3D Unsteady CFD Simulation of Seasonal Solar Thermochemical Heat Storage System for Buildings

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Abstract

Solar energy storage has been an extensive research topic among the several thermal energy applications over the past three decades. Thermal energy storage (TES) systems in general, improve the energy efficiency of systems and sustainability of buildings by reducing the mismatch between supply and demand, and can substantially increase the solar fraction. They expand the use of solar collectors and result in enhanced solar coverage of the space heating demand. TES systems using thermochemical materials are particularly attractive and provide a high energy storage density at a constant temperature. Chemical energy storage has unique advantages of high-energy storage and low heat losses over other storage technologies, and is considered as the most promising alternative. The principle of chemical reaction is based on the reversible reaction between two substances, for instance a solid such a salt and a gas or water vapour, with endothermic decomposition (charging mode in summer) and exothermic synthesis (discharging mode in winter) processes. Heat and mass transfer and momentum transport processes are coupled with chemical reactions in a thermochemical heat storage system (TCHS). The endothermic and exothermic reactions in a chemical reactor in closed or open system are strongly integrated by heat transfer from adjacent heat exchanger.

In this investigation, a three-dimensional unsteady CFD model of a solid/gas thermochemical porous reactive bed with a plate-fin heat exchanger operating in a close system is created in the COMSOL Multiphysics commercial software with CFD, Heat Transfer and Chemical Reaction Engineering modules. It was utilised to simulate and analyse the thermal synthesis of the exothermic hydration reaction of pure salt during the discharging process. Validation of the unsteady reacting flow computation results with data found in the literature has shown a good agreement. Different temporal and spatial dimensional distribution maps of temperatures, velocities and reaction advancements have been obtained; and the effect of the reactive bed thermal conductivity on the performance of the system has been discussed.

Furthermore, the 3D transient CFD model can be used as an effective tool for designing, optimising or improving TCHSs.