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Transport of Magnetohydrodynamic nanofluid in a porous media

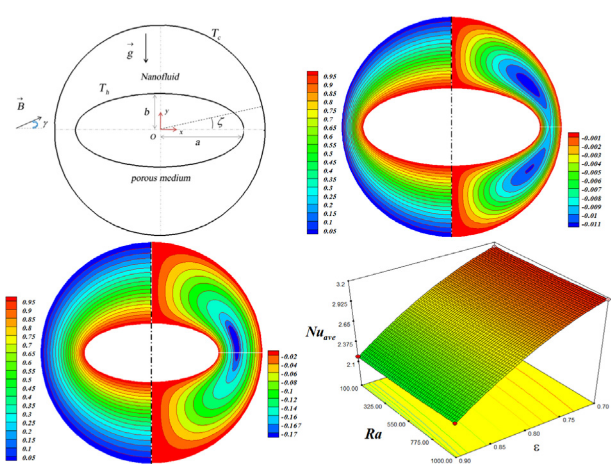
M. Sheikholeslami[a,*], Z. Ziabakhsh[b], D.D. Ganji[c]

[a] Department of Mechanical Engineering, Babol Noshirvani University of Technology, Babol, Iran
[b] Critical Zone Hydrology Group, Department of Earth Sciences, VU University Amsterdam, De Boelelaan 1085, 1081 HV, Amsterdam, The Netherlands
[c] Department of Mechanical Engineering, Sari Branch, Islamic Azad University, Sari, Iran

HIGHLIGHTS

- Magnetic field influence on free convection of nanofluid in porous media is studied.
- CVFEM is applied to solve this problem.
- Nu_{ave} increases with increase of ϕ and *Ra*.
- E increases with increase of *Ha*.

GRAPHICAL ABSTRACT



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ABSTRACT

CuO-water nanofluid MHD convective flow in a porous cavity is studied. Darcy and KKL models are considered for porous media and nanofluid, respectively. The solutions of final equations are obtained by CVFEM. Effective parameters are major axis of elliptic cylinder, CuO-water volume fraction, eccentricity, Hartmann and Rayleigh numbers for porous medium. A correlation for Nu_{ave} is presented.
Results: depicted that heat transfer improvement enhances with rise of buoyancy forces and major axis of elliptic cylinder. Influence of adding nanoparticle augments with augment of Lorentz forces. Increasing eccentricity and Hartmann number leads to reduce Nusselt number.

1. Introduction

Innovative kinds of fluid required to reach more efficient performance in new days. Nanofluid was proposed as innovative way to enhance heat transfer. Rashad [1] studied about the MHD flow of ferrofluid over a wedge. Sheikholeslami and Rokni [2] presented the effect of Lorentz force on free convection of nanofluid. Sheikholeslami and Ganji [3] presented various application of nanofluid

* Corresponding author.
E-mail addresses: mohsen.sheikholeslami@yahoo.com, m.sheikholeslami1367@gmail.com (M. Sheikholeslami).

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Nomenclature

B	Magnetic induction
A	Amplitude
E	Heat transfer enhancement
$\vec{I}$	Electric current
K	Permeability of the porous medium
T	Fluid temperature
Nu	Nusselt number
Ha	Hartmann number
$\vec{g}$	Gravitational acceleration vector
Ra	Rayleigh number
V, U	Vertical and horizontal dimensionless velocity
Y, X	Vertical and horizontal space coordinates
α	Thermal diffusivity
ζ	Rotation angle
Ω&ψ	Dimensionless vorticity & stream function
β	Thermal expansion coefficient
ρ	Fluid density
σ	Electrical conductivity
μ	Dynamic viscosity

Subscripts

nf	Nanofluid
f	Base fluid
loc	Local
c	Cold

Greek symbols

Θ	Dimensionless temperature

in their review paper. Sheremet et al. [4] simulated the unsteady MHD flow in an enclosure. They used FDM to simulate that paper. Influence of asymmetric heating on the heat transfer improvement in a microchannel was examined by Malvandi et al. [5]. They illustrated that Hartmann number enhances the Nu about 42%. Rashad et al. [6] studied the effect of heat generation and magnetic field on free convection in a porous enclosure. Hayat et al. [7] utilized two phase model for nanofluid under the influence of radiation. They showed that temperature gradient reduces with augment of thermal radiation. Sheikholeslami [8] investigated the impact of magnetic field on nanofluid motion in a porous cylinder. Rashad et al. [9] investigated mixed convection of nanofluid in a cavity with slip condiction.

