Available online at www.sciencedirect.com
ScienceDirect
Journal of the Nigerian Mathematical Society 35 (2016) 245–256
Journal of the Nigerian Mathematical Society
www.elsevier.com/locate/jnnms

Unsteady hydromagnetic chemically reacting mixed convection flow over a permeable stretching surface with slip and thermal radiation

Mitiku Daba[a], Ponnaian Devaraj[b,*]

[a] Department of Mathematics, College of Natural Sciences, Jimma University, Jimma-378, Ethiopia
[b] Department of Mathematics, College of Engineering Guindy Campus, Anna University, Chennai-600 025, India

Received 6 June 2015; received in revised form 26 February 2016; accepted 27 February 2016
Available online 24 March 2016

Abstract

The present investigation deals with unsteady hydromagnetic chemically reacting mixed convection flow of incompressible viscous fluid past a vertically moving permeable stretching sheet in the presence of suction/injection, heat source/absorption, thermal radiation, viscous dissipation and slip effects. The governing partial differential equations are reduced into a set of non-linear ordinary differential equations by suitable transformations. Keller box method is applied to solve the system of non-linear ordinary differential equations for which the implementation is made with the help of matlab. The important parameters in this study are: Prandtl number Pr, Schmidt number Sc, buoyancy force parameter λ, radiation parameter Nr, magnetic parameter M, buoyancy forces ratio parameter N, the unsteady parameter A, suction/injection parameter s, Eckert number Ec, heat source/sink parameter Q, chemical reaction parameter R, velocity slip parameter s_v, temperature slip parameter s_t and species concentration slip parameter s_m. Effects of these parameters on velocity, temperature and species concentration profile of the fluid are presented and analyzed graphically. Furthermore, numerical investigations have been made for the skin friction coefficient and surface heat and mass transfer rates for some of the parameters.

Keywords: Mixed convection; Double diffusion; Chemical reaction; Keller box method; Magnetic field; Buoyancy force

1. Introduction

An incompressible viscous fluid flow past a stretching surface has number of applications in industries and engineering areas. For instance, aerodynamics extrusion of plastic sheets, glass fiber, extraction of polymer, paper production, condensation process of metallic plate in a cooling bath, hot rolling, wire drawing and etc. [1–7].

A study of a flow over a stretching sheet has began in the pioneering work of Crane [8]. Slip effect flow over a stretching sheet was studied by Anderson [9] and mixed convection boundary layer flow over a vertically moving plate in the presence of suction/injection have been analyzed by Ali and Yousef [10]. A mixed convection flow over a moving vertical plate due to the effect of thermal and mass diffusion has been studied by

Peer review under responsibility of Nigerian Mathematical Society.
* Corresponding author.
E-mail addresses: mitbru2007@yahoo.com (M. Daba), devaraj@annauniv.edu (P. Devaraj).

http://dx.doi.org/10.1016/j.jnnms.2016.02.006
0189-8965/

Nomenclature

a, b, c and m	constants
A	unsteady parameter
B	uniform magnetic field (T)
B_0	magnetic induction
C	species concentration (mol/m^3)
C_w	species concentration at the wall (mol/m^3)
C_∞	species concentration far from the surface (mol/m^3)
C_f	local skin friction coefficient
c_p	specific heat capacity (J kg^{-1} K^{-1})
D	mass diffusivity (m^2 s^{-1})
Ec	Eckert number
F	dimensionless velocity
f	dimensionless stream function
g	acceleration due to gravity (m s^{-2})
G	dimensionless temperature
G_r	Grashof number due to temperature
G_{r^*}	Grashof number due to concentration
H	dimensionless species concentration
J	species concentration slip factor
k	thermal conductivity (W m^{-1} K^{-1})
k^*	mean absorption coefficient
K	thermal slip factor
L	velocity slip factor
M	magnetic parameter
N	buoyancy forces ratio parameter
Nu_x	local Nusselt number
Nr	radiation parameter
Pr	Prandtl number
Q	local heat source/sink parameter
q_m	surface mass flux (kg s^{-1} m^{-2})
q_r	radiative heat flux (W m^{-2})
q_w	surface heat flux (W m^{-2})
Re_x	local Reynolds number
s	local suction/injection parameter
Sc	Schmidt number
s_v	velocity slip parameter
s_t	temperature slip parameter
s_m	species concentration slip parameter
Sh_x	local Sherwood number
R	local chemical reaction parameter
T	temperature of the fluid (K)
T_∞	temperature of the fluid far away from the wall (K)
t	time (s)
T_w	temperature at the wall (K)
u	velocity component in x-direction (m s^{-1})
U_w	stretching sheet wall velocity (m s^{-1})
U_∞	free stream velocity (m s^{-1})
v	velocity component in y-direction (m s^{-1})