ABSTRACT

Solar energy is an intermittent supply source of energy. Efficient utilization of energy can be achieved by matching the energy supply with demand by means of thermal energy storage systems. In this context, the use of phase change materials in latent energy storage systems is the most effective way to store thermal energy. The purpose of this study is to numerically investigate the thermal behavior and heat transfer characteristics of a local paraffin wax as a phase change material (PCM) filling the annulus of a horizontal double-pipe pipe heat exchanger during melting and solidification processes. Water is chosen as the heat transfer fluid flows through the inner pipe (hot water for charging and cold water for discharging). The thermal conditions of the outer pipe surface insulated (adiabatic) and the inner pipe at constant temperature (isothermal). Finite volume method (FVM) is used to solve the governing equations of transient laminar flow. The fluid flow in the mushy zone was accounted for using the Darcy drag source term in momentum equation, and the liquid percentage in each cell was updated using the enthalpy-porosity method. Simulation results are presented in the form of liquid fraction, average temperature and their contours over different times and locations. It was found that during discharging, thermal conduction dominates and natural convection has an insignificant impact on the LHTES systems performance. This is due to the development of a solid layer of PCM around the heat transfer tubes, which increases the thermal resistance and reduces heat transfer to the liquid PCM. However, it also found that the maximum and minimum temperature changes near the outer pipe surface during the 16 hours are 56.25 % and 42.5 %, respectively. The results showed that during charging, the PCM at the top of the store melts faster than the PCM in the middle and bottom of the store due to natural convection in the PCM and higher-temperature liquid PCM rising due to buoyancy forces. A comparison has been made with previous studies of the temperature profile for both processes. The comparison showed good compatibility between the results, with the percentage of average error not exceeding about 4.5 %. Moreover, this study illustrates the extent to which LHTES systems and heat exchanger designs need to be improved to meet the desired melting and solidification time requirements for most short-term storage applications.