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Experimental comparison of two heat exchanger concepts for latent heat storage applications

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Abstract

In the present work, two different types of heat exchangers are experimentally compared, namely a fin-and-tubes custom made HEX and a commercial asymmetric plate heat exchanger, for the application with phase change materials. In particular, the two devices were tested in a specifically designed testing rig located at CNR-ITAE and suitable for the characterization of thermal energy storages. The testing bench allows simulating a heat source up to 100°C (e.g. solar thermal collectors, low-grade waste heat) and to set the desired discharge temperature in the range 20°C-80°C. The phase change material with which the exchangers were filled, is a commercial paraffin (Plus ICE A82), having a nominal melting temperature of 82°C. The experimental results on charge and discharge tests, realized with the same protocol, were used for a comparison of the systems, through the identification of suitable performance figures and Key Performance Indicators, such as material-to-metal ratio, heat storage density, maximum and average power achievable and effectiveness of the system. The results show that, for the tested material, characterised by a very low thermal conductivity (i.e. about 0.2 W/mK), the selected plate heat exchanger allows a better exploitation of the heat stored inside the material, letting at the same time to reach a power output in the range 1-10 kW.

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Keywords: PCMs; latent heat storage; experimental; storage design

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1. Introduction

Phase change materials possess promising characteristics, in terms of energy storage density and possibility of being tailored for the different applications, thus making latent heat storage technology an attractive alternative [1]. However, to fully exploit their potential, a suitable device for the heat transfer is necessary, since one of the main drawback of PCMs is their low thermal conductivity that negatively affects their practical application.

Therefore, the design and choice of a heat exchanger is one of the key issues to be addressed towards a major applicability of latent heat storage [2].

In [3] a detailed analysis of different heat exchanger configurations was carried out through experimental characterization, during both charging and discharging phases, employing a commercial PCM, RT35. Among them, the most effective from the heat transfer efficiency resulted the compact HEX with PCM between coil and fins. On the contrary, the plate HEX was not considered promising, due to the reduced achievable heat storage per volume.

In the present paper, two heat exchanger concepts, namely a fin-and-tube and an asymmetric plate heat exchanger, have been experimentally investigated for heat storage temperatures in the range 80-100 °C, aiming at the comparison of the two HEX technologies. Particularly, the experimental results were analysed by means of different KPIs, able to define the most effective HEXs in terms of energy storage density and heat transfer efficiency.

Nomenclature

A	exchange area, m^2
cp	specific heat, kJ/ (kg K)
E	energy, kJ
m	mass, kg
P	power, W
T	temperature, °C
t	time, min
U	overall heat transfer coefficient, W/(mK)
V	volume, m^3
ε	efficiency, adm
τ	characteristic time, min/m^3
Subscripts	
ave	average
ch	charge
disch	discharge
in	inlet
out	outlet
tot	total
Abbreviations	
PCM	Phase Change Material
HEX	Heat Exchanger
TESS	Thermal Energy Storage System

2. Phase Change Material

The PCM to be used in the specific application was selected considering that its melting/solidification temperature should match the requested one for the specific applications, e.g. solar cooling with non-concentrating solar collectors. The examined range lies around 80-100 °C. As reported in [4], a screening of literature and market has been carried out and the most promising materials have been tested, in order to obtain information on the effective