Journal of the Taiwan Institute of Chemical Engineers xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Journal of the Taiwan Institute of Chemical Engineers

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

Numerical simulation of two phase unsteady nanofluid flow and heat transfer between parallel plates in presence of time dependent magnetic field

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ARTICLE INFO

Article history:
Received 28 May 2014
Received in revised form 28 August 2014
Accepted 21 September 2014
Available online xxx

Keywords:
Schmidt number
Eckert number
Nanofluid
Brownian
Thermophoresis
HPM

ABSTRACT

In this study, two phase simulation of nanofluid flow and heat transfer between parallel plates is investigated. The important effects of Brownian motion and thermophoresis have been included in the model of nanofluid. The governing equations are solved *via* homotopy perturbation method. According to comparison with previous works, this method has good accuracy to solve this problem. The semi analytical investigation is carried out for different governing parameters namely; the squeeze number, Hartmann number, Schmidt number and Eckert number. The results indicate that absolute skin friction coefficient decreases with increase of Hartmann number and squeeze number. Also it can be found that that Nusselt number is an increasing function of Hartmann number, Eckert number and Schmidt number but it is a decreasing function of squeeze number.

1. Introduction

Most of engineering problems, particularly some heat transfer equations are nonlinear, so some of them are solved using numerical solution and some are solved using the different analytic method, such as perturbation method, homotopy perturbation method and variational iteration method. Therefore, many different methods have recently introduced some ways to eliminate the small parameter. One of the semi-exact methods which do not need small parameters is the homotopy perturbation method. The homotopy perturbation method, proposed by He in 1998 and was further developed and improved by He [1]. This method yields a very rapid convergence of the solution series in the most cases. HPM proved its capability to solve a large class of nonlinear problems efficiently. Usually, few iterations lead to high accuracy solution. This method is employed for many researches in engineering sciences. He's homotopy perturbation method is applied to obtain approximate analytical solutions for the motion of a spherical particle in a plane Couette flow by Jalaal et al. [2]. Sheikholeslami et al. [3] studied rotating MHD viscous flow and heat transfer between stretching and porous surfaces. The three-dimensional problem of steady fluid deposition on an inclined rotating disk is studied by Sheikholeslami et al. [4]. They concluded that by increasing normalized thickness, Nusselt number increase however this trend is more noticeable in grater Prandtl numbers. In recent years some researchers used new methods to solve these kinds of problems [5–30].

Heat transfer enhancement in various energy systems is vital because of the increase in energy prices. In recent years, nanofluids technology is proposed and studied by some researchers experimentally or numerically to control heat transfer in a process. The nanofluid can be applied to engineering problems, such as heat exchangers, cooling of electronic equipment and chemical processes. Almost all of the researchers assumed that nanofluids treated as the common pure fluid and conventional equations of mass, momentum and energy are used and the only effect of nanofluid is its thermal conductivity and viscosity which are obtained from the theoretical models or experimental data. Khanafer et al. [31] conducted a numerical investigation on the heat transfer enhancement due to adding nano-particles in a differentially heated enclosure. Abu-Nada et al. [32] investigated free convection heat transfer enhancement in horizontal concentric annuli. They found that for low Rayleigh numbers, nanoparticles with higher thermal conductivity cause more enhancement

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http://dx.doi.org/10.1016/j.jtice.2014.09.025

Nomenclature

B	magnetic field
c_p	specific heat at constant pressure
D_B	Brownian diffusion coefficient
D_T	thermophoretic diffusion coefficient
Ec	Eckert number $(= 1/c_p\,(\gamma x/2(1-\gamma t))^2)$
ℓ	distance of plate from x axis
Ha	Hartmann number $(= \ell B_x \sqrt{\sigma/\mu(1-\gamma t)})$
k	thermal conductivity
Nb	Brownian motion parameter $(= (\rho c)_p D_B(\phi_h - \phi_c)/(\rho c)_f \alpha)$
Nt	thermophoretic parameter $(= (\rho c)_p D_T(T_h - T_c)/[(\rho c)_f \alpha T_c])$
Nu	Nusselt number
Pr	Prandtl number $(= \mu/\rho_f \alpha)$
P	pressure
S	squeeze number $(= \gamma l^2 \rho_f/2\mu)$
Sc	Lewis number $(= \alpha/D_B)$
T	fluid temperature
C	nanofluid concentration
u, v	velocity components in the x-direction and y-direction
x, y	space coordinates

Greek symbols

α	thermal diffusivity $(= k/(\rho c_P)_f)$
Θ	transformation of θ
γ	rate of squeezing
σ	electrical conductivity of nanofluid
μ	dynamic viscosity of nanofluid
θ	dimensionless temperature
ϕ	dimensionless concentration
ρ	density

