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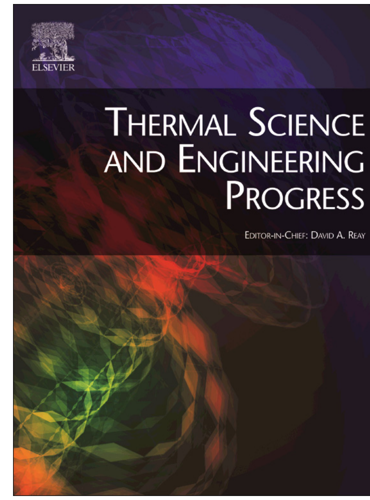

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Experimental and computational investigation of a latent heat energy storage system with a staggered heat exchanger for various phase change materials

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Abstract. This work reports the operation of a Latent Heat Thermal Energy Storage system (LHTES) utilizing a staggered heat exchanger (HE) and using various organic Phase Change Materials. In a LHTES test rig set measurements regarding energy storage and release were performed in the working temperature range of each Phase Change Material (PCM). Nominal melting temperatures of the PCMs used were 40-53^{o}C. Computational Fluid Dynamics (CFD) simulation was applied to follow the operation of the test rig. The test rig consisted of a compact insulated tank, filled with PCM, a staggered heat exchanger to supply or extract thermal energy by the PCM and a water pump to circulate water as a Heat Transfer Fluid (HTF). Different HTF flow rates affect charging (melting) and discharging (solidification) processes but more significant was the effect of heat transfer mechanisms occurring. The latter was confirmed by inserting buoyancy currents created due to convection in a CFD simulation program where melting time was reduced compared to the same conditions with only conduction occurring. The suggested LHTES configuration is a promising compact unit despite the PCMs thermal resistance and solidification hysteresis phenomena, as well as the heat transfer mechanism strongly affecting the energy storage process.

Keywords: heat exchanger, PCM, energy storage, experimental, simulation, convection

1 Introduction

Energy economy demands cost effective solutions for storing heat either in case of a mismatch among production and demand or by heat waste streams. Thermal Energy Storage solutions have been extensively applied on buildings in order to utilize the excess of for example solar energy in the form of sensible energy in a hot water storage tank. Thus solar energy systems for residential cooling/heating and Domestic Hot Water (DHW) production systems require thermal energy storage as a reliable mean to store energy for later use, improving the reliability and the performance of the system and reducing the mismatch between supply and demand of the available solar power [1-2]. Considerably more efficient way to store thermal energy is latent heat thermal energy storage (LHTES) via the integration of PCM, exploiting high values of latent heat [1]. LHTES can store 5-14 times more heat per unit volume than sensible storage materials, such as water [2]. This is due to the utilization of the high storage capacity of PCMs as they release or absorb large amounts of thermal energy during their liquid to solid and vice versa phase transition. This occurs in a small volume, much smaller than sensible storage technical solutions and it is highly related to each PCM molecular physical and chemical properties. In a LHTES a heat exchanger is used to capture or transfer the thermal energy from a PCM to a heat transfer working fluid (HTF) during discharging (solidifying) as well as the opposite during PCM charging (melting). The energy stored can be recovered in a constant temperature of the HTF either a bit higher or lower than the melting temperature of the PCM. This is easily utilized by heat pumps.

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