Selimefendigil and Oztop [10] examined nanofluid conjugate conduction-convection mechanism in a titled cavity. They proved that temperature gradient rises with rise of *Gr*. Sheikholeslami and Ellahi [11] selected LBM to simulate Lorentz forces influence on nanofluid convective heat trasnefer. They depicted that temperature gradient reduces with augment of magnetic strength. Marangoni convection of nanofluid in presence of magnetic field was studied by Sheikholeslami and Chamkha [12]. MHD nanofluid free convective hydrothermal analysis in a tilted wavy enclosure was presented by Sheremet et al. [13]. Their results illustrated that change of titled angle causes convective heat transfer to enhance. Influence of non-uniform Lorentz forces on nanofluid flow style has been studied by Sheikholeslami Kandelousi [14]. He concluded that improvement in heat transfer reduces with rise of Kelvin forces. Akbar [15] reported the entropy production in a tube in existence of magnetic field. She showed that entropy generation number reaches high values near the walls. Sheikholeslami and Shehzad [16] examined the heat flux boundary condition for MHD nanofluid flow in a porous media. MHD nanofluid thermal radiation was presented by Sheikholeslami et al. [17]. Their outputs showed that concentration gradient augments with augment of radiation parameter. Sheikholeslami et al. [18] reported the impact of inconstant Lorentz force on forced convection. They illustrated that higher lid velocity has more sensible Kelvin forces effect. Recently, several papers have been published by several authors [19–32].

The goal of this article is to investigate impact of uniform magnetic field on nanofluid free convection in a porous media with elliptic hot cylinder. CVFEM is chosen to simulate this paper. Impacts of CuO volume fraction, eccentricity, major axis of elliptic, Hartmann and Rayleigh numbers for permeable media on heat transfer treatment are considered.

Table 1
The coefficient values of CuO – Water nanofluid [35].

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

2. Problem definition

Fig. 1 shows the geometry, boundary condition and sample element. The formula of inner cylinder is:

$$b = \sqrt{1-\varepsilon^2}.a \tag{1}$$

where a, b, ε are the major, minor axis of elliptic cylinder and eccentricity for the inner cylinder.

3. Governing equation and simulation

3.1. Governing formulation

2D steady convective flow of nanofluid in a porous media is considered in existence of constant horizontal magnetic field. The PDEs equations are:

$$\nabla.\vec{V} = 0 \tag{2}$$

$$\frac{\mu_{nf}}{K}\vec{V} = \left(\nabla p + \vec{I} \times \vec{B} + \rho_{nf}\,\vec{g}\right) \tag{3}$$

$$\left(\rho C_p\right)_{nf}\left(\vec{V}.\nabla\right)T = k_{nf}\,\nabla^2 T \tag{4}$$

$$\nabla.\vec{I} = 0 \tag{5}$$

$$\sigma_{nf}\left(\vec{V} \times \vec{B} - \nabla\varphi\right) = \vec{I} \tag{6}$$

In Eq. (2), Darcy model is used for porous medium. Eqs. (5) and (6) reduce to$\nabla^2\varphi = 0$ [33]. So electric field can be neglect [34]. So the above equations turn into:

$$\frac{\partial v}{\partial y} + \frac{\partial u}{\partial x} = 0 \tag{7}$$

$$-\frac{K}{\mu_{nf}}\frac{\partial p}{\partial x} - \frac{\sigma_{nf} K B_0^2}{\mu_{nf}}\left(-u\,\sin^2\gamma + v\,\sin\gamma\,\cos\gamma\right) = u \tag{8}$$

$$-\frac{K}{\mu_{nf}}\frac{\partial p}{\partial y} - \frac{\sigma_{nf} K B_0^2}{\mu_{nf}}\left(-v\,\cos^2\gamma + u\,\sin\gamma\,\cos\gamma\right) + g\frac{\left(\rho\beta\right)_{nf} K}{\mu_{nf}}(T - T_c) = v \tag{9}$$