Radiation and Chemical Reaction Effects on MHD Free Convection Flow of a Uniformly Vertical Porous Plate with Heat Source

G. Vidyasagar[1] B. Ramana[2] P. Mohan Krishna[3]

Abstract: In this paper deals with the combined effect of thermal radiation and heat source on the MHD free convection heat and mass transfer flow of a viscous incompressible fluid past a uniformly vertical porous plate. The velocity, temperature and concentration field are obtained and discussed graphically for various values of the physical parameters present. In addition, expressions for the skin friction is also derived and finally discussed with the help of table and graphs.

Index Terms: Heat Source, Thermal radiation, Magnetic Field, Porous Medium, Chemical Reaction.

1. INTRODUCTION

The study of convective heat and mass transfer fluid flow over stretching surface in the presence of thermal radiation, heat generation and chemical reaction is gaining a lot of attention. This study has many applications in industries, many engineering disciplines. These flows occur in many manufacturing processes in modern industry, such as hot rolling, hot extrusion, wire drawing and continuous casting. For example, in many metallurgical processes such as drawing of continuous filaments through quiescent fluids and annealing and tinning of copper wires, the properties of the end product depends greatly on the rare of cooling involved in these processes. The free convection flow of a viscous incompressible electrically conducting fluid through the channel in the presence of a transverse magnetic field has important applications in magnetohydrodynamic generators, pumps, accelerators, cooling systems, centrifugal separation of matter from fluid, petroleum industry, purification of crude oil, electrostatic precipitation, polymer technology and fluid droplets sprays etc. The performance and efficiency of these devices are influenced by the presence of suspended solid particles in the wear activities and/or the combustion processes in MHD generators and plasma MHD accelerators. The study of Magnetohydrodynamics flow for an electrically conducting fluid past a heated surface has attracted the interest of many researchers in view of its important applications in many engineering problems such as plasma studies, petroleum industries. MHD power generators, cooling of nuclear reactors, The MHD fluid flow in a parallel plate channel is an interesting area in the study of fluid mechanics because of its relevance to various engineering applications.

The MHD flow in the planar channels leads to a startup process implying thereby a viscous layer at the boundary is suddenly set into motion and becomes important in the application of various branches of geophysics, astrophysics and fluid engineering. Currently, MHD effects are widely exploited in different industrial processes ranging from metallurgy to the production pure crystals. A field in which MHD will play an essential role is nuclear fusion, where it is involved in at least two different problems: the confinement and dynamics of plasma, and the behavior of the liquid metal alloys employed in some of the currently considered designs of tritium breeding blankets. In recently years the hydro magnetic flow in a rotating channel in the presence of an applied uniform magnetic field as well as constant pressure gradient has been considered by a number of research workers, taking into account the various aspects of the problem. Radiation effect in blood flow is an important subject of research, because it has got significant applications in Biomedical engineering and several medical treatment methods, particularly in thermal therapeutic procedures. Infrared radiation is one of the frequently used techniques for making heat treatment to various parts of the human body. This technique is preferred in heat therapy, because by using infrared radiation it is possible to directly heat the blood capillaries of the affected areas of the body. In the treatment of muscle spams, myalgia (muscle pain), chronic wide-spreed pain (fibromyalgia, in medical terms) and permanent shortening of muscle (medically called as contracture), heat therapy is found to be very effective.

The flow and mass transfer over a viscoelastic fluid was investigated in the presence of chemical reaction by Midya (2012). Effect of chemical reaction, heat and mass transfer on nonlinear boundary layer past a porous shrinking sheet in the presence of suction was studied numerically by Muhaimin et al. (2010). The radiation effect on fluid flow and heat transfer in different physical contexts was then investigated by Ali et al. (1984). Kandasamy *et al.* (2006) analyzed effects of chemical reaction, heat and mass transfer on boundary layer flow over a porous wedge with heat radiation in the presence of suction or injection. Muhaimin *et al.* (2009) studied the effect of chemical reaction, heat and mass transfer on nonlinear MHD boundary layer past a porous shrinking sheet with suction. Rajesh (2011) investigates chemical reaction and radiation effects on the transient MHD free convection flow of dissipative fluid past an infinite vertical porous plate with ramped wall temperature. Cookey *et al*. (2003) researched the influence of viscous dissipation and radiation on unsteady MHD free-convection flow past on infinite heated vertical plate in a porous medium with time dependent suction. Abd El-Naby *et al.* (2004) employed implicit finite-difference methods to study the effect of radiation on MHD unsteady free convection flow past a semi-infinite vertical porous plate but did not take into account the viscous dissipation. Vidyasagar G and Ramana B (2013) is studied thermal diffusion effect on MHD free convection heat and mass transfer flow past a uniformly vertical plate with heat sink. Shit (2009) investigated the Hall effects on MHD free-convective flow and mass transfer over a

