International Journal of Advanced Scientific and Technical Research Issue 6 volume 6, November-December 2016
Available online on http://www.rspublication.com/ijst/index.html ISSN 2249-9954

EFFECT OF CHEMICAL REACTION ON AN OSCILLATORY MHD MIXED CONVECTIVE MASS TRANSFER FLOW PAST AN INFINITE VERTICAL POROUS PLATE WITH VARIABLE SUCTION

Dipak Sarma
Department of Mathematics, Cotton College, Guwahati -01, India

Mamani Kalita
Department of Mathematics, Gauhati University, Guwahati -14, India

Kamalesh Kumar Pandit
Department of Mathematics, Gauhati University, Guwahati -14, India

Sujan Sinha
Department of Mathematics, Gauhati University, Guwahati -14, India

Abstract

An attempt has been made to study the effect of chemical reaction on an oscillatory MHD mixed convective mass transfer flow of an incompressible viscous electrically conducting fluid past an infinite vertical porous plate when the normal suction velocity as well as free stream velocity varies periodically with time . The magnetic Reynolds number is assumed to be so small that the induced magnetic field can be neglected in comparison with the applied magnetic field. The resultant set of the non-dimensional governing equations are solved analytically by adopting regular perturbation technique. Detailed computations of the influence of chemical reaction on the variations in the fluid velocity, fluid concentration, skin friction and Sherwood number at the plate are demonstrated graphically for various values of the physical parameters involved in the problem and the results are physically interpreted.

Keywords: MHD, heat transfer, mass transfer, chemical reaction, thermal radiation, Velocity ratio.

1. INTRODUCTION:

MHD is the science of motion of electrically conducting fluid in presence of magnetic field. There are numerous examples of application of in the recent years, the flows of fluid through porous media are of principal interest because these are quite prevalent in nature. Such flows have attracted the attention of a number of scholars due to their application in many branches of science and technology, viz., in the field of agriculture engineering to study the underground water resources, seepage of water in river-beds, in petroleum technology to study the movement of natural gas, oil and reservoirs, in chemical engineering for filtration and purification processes. The convection problem in porous medium has also important application in geothermal reservoirs and geothermal energy extractions. Further heat and mass transfer in the presence of magnetic field, which is the subject matter of MHD has different applications in natural phenomena and in many engineering problems viz. MHD generators, MHD pumps and MHD flow meters etc. The dynamo and motor is a classical example of MHD principle. MHD principles also find its application in medicine and biology. The principle of MHD is also used in stabilizing a flow against the transition from laminar to turbulent flow. A comprehensive review of the studies of convective heat transfer mechanism through porous media has been made by Nield and Bejan (1998).

Hiremath and Patil (1993) studied the effect on free convection currents on the oscillatory flow through a porous medium which is bounded by vertical plane surface of constant temperature.

The combined heat and mass transfer problems with chemical reaction are of importance in many processes and have, therefore, received a considerable amount of attention in recent years. In processes such as drying, evaporation at the surface of water body, energy transfer in wet cooling tower and the flow in a desert cooler, heat and mass transfer occur simultaneously. There are many transport processes that are governed by the combined action of buoyancy forces due to both thermal and mass diffusion in the presence of the chemical reaction effect. These processes are observed in nuclear reactor safety and combustion systems, solar collectors, as well as metallurgical and chemical engineering. Their other applications include solidification of binary alloys and crystal growth dispersion of dissolved materials or particulate water in flows, drying and dehydration operations in chemical and food processing plants and combustion of atomized liquid fuels.

A chemical reaction can be codified as either a homogeneous or heterogeneous process. A homogeneous reaction is one that occurs uniformly through a given phase. In contrast, a heterogeneous reaction takes place in a restricted region or within the boundary of a phase. A reaction is said to be first order if its rate is directly proportional to the concentration itself (1988). The effect of chemical reaction on heat and mass transfer in a laminar boundary layer flow has been studied under different conditions by several authors (2001, 2003, and 2006). The chemical reaction effect on heat and mass transfer flow along a semi infinite horizontal plate has been studied by Anjali Devi and Kandaswamy (1999), and later it was extended for Hiemenz flow by Seddeek et. al. (2007), and for polar fluid by Patil and Kulkarni (2008). The effects of chemical reaction on the unsteady free convection flow past an infinite vertical permeable moving plate with variable temperature were studied by El-Fayez (2012). Sekhar and Reddy (2012) studied the effect of chemical reaction on MHD free convective oscillatory flow past a porous plate with viscous dissipation and heat sink. C. S. Sravanthi et. al., (2013) studied the effects of chemical reaction and thermo-diffusion on a steady mixed convective heat and mass transfer flow with induced magnetic field.

