International Journal of Heat and Mass Transfer 127 (2018) 914–926

Contents lists available at ScienceDirect

International Journal of Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ijhmt

Nanofluid unsteady heat transfer in a porous energy storage enclosure in existence of Lorentz forces

Zhixiong Li [a,b], M. Sheikholeslami [c,*], M. Samandari [d,e], Ahmad Shafee [f]

[a] School of Mechanical Engineering, Xian Jiaotong University, Xian 710049, China
[b] School of Mechanical, Materials, Mechatronic and Biomedical Engineering, University of Wollongong, Wollongong, NSW 2522, Australia
[c] Department of Mechanical Engineering, Babol Noshirvani University of Technology, Babol, Iran
[d] School of Mechanical Engineering, College of Engineering, University of Tehran, North Kargar St., Tehran 14395-515, Iran
[e] Cellular and Molecular Biomechanics Laboratory, Department of Bioengineering, Imperial College London, London SW7 2AZ, UK
[f] Public Authority of Applied Education & Training, College of Technological Studies, Applied Science Department, Shuwaikh, Kuwait

ARTICLE INFO

Article history:
Received 8 March 2018
Received in revised form 18 June 2018
Accepted 19 June 2018

Keywords:
Heat transfer
Finite element method
Nanoparticle-enhanced PCM
Lorentz forces
Thermal energy storage
Porous media

ABSTRACT

In current article, nanofluid time dependent heat transfer under the influence of Lorentz forces during discharging process is simulated by means of FEM. In order to overcome the limitation of PCM, NEPCM has been utilized. CuO and water are employed as nanoparticles and PCM. Brownian motion role is taken into consideration to estimate nanofluid characteristics. Graphs are illustrated as isotherm, solid fraction and stream line contours. Results reveal that discharging rate improves with augment of Lorentz forces. As Hartmann number augments, solid fraction profile will be converged in lower time. Dispersing nanoparticles has significant impact on phase change front.

1. Introduction

The energy storage unit has two important factors: amount of energy stored and thermal efficiency. Latent heat must be stored during discharging process. Dispersing nanoparticles to based fluid can remove this limitation. Ali et al. [1] investigated particle transportation in blood due to magnetic field. They employed two phase model for their simulation. Tlili et al. [2] investigated multiple slips impacts on non-Newtonian nanofluid treatment in existence of chemical reaction. Sheikholeslami [3] presented a simulation via FEM for discharging process of NEPCM using CuO nanoparticles. Hussanan et al. [4] demonstrated microstructure behavior of magnetic nanofluid over a stretching plate. Sheikholeslami et al. [5] illustrated the exergy loss of nanofluid inside circular duct equipped with new turbulators. Exergy loss enhances with rise of pitch ratio. Sheikholeslami and Rokni [6] wrote a good review paper about different uses of magnetic nanofluid.

Ahmed et al. [7] demonstrated the mixed convection of sodium Alginate based nanofluid considering Brinkman model. Cu and Ag nanoparticles transportation in existence of radiation has been demonstrated by Hayat et al. [8]. Sheikholeslami et al. [9] studied the roles of radiative term on unsteady conduction heat transfer during discharging process. They utilized NEPCM instead of water. Khan et al. [10] considered the joule heating influence on alumina nanofluid behavior over a wedge in presence of thermal radiation. Sheikholeslami and Ghasemi [11] reported the roles of radiation on NEPCM solidification. They showed solidification front for various cases. Xu and Cui [12] simulated nanofluid mixed convection in a porous duct. Their working fluid contains microorganisms and nanoparticles. Sheikholeslami [13] dispersed nanoparticles into base fluid to expedite solidification phenomena. They considered magnetic field impact on discharging process, too. Haq et al. [14] utilized SWCNTs nanoparticles for improvement of heat transfer in a cavity. Khan et al. [15] illustrated the effect of chemical reaction on ferrofluid migration. Recently researchers utilized Newtonian and non-Newtonian nanofluid [16–42].

In current article, FEM simulation for NEPCM discharging phenomena is studied considering magnetic field. Roles of Hartmann number, NEPCM volume fraction and Rayleigh number on solidification phenomena are depicted in results.

---

* Corresponding author.
E-mail addresses: mohsen.sheikholeslami@nit.ac.ir (M. Sheikholeslami), m.samandari@imperial.ac.uk (M. Samandari).

https://doi.org/10.1016/j.ijheatmasstransfer.2018.06.101
0017-9310/© 2018 Elsevier Ltd. All rights reserved.