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stretching sheet in the presence of chemical reaction. P. R. Sharma *et al.* (2010) is studied unsteady MHD free convective flow and heat transfer between heated inclined plates with magnetic field in the presence of radiation effects. Rajesh (2011) investigated chemical reaction and radiation effects on the transient MHD free convection flow of dissipative fluid past an infinite vertical porous plate with ramped wall temperature. Muthucumaraswamy (2010) studied chemical reaction effects on a vertical oscillating plate with variable temperature. K. Sarada & B. Shanker (2013) studied the effect of thermal radiation on an unsteady MHD flow past vertical porous heated plate with chemical reaction and viscous dissipation.

2. MATHEMATICAL FORMULATION

We consider a steady laminar flow of a viscous incompressible fluid past an infinite vertical porous flat plate. Introduce a coordinate system (x, y) with x -axis along the length of the plate in the upward vertical direction and y -axis normal to the plate towards the fluid region. The plate is subjected to a constant suction parallel to y -axis. The viscous dissipations of energy are assumed to be negligible for the study. Since, the plate is infinite in length all the fluid property except possibly the pressure remain constant along the x -direction. The fluid property variation with temperature is limited to density variation only and the influence of variation of density with temperature is restricted to the body force term only, in accordance with the Boussinesq approximation. Under boundary layer and Boussinesq approximations, the equations governing the steady laminar two dimensional free convective flow with medium concentration in presence of Soret and heat generation effects reduce to:

Continuity Equation:

$$\frac{\partial \bar{v}}{\partial \bar{y}} = 0$$

Momentum Equation:

$$\bar{\upsilon}\frac{\partial \bar{u}}{\partial \bar{y}} = \upsilon\frac{\partial^2 \bar{u}}{\partial \bar{y}^2} + g\beta(\bar{T}-\bar{T}_\infty) + g\beta^*(\bar{C}-\bar{C}_\infty) - \frac{\sigma B_o^2}{\rho}\bar{u} - \frac{\upsilon}{k}\bar{u}$$

Energy Equation:

$$\bar{\upsilon}\frac{\partial \bar{T}}{\partial \bar{y}} = \frac{k}{\rho c_p}\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} - \frac{1}{\rho c_p}\frac{\partial q_r}{\partial \bar{y}} - \frac{Q_o}{\rho c_p}(\bar{T}-\bar{T}_\infty)$$

Species Concentration

$$\bar{\upsilon}\frac{\partial \bar{C}}{\partial \bar{y}} = D_M\frac{\partial^2 \bar{C}}{\partial \bar{y}^2} + D_T\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} + K_1(\bar{C}-\bar{C}_\infty)$$

The boundary conditions are

$$\left.\begin{array}{ll} \bar{u}=\bar{U}, \bar{v}=-V_o(V_o>0), \bar{T}=\bar{T}_w, \bar{C}=\bar{C}_w & at\ \bar{y}\to 0 \\ \bar{u}\to 0, \bar{v}\to -V_o,\ \bar{T}\to \bar{T}_w, \bar{C}\to \bar{C}_w & at\ \bar{y}\to\infty \end{array}\right\}\text{We}$$

introduce the following non-dimensional quantities as

Dulal Pal *et al.* (2010) studied Perturbation analysis of unsteady magnetohydrodynamic convective heat and mass transfer in a boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction. Sudersan Reddy *et al.* (2012) studied radiation and chemical reaction effects on MHD heat and mass transfer flow inclined porous heated plate.