The radiation heat transfer becomes very important for the design of pertinent equipment. Recent developments in hypersonic flights, gas cooled nuclear reactors and nuclear power plants, gas turbines and space vehicles have attracted researchers in such engineering areas. The interaction of radiation with mixed convection flows past a vertical plate was investigated by Hossain and Takhar (1996), Aboeldhab (2000) studied the radiation effect in heat transfer in an electrically conducting fluid at stretching surface. Aydin and Kaya (2008), studied the effect of radiation on MHD mixed convection flow about a permeable vertical plate. The effect of radiation on the heat and fluid flow over an unsteady stretching surface has been analyzed by El-Aziz (2009). Singh et. al. (2010) studied the heat transfer over stretching surface in porous media with transverse magnetic field. Elbashbeshy et. al. (2010) investigated the effects of thermal radiation and magnetic field on unsteady boundary layer mixed convection flow and heat transfer problem from a vertical porous stretching surface. Ramachandra Prasad et. al. (2008) studied the effects of thermal radiation on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium. Sudheer Babu and Satyanarayana (2009) studied the effects of chemical reaction and radiation absorption on free convection flow through porous medium with variable suction in the presence of uniform magnetic field. Dulal Pal et. al. (2010) studied perturbation analysis of unsteady MHD convective heat and mass transfer in a boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction. Recently, Ramana Reddy et. al. (2010) have studied the mass transfer and radiation effects of unsteady MHD free convective fluid flow embedded in a porous medium with heat generation/absorption. Ibrahim et. al. (2008) studied the effect of chemical reaction and radiation absorption on the unsteady MHD free convection flow past a semi-infinite vertical permeable moving plate with heat source and suction. The analysis of MHD mixed convection interaction with thermal radiation and higher order chemical reaction is carried out by Makinde (2011). Recently, A. D. M. Gururaj and S. P. Anjali Devi (2014) studied the effects of radiation on MHD boundary layer with forced convection past a nonlinearity stretching surface with variable temperature. K. K. Pandit and D. Sarma (2015) analyzed the effect of thermal radiation and chemical reaction on steady MHD mixed convective flow over a vertical porous plate with Induced Magnetic field.

In spite of all these studies, the steady MHD mixed convection for a heat generating fluid with thermal radiation and chemical reaction has received little attention. Hence, the main objective of this paper is to investigate the effects of thermal radiation and chemical reaction on the unsteady mixed free-force convection flow of an electrically conducting fluid past an infinite vertical porous plate with variable suction velocity. This paper is the extension of the recent works of N. Ahmed and S. Sinha (2013). The plate is assumed to be embedded in a uniform porous medium and moves with a constant velocity in the flow direction in presence of a transverse magnetic field.

2. MATHEMATICAL FORMULATION

We now consider an unsteady MHD conducting flow of a viscous incompressible electrically conducting fluid past an infinite vertical porous plate with variable suction under the influence of a uniform transverse magnetic field. Our investigation is restricted to the following assumptions:

1. The polarization effects are assumed to be negligible and hence the electric field is also negligible.

2. The variations of all fluid properties other than the variations of density except in so far as they give rise to a body force are ignored completely.

3. All the physical variables are functions of y' and t' only as the plate are infinite.

4. It is assumed that the variation of expansion co-efficient is negligibly small and the pressure and influence of the pressure on the density are negligible.

We introduce a co-ordinate system (x', y', z') with X-axis vertically upwards along the plate, Y-axis perpendicular to the plate and directed into the fluid region and Z-axis along the width of the plate as shown in Figure1. Let the components of velocity along with X and Y axes should be u' and v'. Let these velocity components are chosen in the upward direction along the plate and normal to the plate respectively.

