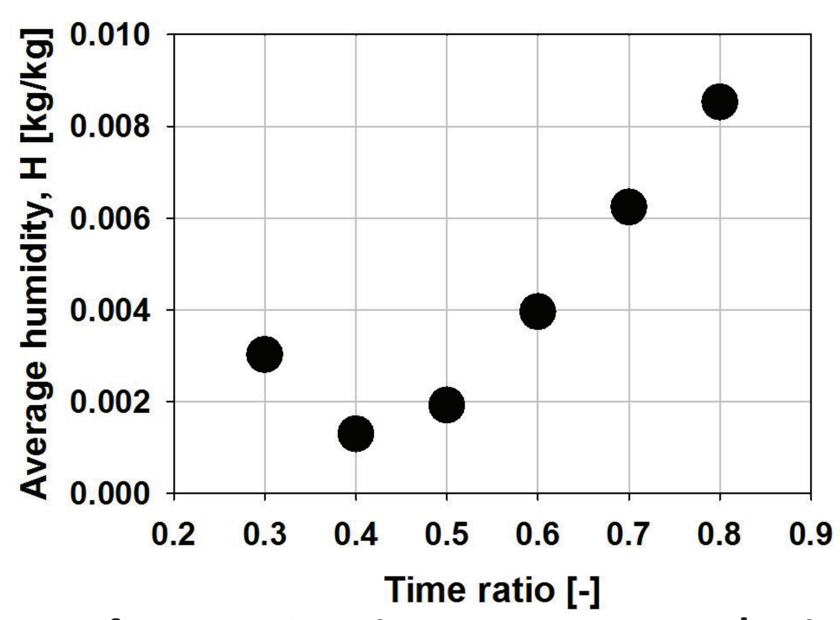

Figure 4. Time averaged air humidity at the exit of the wheel as a function of process/regeneration time ratio.

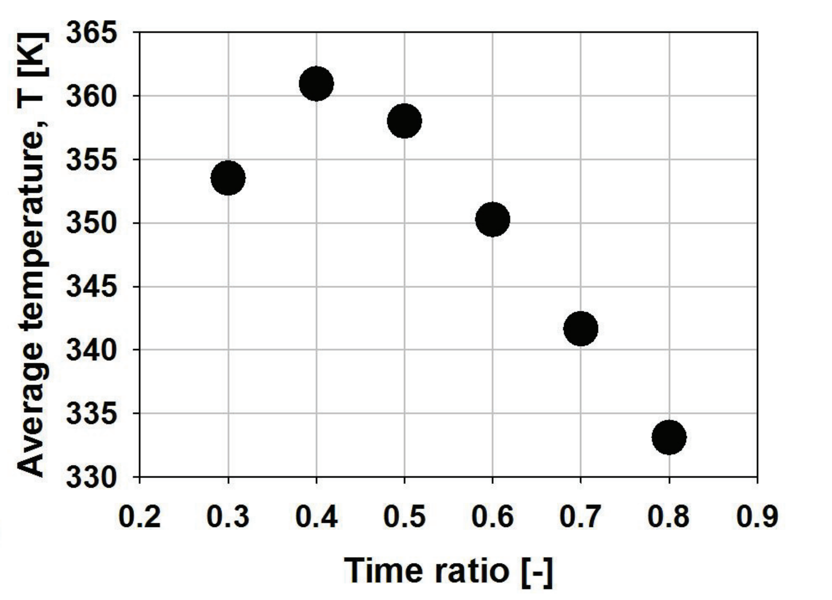

Figure 5. Time averaged air temperature at the exit of the wheel as a function of process/regeneration time ratio.

Conclusions: Numerical results are in good agreement with previously published data [2]. Fine tuning of the model with data obtained from an experimental facility located in the "Università degli Studi del Sannio" laboratory and operated under different conditions is ongoing.

References:

1. Ahmed M.H., Kattab N.M., Fouad M., Evaluation and optimization of a solar desiccant wheel performance, Renew. Energy, 30, 305-25 (2005)
2. Angrisani G., Roselli C., Sasso M., Effect of rotational speed on the performances of a desiccant wheel, Applied Energy 104 268–275 (2013)

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