3D Unsteady CFD with Heat and Mass Transfer Simulations of Solar Adsorption Cooling System for Buildings

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Abstract

Conventional cooling systems for air conditioning of buildings are responsible for a significant percentage of the greenhouse and ozone depletion effect because of refrigerant harmful gases released into the atmosphere. In recent years, extensive attention has been paid on the application of solar cooling for buildings. Solar cooling technology appears to be a promising alternative to the conventional vapour compression electrical driven machines. Solar cooling systems have the advantage of using harmless working fluids such as water. They can decrease the peak loads for electricity utilities and can contribute to a significant decrease of the CO2 emissions, which cause greenhouse effect.

Amongst cooling technologies, low-temperature solar-driven environment-friendly adsorption cooling systems are emerging viable alternatives to electricity-driven vapour compression systems. They seem to have a promising market potential. Adsorption cooling systems are already a commercialised product for more than two decades with several competitors in the market. The greatest challenge for their widespread use is the reduced thermal and mass transfer in the adsorption bed resulting in slow reaction rates, long cycle times, low specific cooling power and small coefficient of performance. Therefore, the technology still needs research for performance design optimisation under different climate conditions when powered by solar heat.

This study presents the results of three-dimensional (3D) unsteady coupled Computational Fluid Dynamics (CFD) with heat and mass transfer simulations to investigate the influence of design and operating parameters on the performance of a solar powered adsorption cooling system for buildings. 3D unsteady models of plate-fin and finned adsorption cooling units were built in the COMSOL Multiphysics commercial software with CFD, Heat Transfer and Chemical Reaction Engineering modules. Validation of the unsteady flow computation results with experimental data found in literature showed a good agreement. A base case adsorption cooling system using silica gel-water as the working pair is simulated. Different computation test cases were run to systematically analyse the effects of key parameters on the system performance.

The computational results confirmed the importance of the combined geometrical and operating effects on the system performance. Furthermore, 3D transient simulations can be used as an effective tool to improve and optimise adsorption cooling system parameters on existing prototypes or at early design stages.

Figures used in the abstract