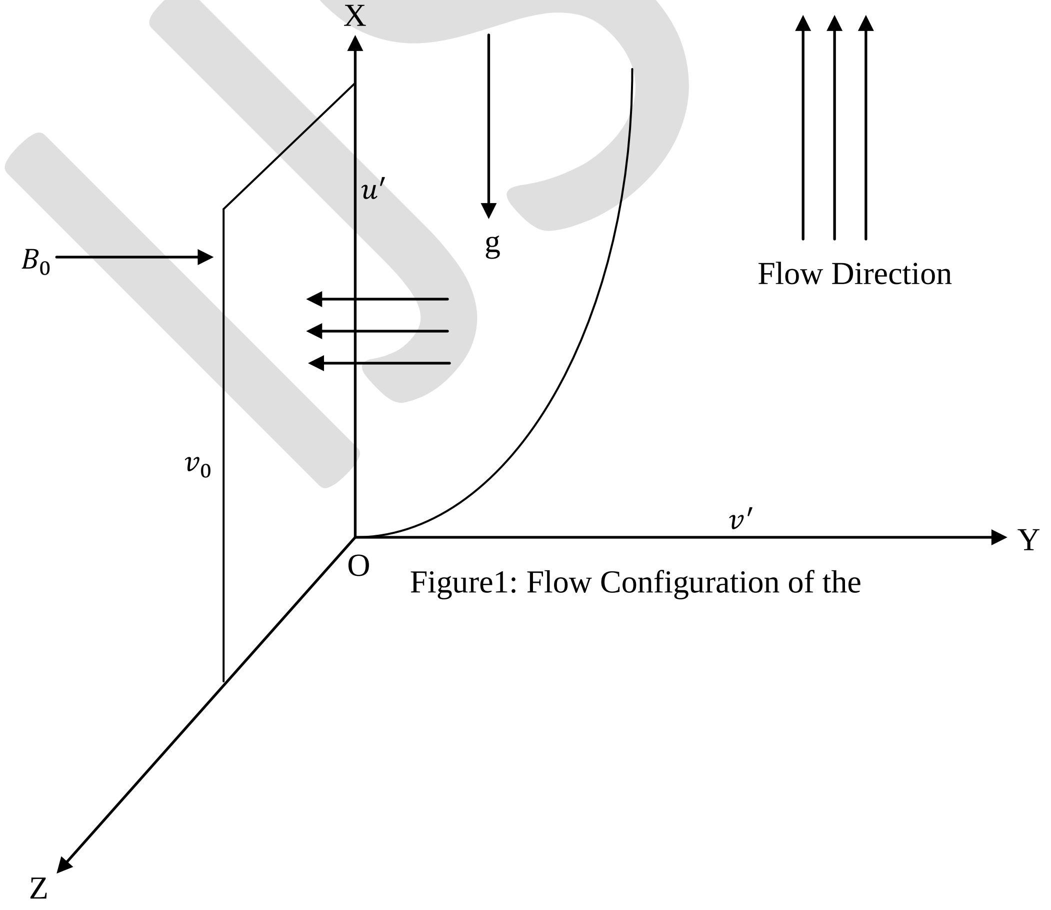

Figure1: Flow Configuration of the

1 .Basic Equations are

Continuity equation

$$\frac{\partial \bar{v}}{\partial \bar{y}} = 0 \tag{1}$$

Momentum equation

$$\frac{\partial \bar{u}}{\partial \bar{t}} + \bar{v}\frac{\partial \bar{u}}{\partial \bar{y}} = -\frac{1}{\rho}\frac{\partial \bar{p}}{\partial \bar{x}} + \upsilon\frac{\partial^2 \bar{u}}{\partial \bar{y}^2} + g\beta\left(\bar{T} - \bar{T}_\infty\right) + g\bar{\beta}\left(\bar{C} - \bar{C}_\infty\right) - \frac{\sigma B_0^2 \bar{u}}{\rho} - \upsilon\frac{\bar{u}}{\bar{K}} \tag{2}$$

Energy equation

$$\frac{\partial \bar{T}}{\partial \bar{t}} + \bar{v}\frac{\partial \bar{T}}{\partial \bar{y}} = \frac{K_T}{\rho C_P}.\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} - \frac{1}{\rho C_P}\frac{\partial \bar{q}_r}{\partial \bar{y}} \tag{3}$$