The objective of the present study is to investigate the effects of thermal diffusion and heat absorption on two-dimensional MHD free convection flow past a uniformly vertical porous plate in the presents effects of thermal radiation and chemical reactions.

$$\begin{array}{l} y=\frac{V_0\bar{y}}{\upsilon}, u=\frac{\bar{u}}{V_0}, U_0=\frac{\bar{U}}{V_0}, v=\frac{\bar{v}}{V_0}, \theta=\frac{\bar{T}-\bar{T}_\infty}{\bar{T}_w-\bar{T}_\infty}, \phi=\frac{\bar{C}-\bar{C}_\infty}{\bar{C}_w-\bar{C}_\infty} \\ Gr=\frac{g\beta\upsilon(\bar{T}_w-\bar{T}_\infty)}{V_0^3}, Gc=\frac{g\beta^*\upsilon(\bar{C}_w-\bar{C}_\infty)}{V_0^3}, \Pr=\frac{\upsilon^2\rho c_p}{k}, K=\frac{\upsilon^2 V_0}{k} \qquad 2 \\ R=\frac{4\alpha^2\upsilon}{\rho c_p}, Q=\frac{Q_0\upsilon}{\rho c_p}, Sc=\frac{\upsilon}{D_M}, Sr=\frac{D_T(\bar{T}_w-\bar{T}_\infty)}{\upsilon^2(\bar{C}_w-\bar{C}_\infty)}, M=\frac{\sigma B_0^2\upsilon}{\rho V_0^2}, C=\frac{K_1\upsilon}{V_0^2} \end{array}$$

The non-dimensional forms of equations are

$$\frac{\partial v}{\partial y} = 0$$

$$\frac{\partial^2 u}{\partial y^2} + \frac{\partial u}{\partial y} - (M+K)u = -Gr\theta - Gc\phi$$

$$\frac{\partial^2 \theta}{\partial y^2} + \Pr\frac{\partial \theta}{\partial y} - \Pr(R+Q)\theta = 0$$

$$\frac{\partial^2 \phi}{\partial y^2} + Sc\frac{\partial \phi}{\partial y} + CSc\phi = -ScSr\frac{\partial^2 \theta}{\partial y^2}$$

The corresponding non- dimensional boundary conditions are

$$\left.\begin{array}{l} u=U_0, v=-1, \theta=1, \phi=1, \quad at\ y=0 \\ u\to 0, v\to -1, \theta\to 0, \phi\to 0, at\ y\to\infty \end{array}\right\}$$

The solutions of equations (8), (9) and (10) are

$$u(y) = U_0e^{-A_5y} - A_9e^{-A_5y} + A_{10}e^{-A_1y} + A_6e^{-A_2y}$$

$$\theta = e^{-A_1y}$$

$$\phi = A_4e^{-A_2y} - A_3e^{-A_1y}$$

where

$$A_1=\frac{\Pr+\sqrt{\Pr^2+4\Pr(R+Q)}}{2},\ A_2=\frac{Sc+\sqrt{Sc^2-4CSc}}{2}$$

$$A_3=\frac{ScSrA_1^2}{A_1^2-ScA_1+CSc},\ A_4=1+A_3, A_5=\frac{1+\sqrt{1^2+4(M+K)}}{2}$$

$$A_6=\frac{GcA_4}{A_1^2-A_1-(M+K)}, A_7=\frac{Gr}{A_1^2-A_1-(M+K)},$$

$$A_8=\frac{GcA_3}{A_1^2-A_1-(M+K)}, A_9=A_6-A_{10}, A_{10}=A_8-A_7$$

Skin Friction at the plate

The non- dimensional skin friction at the plate is

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$$\tau = \left(\frac{\partial u}{\partial y}\right)_{y=0} = A_5 A_9 - A_1 A_{10} - A_2 A_6 - U_0 A_5$$

3. RESULT AND DISCUSSION

Numerical computations have been carried out for different values of Grashof number (Gr), Magnetic Parameter (M), Thermal radiation (R), Permeability parameter (K) Modified Grashof Number (Gc), Heat Source Parameter (Q), Prandtl number (Pr), Schmidt number (Sc), Chemical Parameter (C) and Soret number (Sr). The above mentioned flow parameters, the results are displayed in Figures 1-10 in terms of the concentration, temperature and velocity profiles.

Fig (1) shows that the variation of concentration for different values of chemical reaction Parameter (C). From this figure, we notice that the concentration decreases with the increase of chemical reaction parameter (C). The variation of concentration for different values of Prandtl Number (Pr) are shown in fig (2). From this figure, we notice that the concentration increases with the increase of Prandtl number (Pr). From fig (3) shows that the variation of concentration for different values of heat source parameter (Q). It is observer that the concentration increases with the increase of heat source parameter (Q).The concentration for different values of Schmidt number (Sc) is shown in fig (4). We observer that the Schmidt number (Sc) increases with the decrease of concentration. Fig (5) shows that the variation of concentration for different values of Soret number (Sr). We notice that the concentration increases with the decrease of Soret number (Sr).

