Latent thermal energy storage system using phase change material in corrugated enclosures

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HIGHLIGHTS

► A novel system design for latent thermal energy storage.
► Heat transfer enhancement in thermal energy storage systems was achieved by increasing surface area and aspect ratio.
► Faster response time of thermal energy storage system when meet demand load.
► Heat transfer fluid direction plays a decisive role in charging and discharging processes of the thermal energy storage system.

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ABSTRACT

Latent thermal energy storage (TES) systems rely on the use of phase change materials (PCMs) to store a significant amount of thermal energy. Current systems consist of small surface-to-volume ratio containers or enclosures that exhibit poor transient thermal performance. There is a need to enhance heat transfer in TES system with the goal of reducing charging and discharging times while maximizing surface-to-volume ratio. The aim of this study was to experimentally investigate the effectiveness of a newly designed TES system with high surface-to-volume ratio and high aspect ratio. Several parameters including Reynolds number, Stefan number, and heat transfer fluid (HTF) flow direction were considered and are presented in this paper. The TES consists of sealed corrugated copper panels containing octadecane arranged in a vertical configuration to promote a self-induced internal natural convection mechanism. Results show significant enhancement in charging and discharging rates by as much as 9 times when compared to concentric systems due to the high surface-to-volume ratio of the PCM panels used in the study. Buoyancy effects, observed at high Stefan numbers, were significant during the charging (melting) process and greatly influenced the temperature profiles along each vertical channel. A comparison of the effectiveness of the new TES device with other conventional devices found in the literature indicates that the devised TES performs better both in terms of thermal response time and heat transfer effectiveness.

1. Introduction

Latent thermal energy storage (TES) systems have gained considerable attention lately in many engineering applications since they can provide a high density thermal energy storage capacity when energy demand and supply loads do not match accordingly. In such systems, energy is stored by taking advantage of the melting process of phase change material (PCM) and recovered during solidification of the PCM. The main practical difficulty that hinders the wide spread use of these systems is the inherent low thermal conductivity of PCMs which delays the system thermal response to system demand loads. As result of this disadvantage, TES systems should be redesigned so heat transfer rates can be enhanced while increasing charging and discharging rates. Several approaches of heat transfer enhancement in latent TES systems have been investigated in recent years. Sharma et al. [1] summarized the investigations and analyses of available thermal storage systems that use PCMs. Some of the techniques for enhancing heat transfer include the use of multiple PCMs [2,3], high thermal conductivity nanoparticles [4–6], microencapsulated PCMs [7–11] and extended surfaces [12,13].

Lacroix [13] developed a three-dimensional numerical model to account for the melting process in a finned shell-and-tube latent...