Species Concentration equation

$$\frac{\partial \bar{C}}{\partial \bar{t}} + \bar{v}\frac{\partial \bar{C}}{\partial \bar{y}} = D\frac{\partial^2 \bar{C}}{\partial \bar{y}^2} D_1 \frac{\partial^2 \bar{T}}{\partial \bar{y}^2} - \bar{K}_r\left(\bar{C} - \bar{C}_\infty\right) \tag{4}$$

The boundary conditions are

$$\bar{u} = 0, \bar{T} = \bar{T}_\infty + \left(1 + \varepsilon e^{i\bar{\omega}\bar{t}}\right)\left(\bar{T}_W - \bar{T}_\infty\right), \bar{C} = \bar{C}_W \quad \text{at} \quad \bar{y} = 0 \tag{5}$$

$$\bar{u} \to \bar{U} = U_0\left(1 + \varepsilon e^{i\bar{\omega}\bar{t}}\right), \bar{T} \to \bar{T}_\infty, \bar{C} \to \bar{C}_\infty \quad \text{as} \quad \bar{y} \to \infty$$

The equation (1) yields that the suction velocity at the plate is either a constant or a function of time and we take the suction velocity normal to the plate in the form $\bar{v} = -V_0\left(1 + \varepsilon A e^{i\bar{\omega}\bar{t}}\right)$
(6)

Where A is a real constant, $\varepsilon << 1, V_0$ is a scale of suction velocity which is none zero positive constant. The negative sign indicates that the suction is towards plate.

Outside the boundary layer equation (2) gives

$$-\frac{1}{\rho}\frac{\partial \bar{p}}{\partial \bar{x}} = \frac{d\bar{U}}{d\bar{t}} + \frac{\upsilon}{\bar{K}}\bar{U} + \frac{\sigma B_0^2 \bar{U}}{\rho} \tag{7}$$

Now we use the following non dimensional quantities:

$$u = \frac{\bar{u}}{V_0}, v = \frac{\bar{v}}{V_0}, y = \frac{\bar{y}V_0}{\upsilon}, U = \frac{\bar{U}}{U_0}, \lambda = \frac{U_0}{V_0}, t = \frac{\bar{t}V_0^2}{4\upsilon}, \theta = \frac{\bar{T} - \bar{T}_\infty}{\bar{T}_W - \bar{T}_\infty}, C = \frac{\bar{C} - \bar{C}_\infty}{\bar{C}_W - \bar{C}_\infty},$$

$$Sc = \frac{\upsilon}{D}, M = \frac{\sigma B_0^2 \upsilon}{\rho V_0^2}, Gr = \frac{\upsilon\beta g\left(\bar{T}_W - \bar{T}_\infty\right)}{V_0^3}, \omega = \frac{4\upsilon\bar{\omega}}{V_0^2}, K = \frac{\bar{K}V_0^2}{\upsilon^2}, \Pr = \frac{\upsilon}{\alpha} = \frac{\mu C_P}{K_T},$$

$$Gm = \frac{\upsilon \bar{\beta} g\left(\bar{C}_W - \bar{C}_\infty\right)}{V_0^3}, Sr = \frac{D_1\left(\bar{T}_W - \bar{T}_\infty\right)}{\upsilon\left(\bar{C}_W - \bar{C}_\infty\right)}, K_r = \frac{\bar{K}_r \upsilon}{V_0^2}, N = \frac{K_T K_1}{4\sigma \bar{T}_\infty^3}$$

Using all these dimensionless quantities, equations (2) – (4) reduces to the following non dimensional form:

$$\frac{1}{4}\frac{\partial u}{\partial t} - \left(1 + \varepsilon A e^{i\omega t}\right)\frac{\partial u}{\partial y} = \frac{\lambda}{4}\frac{dU}{dt} + \frac{\partial^2 u}{\partial y^2} + Gr\theta + GmC + M_1\left(\lambda U - u\right) \tag{8}$$

$$\frac{1}{4}\frac{\partial \theta}{\partial t} - \left(1 + \varepsilon A e^{i\omega t}\right)\frac{\partial \theta}{\partial y} = \frac{\lambda_1}{\Pr}\frac{\partial^2 \theta}{\partial y^2} \tag{9}$$

$$\frac{1}{4}\frac{\partial C}{\partial t} - \left(1 + \varepsilon A e^{i\omega t}\right)\frac{\partial C}{\partial y} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} + Sr\frac{\partial^2 \theta}{\partial y^2} - K_r C \tag{10}$$

