Journal of Molecular Liquids 223 (2016) 521–527

Contents lists available at ScienceDirect

Journal of Molecular Liquids

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

Thermal radiation effect on the Nano-fluid buoyancy flow and heat transfer over a stretching sheet considering Brownian motion

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ARTICLE INFO

Article history:
Received 12 June 2016
Received in revised form 28 July 2016
Accepted 23 August 2016
Available online 24 August 2016

Keywords:
Nanofluid
Brownian motion
MHD
Thermal radiation
KKL

ABSTRACT

In this paper, buoyancy flow and heat transfer of MHD nanofluid over a stretching sheet in the presence of thermal radiation and considering Brownian motion is studied. The effective thermal conductivity and viscosity of nanofluid are calculated by KKL (Koo-Kleinstreuer-Li) correlation in which influence of Brownian motion on the effective thermal conductivity is considered. The effects of various parameters such as the buoyancy parameter, the magnetic parameter, the volume fraction of nanofluid and the radiation parameter are investigated on the velocity and temperature. Furthermore, the values of the Nusselt number and the skin friction coefficient are calculated and presented through figures. The results show that the fluid velocity and temperature distribution decreases with the increasing of radiation parameter.

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1. Introduction

The primary obstacle to enhance the heat transfer in engineering systems is the low thermal conductivity of conventional fluids such as water, air, ethylene glycol mixture and oil. Solid usually has a higher thermal conductivity than liquids. When the nanoparticles are added to the pure fluid, the so called "Nano-fluid", the thermal conductivity of the mixture can be improved. The Nano-fluids cause larger thermal conductivity compared to the base fluids. The idiom nanofluid was first introduced by Choi [1] to refer to the fluids with dispersed Nano-particles. Magnetohydrodynamic (MHD) has many engineering and industrial applications such as crystal growth, metal casting and liquid metal cooling blankets for fusion reactors. Several studies were performed in the fields of nanofluid and magnetohydrodynamic [2–9]. Influence of variable magnetic field on ferrofluid flow and heat transfer was investigated by Sheikholeslami and Rashidi [2]. They applied control volume based finite element method (CVFEM) to solve the governing equations. Their results show that the Nusselt number is a rising function of Magnetic number, Rayleigh number and volume fraction of nanoparticle while it is a decreasing function of Hartmann number. Force convection heat transfer in a lid driven semi annulus enclosure in presence of non-uniform magnetic field was studied by Sheikholeslami et al. [3]. They applied control volume based finite element method (CVFEM) to solve the governing equations. Abolbashari et al. [4] studied the entropy for an unsteady MHD nanofluid flow past a stretching permeable surface. They reported that the rising of the nanoparticle volume fraction parameter, unsteadiness parameter, magnetic parameter, suction parameter, Reynolds number, Brinkman number, and Hartmann number cause a rise of the entropy generation number. Free convection in a square differentially heated porous cavity filled with a nanofluid was analyzed by Sheremet et al. [5]. They found that the average Nusselt number is a rising function of the Rayleigh number and a decreasing function of the porosity of the porous medium. The heat transfer of a steady, viscous incompressible water based MHD nanofluid flow between two stretchable walls with thermal radiation effect was investigated by Dogonchi and Ganji [6]. Their results indicate that the fluid velocity and temperature profile increase with the increasing of stretching parameter. The unsteady squeezing flow and heat transfer of MHD nanofluid between the infinite parallel plates with thermal radiation effect was studied by Dogonchi et al. [7]. Their results show that the temperature profile and Nusselt number increase with the increase of radiation parameter.

In all previous mentioned studies the effective thermal conductivity depends on the thermal conductivity of the base fluid and particles and on the volume fraction of particles, whereas numerous studies [10–13] show that the temperature, the particle size, random motion and the kind of nanoparticle can also affect the effective thermal conductivity of a nanofluid. The hydrothermal behavior of nanofluid flow in a permeable channel considering Brownian motion was investigated by Kandelousi [14]. His results indicate that heat transfer enhancement has a direct relationship with Reynolds number when power law index is equal to zero. Nanofluid flow and heat transfer between parallel plates considering Brownian motion was studied by Sheikholeslami and Ganji [15]. They applied the differential transformation method [16–20]

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http://dx.doi.org/10.1016/j.molliq.2016.08.090
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Table 1
Thermo-physical properties of water and nanoparticles [15].

	$\rho(kg/m^3)$	$C_p(J/kg\ K)$	$k(W/m\ K)$	$\beta\times10^5(K^{-1})$	$dp(nm)$
CuO	6500	540	18	1.8	29
Al_2O_3	3970	765	25	0.8	38.4
Pure water	997.1	4179	0.613	21	–

Table 2
The coefficient values of CuO-water and Al_2O_3-water nanofluids [25].

Coefficient values	CuO–water	Al_2O_3–water
a_1	−26.59331085	52.81348876
a_2	−0.403818333	6.115637295
a_3	−33.3516805	0.695574508
a_4	−1.915825591	0.041745555
a_5	6.42185846658E−02	0.1769193
a_6	48.40336955	−298.1981908
a_7	−9.787756683	−34.53271691
a_8	190.24561	−3.922528928
a_9	10.92853866	−0.235432963
a_{10}	−0.720099837	−0.999063481

Table 3
Comparison between Present and Rashidi et al. [8] results for $f''(0)$ and $\theta'(0)$.

