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Thermal Analysis of Latent Heat Thermal Energy Storage Systems Enhanced with Annular and Radial Fins

Saeed Tiari[1], Addison Hockins[1], Samantha Moretti[1]
[1]Gannon University
109 University Square, Erie, PA, USA
tiari001@gannon.edu; hockins001@gannon.edu; moretti001@gannon.edu

Extended Abstract

A major drawback of latent heat thermal energy storage (LHTES) systems is the low thermal conductivity of phase change materials (PCMs) used as storage media in them. Different passive heat transfer techniques such as using embedded heat pipes [1], impregnation of highly conductive porous media with PCMs [2], dispersion of highly conductive nanoparticles into PCMs [3], and the inclusion of fins into PCMs have been employed to improve the thermal performance of these systems. In the current study, effects of annular and radial fins on the thermal characteristics of a LHTES system during the charging and discharging processes are studied experimentally. Rubitherm RT-55 is used as the phase change material (PCM) and is enclosed within a vertical insulated cylindrical container. The container is manufactured from a 1.27 cm thick clear acrylic tube with a height of 30.48 cm and an inner diameter of 17.78 cm. Water is used as the heat transfer fluid (HTF) which is circulated in a copper pipe that passes through the center of the container. For the charging process, hot HTF at 70 °C is circulated through the system until the entire mass of solid PCM inside the container is fully molten. For the discharging process, cold 20 °C HTF is pumped through the system until all the molten PCM had solidified. Twelve k-type thermocouples are inserted into the PCM container at different heights and depths to monitor the PCM temperature. The inlet and outlet temperature are monitored by two 100 Ohm RTDs. The effects of four different fin configurations attached to the central pipe are studied with the same amount of material used for each configuration. This allows for the understanding of system efficiency while maintaining the same material cost and loss of volume of PCM for energy storage. The two annular fin configurations have fins of 4.0 cm in length with the first configuration having ten fins with a thickness of 1.58 cm. While the second configuration has twenty fins of thickness 0.79 cm. The two radial configurations are rectangular in shape being 7.77 cm in length and 22.94 cm in height. Configuration three has four fins of thickness 1.58 cm while configuration four has eight fins of thickness 0.79 cm. The effects these fin configurations on the total charging and discharging times as well as the PCM temperature distribution have been studied during charging and discharging cycles. The no-fin benchmark case took 48 hours to fully charge and 42.5 hours to discharge. The 10 annular fins charged the system 84.1% faster than the no-fin case. The 20 annular fin case reduced the charging time by 85.8%. The 10 annular fins decreased discharging time by 68.21% and the 20 annular fins decreased charging time by 68.58%. The radial fin configurations of four and eight fins were found to decrease the charging time by 81.9% and 86.6%, respectively. The discharging time was improved by 4 radial fins by 70.0% and by the 8 radial fins by 80.1%. Overall, it was found for the same amount of fin material, the 8-fin radial design produces the best results in accelerating the charging and discharging processes.

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