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Experimental Analysis of a Latent Heat Thermal Energy Storage System Enhanced by Variable-Length Radial Fins

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Extended Abstract

Latent heat thermal energy storage (LHTES) systems can store or release relatively high amounts of thermal energy through melting and solidification of phase change materials (PCM), which function as the storage media. Although these systems provide an alternative for energy storage, their thermal performance is hindered by the low thermal conductivity of PCMs. To improve heat transfer in LHTES systems, passive heat transfer enhancement techniques such as impregnating conductive porous materials with PCMs, dispersing conductive nanoparticles within PCMs [1], embedded heat pipes [2], and inclusion of extended surfaces or fins have been employed. Previously, Tiari and Hockins [3] experimentally studied the effect of annular and radial fins of uniform length on the thermal performance of a LHTES unit. The current study utilized radial fins with uniform or variable length to improve the thermal performance of a LHTES system. The LHTES system consists of an acrylic cylinder with a height of 30.48 cm, outer diameter of 17.78 cm, and wall thickness of 1.27 cm. The container holds the PCM, Rubitherm RT-55. A copper pipe with a diameter of 2.54 cm runs through the center of the cylinder. The heat transfer fluid (HTF), water, is contained within a hot or cold reservoir for charging and discharging processes, respectively. A charging process is complete when all the PCM is molten, while a discharging process completely solidifies the PCM. The PCM temperature is continuously recorded by 12 k-type thermocouples inserted at various heights and depths within the PCM. Inlet and outlet temperatures of the HTF are recorded by two 100 Ohm Class A RTDs. The HTF flow rate is measured by a flow meter before entering the PCM container. Four fin arrangements, each with 4 radial fins, were tested: two with uniform length and two with variable length fins. Within the arrangements there were two configurations with 1/16" (0.15875 cm) and 1/32" (0.079375 cm) thick fins. The 1/16" and 1/32" uniform arrangements had lengths of 0.75" (1.905 cm) and 1.5" (3.81 cm) from the center pipe. The variable fins increase in length from the top of the pipe to the bottom, where length is measured from the base of the fin. The two variable fin arrangements, 1/16" and 1/32", have lengths of 1.5" (3.81 cm) and 3" (7.62 cm), respectively. Each charging cycle has the HTF entering the system at 70°C and a flow rate of 2 gpm. Each discharging cycle has the HTF entering at 20°C and a flow rate of 1 gpm. The volume of copper used in each fin configuration was constant, which allowed for the volume of PCM to remain constant between trials as well; this allows for direct comparison of the fin arrangements. The charging and discharging times for each trial were determined to compare the thermal performance of the uniform and variable fin arrangements. The 1/16" uniform fins had charging and discharging times of 19.05 and 28.79 hours, respectively. The 1/16" variable fins had charging and discharging times of 14.65 and 27.07 hours, respectively. The 1/32" uniform fins had charging and discharging times of 12.43 and 21.28 hours, respectively. The 1/32" variable fins had charging and discharging times of 11.12 and 19.51 hours, respectively.

References

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