Mn	Rashidi et al. [8]		Present results	
	$f''(0)$	$\theta'(0)$	$f''(0)$	$\theta'(0)$
2	1.44214325	0.88544087	1.442143250	0.885440929
3	1.65402315	0.84801483	1.654023152	0.848014863

to solve governing equations. They found that Nusselt number rises with the augment of nanoparticle volume fraction, Hartmann number while it decreases with the rise of the squeeze number.

Radiative heat transfer flow is very momentous in manufacturing industries for the sketch of reliable equipment, gas turbines, nuclear power plants and different propulsion devices for satellites, missiles, aircraft and space vehicles. The influence of Radiative heat transfer on magnetohydrodynamics (MHDs) nanofluid flow between two rotating plates was studied by Sheikholeslami et al. [21]. Their results indicate that the Nusselt number has a direct relationship with Reynolds number and radiation parameter while it has an opposite relationship with other embedded parameters. Ferrofluid flow in a semi annulus enclosure considering Radiative heat transfer was studied by Sheikholeslami et al. [22]. Their results show that the Nusselt number is a rising function of Rayleigh number and Magnetic number while it is a decreasing function of radiation parameter.

The main objective of this paper is to investigate Buoyancy flow and heat transfer of MHD nanofluid over a stretching sheet in the presence of thermal radiation and considering Brownian motion. The effects of the buoyancy parameter, the magnetic parameter, the volume fraction of nanofluid and the radiation parameter on flow and heat transfer characteristics are investigated.

2. Problem description

We consider the steady state laminar 2-D, radiative flow of an incompressible viscous nanofluid along a semi-infinite vertical stretching

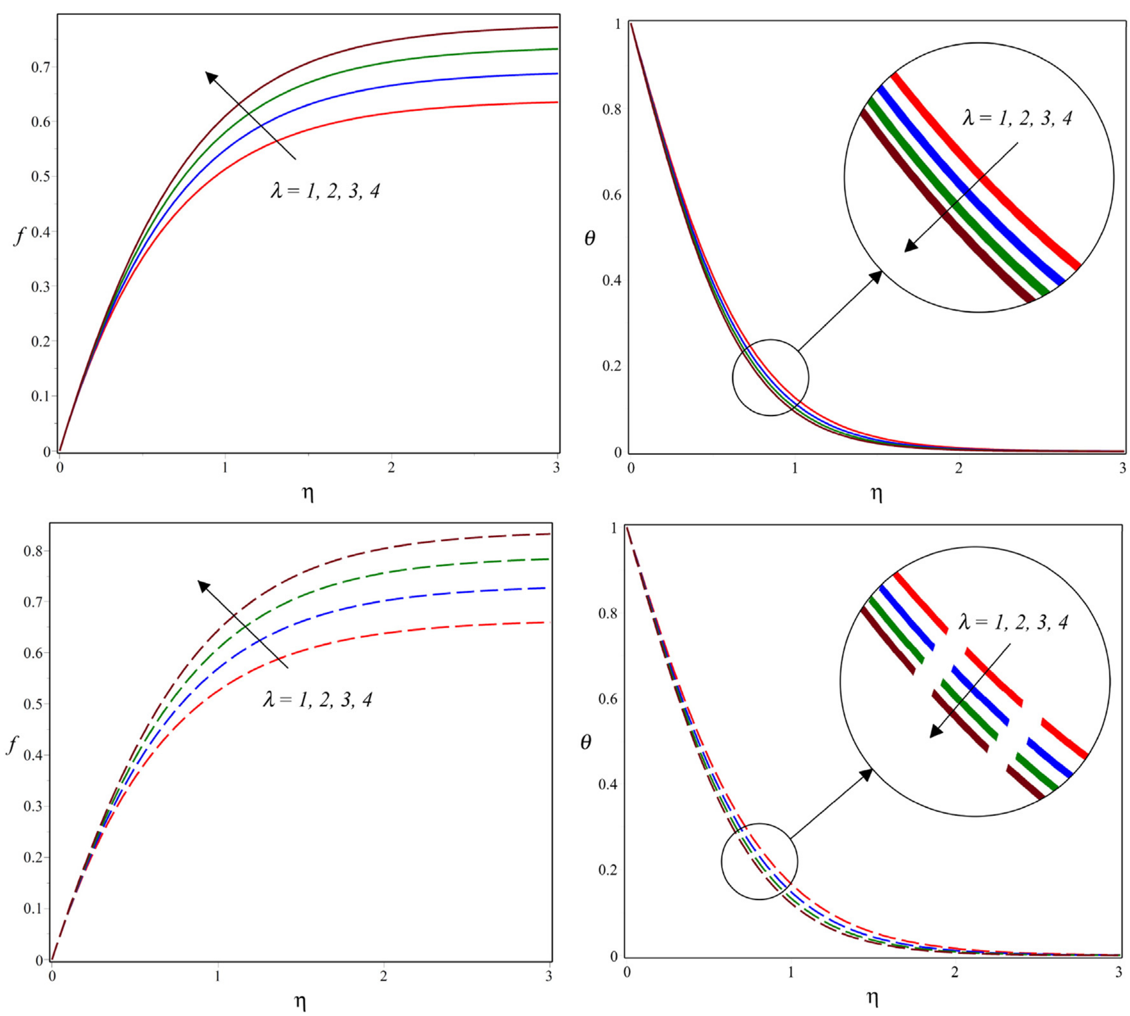

Fig. 1. Velocity and temperature profiles of CuO-Water nanofluid (Solid line) and pure water (Dash line) for different values of buoyancy parameter when $Mn = 2$, $Nr = 2$ and $Pr = 6.2$.

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