Propulsion and Power Research ▮▮▮▮;▮(▮):▮▮▮–▮▮▮

HOSTED BY

ELSEVIER

http://ppr.buaa.edu.cn/

Propulsion and Power Research

www.sciencedirect.com

ORIGINAL ARTICLE

On radiative-magnetoconvective heat and mass transfer of a nanofluid past a non-linear stretching surface with Ohmic heating and convective surface boundary condition

Shweta Mishra[a], Dulal Pal[b,*], Hiranmoy Mondal[c], Precious Sibanda[c]

[a]*School of Engineering and Technology, Amity University, New Town, Kolkata, West Bengal 700135, India*
[b]*Department of Mathematics, Institute of Science, Visva-Bharati (A Central University), Santiniketan, West Bengal 731235, India*
[c]*School of Mathematics, Statistics and Computer Science, University of KwaZulu-Natal, Private Bag X01, Scottsville, Pietermaritzburg 3209, South Africa*

Received 30 April 2015; accepted 23 May 2016

KEYWORDS

Nanofluid;
Magnetoconvection;
Thermal radiation;
Non-linear stretching sheet;
Ohmic heating

Abstract In this paper magnetoconvective heat and mass transfer characteristics of a two-dimensional steady flow of a nanofluid over a non-linear stretching sheet in the presence of thermal radiation, Ohmic heating and viscous dissipation have been investigated numerically. The model used for the nanofluid incorporates the effects of the Brownian motion and the presence of nanoparticles in the base fluid. The governing equations are transformed into a system of nonlinear ordinary differential equations by using similarity transformation. The numerical solutions are obtained by using fifth order Runge–Kutta–Fehlberg method with shooting technique. The non-dimensional parameters on velocity, temperature and concentration profiles and also on local Nusselt number and Sherwood number are discussed. The results indicate that the local skin friction coefficient decreases as the value of the magnetic parameter increases whereas the Nusselt number and Sherwood number increase as the values of the Brownian motion parameter and magnetic parameter increase.

*Corresponding author. Tel.: (+91) 3463261029.

E-mail addresses: dulalp123@rediffmail.com (Dulal Pal), hiranmoymondal@yahoo.co.in (Hiranmoy Mondal), sibandap@ukzn.ac.in (Precious Sibanda).

Peer review under responsibility of National Laboratory for Aeronautics and Astronautics, China.

http://dx.doi.org/10.1016/j.jppr.2016.11.007
2212-540X

1. Introduction

The study of flow, heat and mass transfer over a non-linear stretching surface stretching surface has been given considerable attention in recent times due to its vast applications in industrial and several technological and natural processes, such as materials manufactured by extrusion, glass-fiber production, paper production, plastic and rubber sheets production, crystals growing, cooling of metallic sheets or electronic chips, etc. Ishak et al. [1] observed the mixed convection boundary layer stagnation point flow towards a stretching sheet because of wide range of applications of nanofluids, significant research interest has been found in the recent past to study heat and mass transfer characteristics on these fluids. Heat and mass transfer due to free and mixed convection in engineering systems are quite important for its wide range of applications in electronic cooling, heat exchangers etc. Tiwari and Das [2] have studied and reported results on natural convection heat transfer in nanofluids considering various flow conditions in different geometries. Partha et al. [3] studied the effects of viscous dissipation on the mixed convection heat transfer from an exponentially stretching surface.

The study of magnetohydrodynamic (MHD) flow of an electrically conducting fluid due to stretching of the sheet is of considerable interest in modern metallurgical and metal-working processes. The effect of chemical reaction and thermal radiation absorption on unsteady MHD free convection flow past a semi-infinite vertical permeable moving surface with internal heat source/suction was analyzed by Ibrahim et al. [4]. Pal [5] studied the MHD flow and heat transfer past a semi-infinite vertical plate embedded in a porous medium of variable porosity. The study of convection boundary layer flow in porous media has received special attention in recent years due to its important roles and wide applications in geophysics and thermal sciences, such as geothermal energy technology, petroleum recovery, building thermal insulation, packed bed reactors, underground disposal of chemical and nuclear waste. Rana and Bhargava [6] analyzed the flow and heat transfer of a nanofluid over a nonlinear stretching sheet. Ferdows et al. [7] investigated the effects of MHD mixed convective boundary layer flow of a nanofluid through a porous medium due to an exponentially stretching sheet. Bidin and Nazar [8] studied numerical solution of the boundary layer flow over an exponentially stretching sheet with thermal radiation. Pal and Mondal [9] studied the influence of thermal radiation on hydromagnetic Darcy–Forchheimer mixed convection flow past a stretching sheet embedded in a porous medium. Olanrewaju et al. [10] studied the boundary layer flow of nanofluids over a moving surface in a flowing fluid in the presence of radiation.

