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Measurement and Modeling of Mass Transport in Porous Composite Structures for Adsorption Heat Pumps

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1. Introduction

Adsorption technology can be used for energy efficient heat transformation applications like adsorption chillers or heat pumps [1]. In an adsorption chiller working with the pair water/zeolite, a heat source (e.g. solar collector or waste heat) is used to desorb the adsorbed water from the zeolite. During the adsorption phase, water is evaporated at pressures between 10-50 mbar and adsorbed in the zeolite, thus cooling the evaporator and releasing the heat of adsorption in the adsorber. The rate of the transient adsorption process may be limited by the water steam transport into and/or the heat transfer out of the adsorber. These two processes are coupled by the adsorption process. State of the art is a lamella heat exchanger filled with adsorbent granules or pellets.

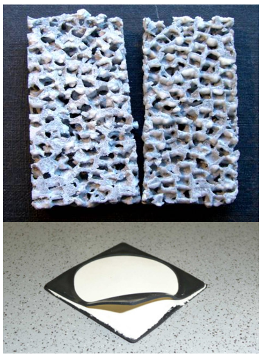

Fig. 1: Coated metal foam and compact porous adsorbent-polymer foil prepared for permeability measurement.

A possible way of speeding up this coupled process and thus reaching higher power densities within the adsorber is the use of compact porous composite structures e.g. binder-adsorbent coatings or high surface metal fibres/foams coated with an adsorbent (see Fig. 1).

To describe and optimize the adsorption process in such composites it is necessary to determine the heat and mass transport parameters separately. Water steam transport in the hierarchical structure of such porous adsorbers takes place on several scales from continuous viscous flow to slipflow and free molecular (Knudsen) or intracrystalline diffusion due to the low pressure and pore size distribution [2].

2. Experimental setup

An experiment has been set up to determine effective mass transport parameters of such composite structures by measuring the apparent permeability [3,4] at pressures between 10 and 100 mbar with various mass flow rates of the probe gas. It can be seen that effective transport parameters do not only depend on the geometry but also on the gas used. Results for measurements on compact adsorbent layers with a binder as well as on open porous metal structures coated with adsorbent will be presented.

In a separate experiment, the whole transient water adsorption process is measured in a closed volume setup which allows quantifying the progress of water uptake in a sample by the pressure lowering in the measurement cell [5]. With comparison to simulations, transport parameters can also be found from these measurements [6,7,8].

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3. Simulation of adsorption kinetics

An existing 1d finite element model of the transient adsorption behaviour [9] is extended to couple dynamically the two very different scales influencing the mass transport (structure pores of the composite and nano-/micropores of the zeolite). The model is validated and calibrated by measurements as described above. It can be used to determine the influence of mass and/or heat transfer limitations and to predict the coupled transient adsorption behaviour and achievable power densities for more realistic geometries and working conditions.

4. Conclusion

Two scales of mass transport in porous composite adsorbers for heat transformation applications are measured by permeability measurements and adsorption kinetics measurements. By simulation of the coupled heat and mass transfer processes, effective transport parameters are determined.

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