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Simulation of heat transfer in a nanoparticle enhanced phase change material to design battery thermal management systems: A lattice Boltzmann method study

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Highlights

- Natural convection of PCM in a T-shaped cavity is investigated by LBM.
- The enclosure contains CuO nanoparticles and two heat sources on the sidewalls of the cavity.
- PCM melting speed is much lower for low Ra numbers compared to when $Ra=10^5$.
- melting rate is little affected by the addition of nanoparticles.
- Such a study can be used to design battery thermal management systems (BTMS).

Abstract

Background

In the present paper, the natural convection of phase change material (PCM) in a T-shaped cavity is investigated by the lattice Boltzmann method (LBM). In recent years, LBM has become a powerful method for computational modeling of a broad variety of complex fluid flow concerns, including the simulation of the melting process in PCMs.

Methods

The enclosure contains CuO nanoparticles and two constant temperature heat sources on the sidewalls of the cavity. The obtained results are presented in different Rayleigh numbers ($Ra=10^3$–10^5), cavity angles ($\theta=0$–90), the volume fraction of nanoparticles ($\varphi=0$–0.03), and aspect ratios. Results show that the PCM melting speed is lower for low Rayleigh numbers compared to when the number is equal to 10^5 by 50%. To alter melting time in a specific Ra number, adding nanoparticles, changing cavity slope, and aspect ratio are investigated. Results show that the melting rate is little affected by the addition of nanoparticles but, generally adding nanoparticles delays PCM melting.

Significant findings

Raising the distance between the battery and the top of the cavity is known to delay melting by 70% when the distance ratio increase from $H1/H=0.25$ to 075, whereas increasing or lowering the distance between the batteries does not affect the melting time. Such a study can be used to design battery thermal management systems (BTMS).