Nanofluid consists of a base fluid containing colloidal suspension of nanoparticles, a term which was first introduced by Choi [11]. Nanoparticles are particles with a range of diameters from 1 to 100 nm. Common base fluids are water, oil and ethylene–glycol mixtures. The literature has revealed that the low thermal conductivity of these common base fluids is a primary limitation in enhancing the performance and the compactness of many devices. When nanoparticles are added to these base fluids, a drastic increase in thermal conductivity is observed. The thermal conductivity of a nanofluid is found to be highly temperature dependent. Nanofluids also exhibit an increased boiling critical heat flux. Narasimhan et al. [12] studied forced convection through porous media in Newtonian fluid having temperature-dependent viscosity. Nanofluids can be utilized in several applications such for chemical production, power generation in a power plant, production of microelectronics and advanced nuclear systems due to better performance in heat exchange.

Thermophoresis is a phenomenon by which small sized particles suspended in a non-isothermal gas acquire a velocity relative to the gas in the direction of decreasing temperature. The velocity acquired by the particles is called thermophoretic velocity and the force experienced by the suspended particles due to the temperature gradient is known as thermophoretic force. Thermophoretic deposition of radioactive particles is considered to be one of the important factors causing accidents in nuclear reactors. Thermophoresis causes small particles to deposit on cold surfaces. Pakravan and Yaghoubi [13] investigated theoretically the combined thermophoresis, Brownian motion and Dufour effects on natural convection of nanofluids. Mehdi and Hosseinalipour [14] studied particle migration in nanofluids considering thermophoresis and its effect on convective heat transfer. Anbuchezhian et al. [15] investigated thermophoresis and Brownian motion effects on boundary layer flow of nanofluid in the presence of thermal stratification due to solar energy. Wubshet Ibrahim [16] observed nonlinear radiative heat transfer in magnetohydrodynamic (MHD) stagnation point flow of nanofluid past a stretching sheet with convective boundary condition. A critical review on thermal convection in nanofluids can be found in a recent book by Straughan [17]. Khan and Pop [18] studied forced convective boundary layer flow of a nanofluid past a stretching surface by considering the model of Buongiorno [19] which includes Brownian diffusion and thermophoresis, whereas Hamad and Pop [20] studied the boundary layer flow near a stagnation-point on a heated permeable stretching surface in a porous medium saturated with a nanofluid in the presence of heat generation and absorption neglecting the Brownian diffusion and thermophoresis. Aziz [21] studied the Blassius flow over a flat plate with a convective thermal boundary condition and established the existence of similarity solution. Bataller [22] investigated the effect of radiation on the Blassius and Sakiadis flows with convective boundary condition. Makinde and Aziz [23] studied magnetohydrodynamic mixed convection heat and mass transfer flow along a vertical plate embedded in a porous medium with a convective boundary condition. Pal [24] analyzed radiative heat transfer flow over an unsteady stretching permeable surface in the presence of non-uniform heat source/sink. Makinde et al. [25] studied numerical study of chemically reacting hydromagnetic boundary layer flow with Soret/Dufour effects under convective surface boundary condition.

Please cite this article as: Shweta Mishra, et al., On radiative-magnetoconvective heat and mass transfer of a nanofluid past a non-linear stretching surface with Ohmic heating and convective surface boundary condition, Propulsion and Power Research (2016), http://dx.doi.org/10.1016/j.jppr.2016.11.007