The temperature profile for different values of Prandtl number (Pr) is shown in fig (6). It is notice that the temperature decreases with the increase of Prandtl number (Pr). The variation of temperature for different values of heat source parameter (Q) is shown in fig (7). We observe that the temperature decreases with the increase of heat source parameter (Q). From fig (8) shows that the variation of temperature for different values of radiation parameter (R). We notice that the temperature decreases with the increase of radiation parameter (R).The variation of velocity for different values of permeability parameter (K) is shown in fig (9). We notice that the velocity decreases with the increase of Permeability parameter (K). From fig (10) shows that the variation of velocity for different values of magnetic parameter (M). It is observe that the velocity decreases with the increase of magnetic parameter (M).

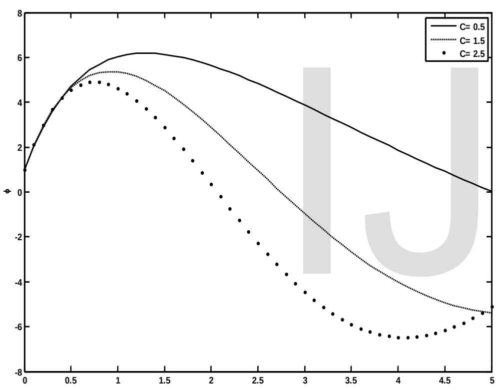

Fig (1): The concentration profile for different values of C

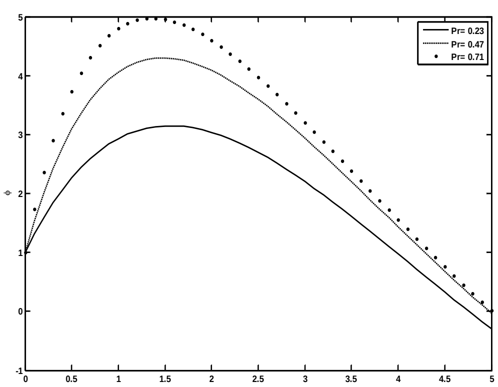

Fig (2): The concentration profile for different values of Pr

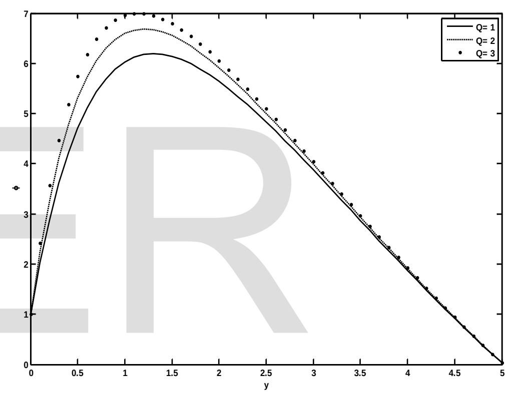

Fig (3): The concentration profile for different values of Q

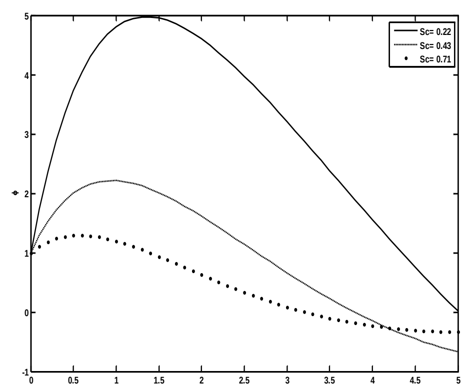

Fig (4): The concentration profile for different values of Sc

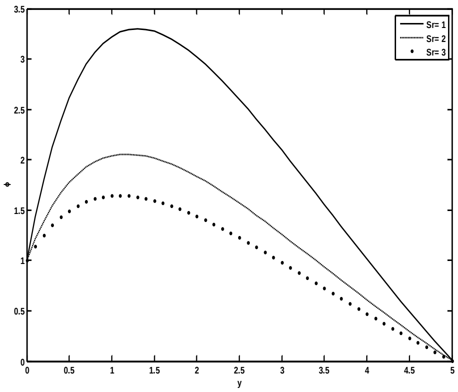

Fig (5): The concentration profile for different values of Sr