Nomenclature

K	permeability
L_f	latent heat of fusion
NEPCM	nano-enhanced PCM
d_p	diameter of nanoparticle
k	thermal conductivity
KKL	Koo–Kleinstreuer–Li
PCM	phase change material

Greek symbols

α	thermal diffusivity
ϕ	nanoparticle volume fraction
ρ	fluid density

Subscripts

nf	NEPCM
p	particle
f	pure PCM

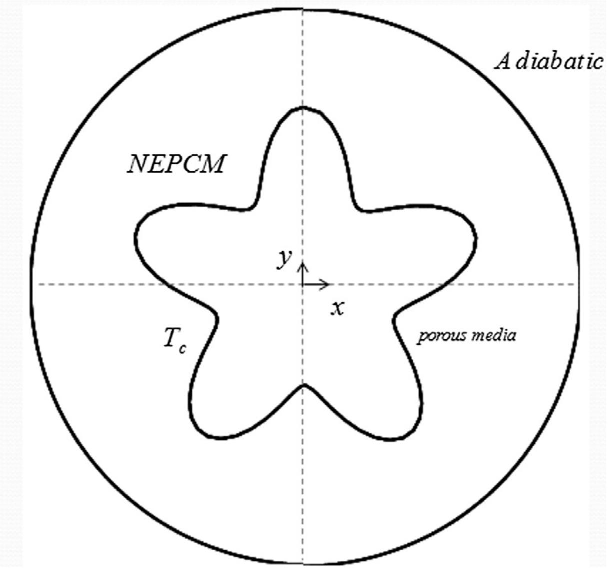

Fig. 1. Current problem energy storage system.

Table 1
The physical properties of water as PCM, CuO as nanoparticles.

Property	PCM	Nanoparticles
ρ [kg/m^3]	997	*6500*
C_p [J/kg K]	4179	*540*
k ([W/m K])	0.6	*18*
L_f [J/kg]	335,000	–

2. Explanation of present problem

Fig. 1 demonstrates the shape of the present LHTESS. NEPCM is utilized instead of pure PCM. Table 1 depicts the summarization of NEPCM's characteristics. The sinusoidal wall is kept at constant temperature of 240 K. To expedite the solicitation, uniform magnetic field was employed.

3. Governing equations

Current unsteady process can be summarized by following equations in presence of magnetic field:

$$\nabla \cdot \vec{V} = 0 \tag{1}$$

$$\frac{\mu_{nf}}{K}\vec{V} = (\rho_{nf}\vec{g} - \nabla p + \vec{I} \times \vec{B}) \tag{2}$$

Table 2
The coefficient values of *CuO* – *Water* nanofluids.

Coefficient values	*CuO* – *Water*
a_1	−26.593310846
a_2	−0.403818333
a_3	−33.3516805
a_4	−1.915825591
a_5	6.42185846658E−02
a_6	48.40336955
a_7	−9.787756683
a_8	190.245610009
a_9	10.9285386565
a_{10}	−0.72009983664

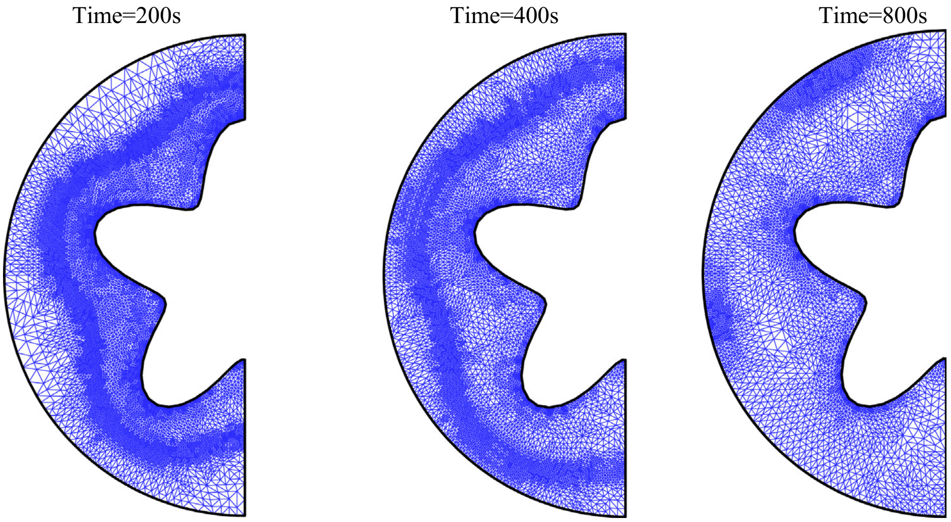

Fig. 2. Samples of mesh when $\phi = 0.04, Ra = 10, Ha = 0$.