Subscripts

c	cold
H	hot
f	base fluid

in heat transfer. Rashidi et al. [33] studied the analysis of the second law of thermodynamics applied to an electrically conducting incompressible nanofluid fluid flowing over a porous rotating disk. Nanofluid flow and heat transfer characteristics between two horizontal parallel plates in a rotating system were investigated by Sheikholeslami et al. [34]. They proved that Nusselt number increases with increase of nanoparticle volume fraction and Reynolds number but it decreases with increase of Eckert number, magnetic and rotation parameters. Sheikholeslami et al. [35] studied the problem of MHD free convection in an eccentric semi-annulus filled with nanofluid. They showed that Nusselt number decreases with increase of position of inner cylinder at high Rayleigh number. Recently several authors investigated about nanofluid flow and heat transfer [36–77].

All the above studies assumed that there are not any slip velocities between nanoparticles and fluid molecules and assumed that the nanoparticle concentration is uniform. It is believed that in natural convection of nanofluids, the nanoparticles could not accompany fluid molecules due to some slip mechanisms such as Brownian motion and thermophoresis, so the volume fraction of nanofluids may not be uniform anymore and there would be a variable concentration of nanoparticles in a mixture. Nield and Kuznetsov [78] studied the natural convection in a horizontal layer of a porous medium. Khan and Pop [79] published a paper on boundary-layer flow of a nanofluid past a stretching sheet. Free convection heat transfer in an enclosure filled with nanofluid was investigated by Sheikholeslami et al. [80]. They found that Nusselt number is an increasing function of buoyancy ratio number while it is a decreasing function of Lewis number and angle of turn. Sheikholeslami and Ganji [81] investigated two phase modeling of nanofluid in a rotating system with permeable sheet. They found that Nusselt number has direct relationship with Reynolds number and injection parameter while it has reverse relationship with rotation parameter, Schmidt number, thermophoretic parameter and Brownian parameter.

The study of unsteady squeezing viscous flow between two parallel plates has wide spectrum of scientific and engineering applications such as hydrodynamic machines, polymer processing, lubrication system, chemical processing equipment, formation and dispersion of fog, damage of crops due to freezing, food processing and cooling towers. Mahmood et al. [82] investigated the heat transfer characteristics in the squeezed flow over a porous surface. Magnetohydrodynamic squeezing flow of a viscous fluid between parallel disks was analyzed by Domairry and Aziz [83].

The main aim of this study is to study the problem of unsteady nanofluid flow between parallel plates using HPM. Two phase model used in order to simulate nanofluid flow and heat transfer. The influence of the squeeze number, Hartmann number, Schmidt number and Eckert number on temperature and concentration profiles is investigated.

2. Governing equations

Heat and mass transfer analysis in the unsteady two-dimensional squeezing flow of nanofluid between the infinite parallel plates is considered (Fig. 1). The two plates are placed at $\ell(1-\gamma t)^{1/2} = h(t)$. When $\gamma > 0$ the two plates are squeezed until they touch $t = 1/\gamma$ and for $\gamma < 0$ the two plates are separated. The viscous dissipation effect, the generation of heat due to friction caused by shear in the flow, is retained. Also, it is also assumed that the uniform magnetic field $(\vec{B} = B\vec{e_y})$ is applied, where $\vec{e_y}$ is unit vectors in the Cartesian coordinate system. The electric current J and the electromagnetic force F are defined by $J = \sigma(\vec{V} \times \vec{B})$ and $F = \sigma(\vec{V} \times \vec{B}) \times \vec{B}$, respectively.

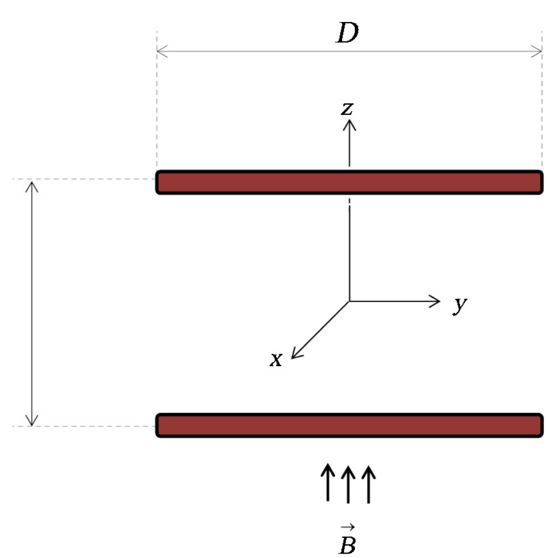

Fig. 1. Geometry of problem.

Please cite this article in press as: Sheikholeslami M, et al. Numerical simulation of two phase unsteady nanofluid flow and heat transfer between parallel plates in presence of time dependent magnetic field. J Taiwan Inst Chem Eng (2014), http://dx.doi.org/10.1016/j.jtice.2014.09.025