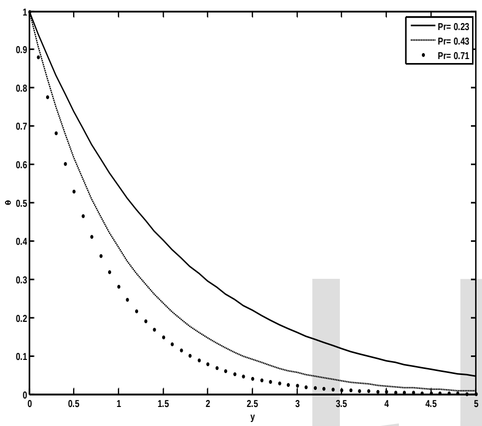

Fig (6): The temperature profile for different values of Pr

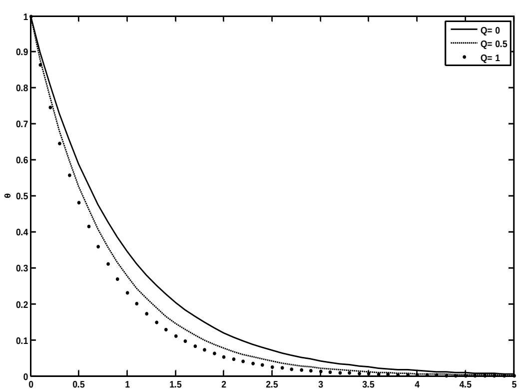

Fig (7): The temperature profile for different values of Q

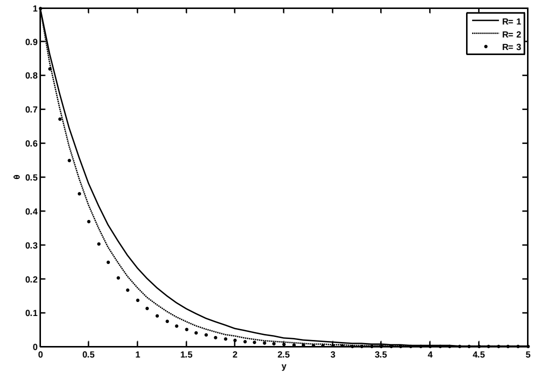

Fig (8): The temperature profile for different values of R

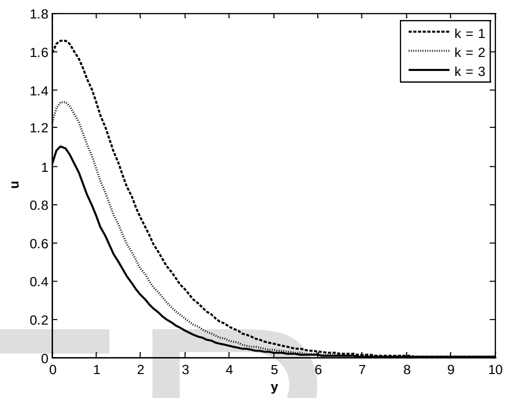

Fig (9): The velocity profile for different values of K

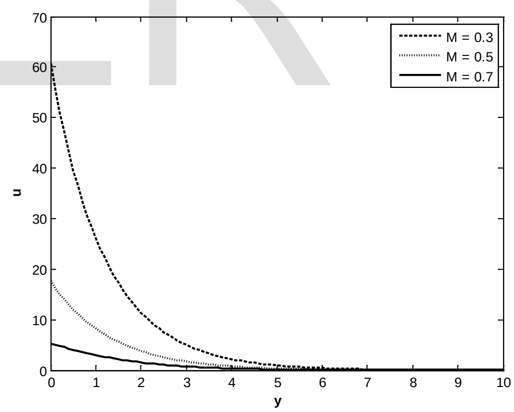

Fig (10): velocity profile for different values of M

4. SKIN FRICTION:

Table 1. Numerical values of the Skin-friction coefficient (C_f), for M, K, Pr, R, Sr, Sc, Q, Gr, Gc and C.

Sr	Sc = 0.22	Sc = 0.708	Sc = 0.709
0	10.374333	0.687879	0.681343
1	10.364343	-0.311055	-0.311107
2	6.612613	-1.311098	-1.305849

3	3.058871	-2.331011	-2.308483
4	-0.483747	-3.331067	-3.312034
5	-4.236478	-4.341100	-4.325667

5. CONCLUSION

In this Paper we discuss the radiation and chemical reaction effects on MHD free convection flow of a uniformly vertical porous plate with heat source. The expressions for the velocity, temperature and concentration distributions are the equations governing the flow are numerically solved by perturbation technique.

- The velocity increases with the increase of permeability parameter K.
- The temperature decreases with the increase of radiation parameter R.
- The concentration decreases with the increase of chemical reaction parameter C.

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