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ABSTRACT

Effect of the Fin Density on the Thermal Performance of a Finned-Tube Heat Exchanger Loaded with a Paraffinic PCM

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Recently, we have been experiencing a shift towards an increasing use of renewable energy sources (RES) in place of fossil fuels, in order to mitigate greenhouse gas emissions. Nevertheless, the use of RES introduces the issue of intermittent energy sources (e.g., sun, wind), which makes the adoption of energy storage systems mandatory. Thermal energy storages can be either sensible thermal energy storage (STES) systems, or latent thermal energy storage (LTES) ones. The first typology consists of storage tanks where heat can be stored and released thanks to a temperature change of the storage medium (typically water), whereas LTES employ phase change materials (PCMs), that are properly added in the tank. Thanks to the phase change from solid to liquid state and vice-versa undertaken by these materials, LTES can store and release higher amounts of thermal energy by exploiting the PCM latent heat of fusion.

In this work, we analyze, by means of experiments, the thermal energy performance of a prototype of LTES made by a finned-tube heat exchanger immersed in a PCM (paraffin RT50). In particular, the heat exchanger consists of a single row of copper tubes and a variable number of aluminum fins, and is located within a metal case. Water flows through the copper tube, whereas the cavity outside of the heat exchanger is completely filled by the PCM, which acts as a thermal storage medium. Different tests have been performed with the LTES, both in charging and discharging phases, by varying the water mass flow rate and the water inlet temperature, and by considering different fin densities. In detail, we obtained a different number of aluminum fins by reducing the fin density by 50% and 75% with respect to the value originally present in the heat exchanger.

The obtained results show that, in all the tested cases, the energy stored during the charging process is then released during the discharging phase. A higher heat transfer fluid (water) flow rate means lower charging/discharging times and a higher heat transfer rate. The water mass flow rate and inlet temperature have a strong impact on the LTES thermal performance, as well as the fin density. Indeed, a lower density of fins allows a negligible increase of the stored energy (slightly more PCM can be inserted in the LTES), but causes a dramatic reduction of the LTES thermal performance. Charging and discharging process durations can be decreased by 3 times with a higher mass flow rate and by about 5-10 times with a higher fin density. A higher temperature difference between the inlet water and the PCM allows to more than double the average heat transfer rate. The presented outcomes will contribute to the study and realization of more efficient thermal energy storages, suitable to be implemented in HVAC systems based on RES.