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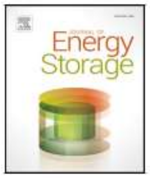

Research papers

Melting control of phase change material of semi-cylinders inside a horizontal baffled channel: Convective laminar fluid–structure interaction

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ABSTRACT

The problem studied in this paper consists of forced fluid flow inside a horizontal channel involving two semi-cylinders and two flexible baffles attached alternatively to the lower and upper walls of the channel. A phase change material fills the semi-cylinders, which are being heated by constant temperature. Cold air is forced through the channel to induce the contributions of convective and conductive heat transfers, fluid–structure interaction and the melting of phase change material. The prevailing mathematical equations of these physics are normalized and solved using the finite element method with the ALE scheme. The influential parameters are: dimensionless time τ, the elasticity modulus of the baffles E and the Reynolds number Re. The most important results show a retardation of melting volume fraction with increasing Reynolds number and decreasing the elasticity modulus of the flexible baffles. It is found that elevating Re from 10 to 500 and E from 5×10^4 to 5×10^6, the melting volume fraction MVF at $\tau = 15$ reduces by 4.15% and increases by 5.2%, respectively. The flexible baffles having a lower modulus of elasticity augment the Nusselt number very slightly (0.9%), while the pressure drop along the channel decreases notably.

1. Introduction

Storage of alternative energy sources is significant for regulating the mismatch between the consumed and demanded energy in time for systems to operate more effectively and reliably. Over the past two decades, researchers have focused on using phase change materials (PCMs) as latent thermal energy storage (LTES) instead of sensible thermal energy storage (STES). This can be attributed to a solid–liquid PCM capability of periodically absorbing, storing, and releasing thermal energy in the form of latent heat during phase change for charging/discharging periods under the nearly isothermal system. During the phase transition of materials, thermal energy is stored when they melt, and it is recovered when they solidify [1]. Hence, LTES is considered more attractive for various engineering applications, including climate control of domestics, drying of industrial and agricultural products, and water desalination [2–6].

Despite the high storage capacity of LTES of gained energy during the melting time, its melting/solidification rates in the system are still low due to the poor PCM conductivity and the energy exchange rate between the fluid streams and the paraffin wax layers into containers of storage. Several studies have employed various technologies for improving the effective thermal conductive rate, such as nanoparticle-paraffin wax [7–9], PCM encapsulation [10–12], multi-PCM [13–15], porous metal foam [16–18], and fins structure [19,20]. Utilizing fins in the LTES units gives better enhancement than nanotechnology [21].

Numerical optimization of PCM with fins in heat sinks was achieved by Pakrouh et al. [22]. They concluded that the optimum PCM percentage was highly influenced by the fin parameters, such as number, height, and thickness. Arshad et al. [19] investigated the cooling enhancement of electronic devices' performance experimentally using different thicknesses of aluminum pins in PCM enclosures. They concluded that the optimum efficiency of the system was reached for a 2 mm thick finned-PCM heat sink.

Bhagat et al. [23] analyzed numerically the solar thermal storage utilizing PCM, the influence of fin parameters on the PCM layer, and

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