Introduction

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 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 contribute to 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 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 as salt and a gas or water vapour, with endothermic decomposition (charging mode in summer), and exothermic synthesis (discharging mode in winter) processes.

Heat, mass transfer and momentum transport processes are coupled with chemical reactions in a thermochemical heat storage system. 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 developed to simulate and analyse the thermal synthesis of the exothermic hydration reaction of pure salt during the discharging process for seasonal heat storage in building applications.

Operating Principles

Fig. 1 illustrates the operating principles of a thermochemical heat storage system using solid-gas chemical reaction. The heat exchanger that is used in dissociation mode as a condenser is the same, which is used in synthesis mode as an evaporator.

Model Geometry

Figs. 2a,b illustrate the geometric models of the thermochemical heat storage (TCHS) reactor based on MgCl2·2H2O for the synthesis (hydration) mode for discharge process for the validation case and the study. 3D unsteady models were built in the CFD commercial software COMSOL. The unsteady simulations were run for a time period, which corresponds to the time required to complete the chemical reaction in the TCHS reactor. This corresponds to a residence time of 14 hours and a time step of 20 s, which was considered to be acceptable in terms of accuracy and efficiency.

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Conclusion

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 developed 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 observed. The effect of the reactive bed thermal conductivity on the performance of the system has shown small increase in the system performance for thermal conductivities up to 50 W/m·K. The CFD model may serve as a valuable design tool for future simulation and optimisation of TCHS for both charge and discharge modes.

References