The corresponding boundary conditions are:

$$u = 0, \theta = 1 + \varepsilon e^{i\omega t}, C = 1, \text{ at y =0} \tag{11}$$

$$u \to U = \lambda\left(1 + \varepsilon e^{i\omega t}\right), \theta \to 0, C \to 0 \text{ as } y \to \infty$$

Method of Solutions

$$u = u_0\left(y\right) + \varepsilon e^{i\omega t} u_1\left(y\right) + o\left(\varepsilon^2\right)$$

$$\theta = \theta_0\left(y\right) + \varepsilon e^{i\omega t}\theta_1\left(y\right) + o\left(\varepsilon^2\right) \tag{12}$$

$$C = C_0\left(y\right) + \varepsilon e^{i\omega t} C_1\left(y\right) + o\left(\varepsilon^2\right)$$

$$U = \lambda\left(1 + \varepsilon e^{i\omega t}\right)$$

Substituting (12) in equations (8)-(10) and equating the like powers of ε on both sides and neglecting the higher order terms of $o\left(\varepsilon^2\right)$, we get

$$u_0'' + u_0' - M_1 u_0 = -Gr\theta_0 - GmC_0 - M_1\lambda^2 \tag{13}$$

$$u_1'' + u_1' - u_1\left(M_1 + \frac{i\omega}{4}\right) = Au_0' - \lambda^2\left(M_1 + \frac{i\omega}{4}\right) - Gr\theta_1 - GmC_1 \tag{14}$$

$$\theta_0'' + \frac{\Pr}{\lambda_1}\theta_0' = 0 \tag{15}$$

$$\theta_1'' + \frac{\Pr}{\lambda_1}\theta_1' - \frac{i\omega}{4}\frac{\Pr}{\lambda_1}\theta_1 = -\frac{\Pr}{\lambda_1}A\theta_0' \tag{16}$$

$$C_0'' + ScC_0' - ScK_rC_0 = -ScSr\theta_0'' \tag{17}$$

$$C_1'' + ScC_1' - \left(K_r + \frac{i\omega}{4}\right)ScC_1 = -ScAC_0' - ScSr\theta_1'' \tag{18}$$

The boundary conditions are:

$$u_0 = 0, u_1 = 0, \theta_0 = 1, \theta_1 = 1, C_0 = 1, C_1 = 0 \text{ at } y = 0$$

$$u_0 \to \lambda, u_1 \to \lambda, \theta_0 \to 0, \theta_1 \to 0, C_0 \to 0, C_1 \to 0 \text{ as } y \to \infty$$

(19)

The equation (13)-(18) subject to the boundary conditions (19) have been solved but are not presented here for the sake of brevity.

Skin friction:

The skin friction at the plate is given by:

$$Cf = \left(\frac{\partial u}{\partial y}\right)_{y=0} = \left[\begin{array}{l} -B_6\left(A_8 + A_9 - A_{10} - 1\right) + A_1A_8 + B_3A_9 - A_1A_{10} \\ -\varepsilon e^{i\omega t}B_7\left\{\begin{array}{l} A_{11} - \left(A_{12} - A_{14} - A_{16} + A_{20} + A_{23}\right) - \left(A_{13} - A_{18} - A_{19}\right) - \\ \left(-A_{15} + A_{21} - A_{22}\right) - A_{17} - 1 \end{array}\right\} + \\ \varepsilon e^{i\omega t}B_6A_{11} - \varepsilon e^{i\omega t}A_1\left(A_{12} - A_{14} - A_{16} + A_{20} + A_{23}\right) - \varepsilon e^{i\omega t}B_3\left(A_{13} - A_{18} - A_{19}\right) - \\ \varepsilon e^{i\omega t}B_1\left(-A_{15} + A_{21} - A_{22}\right) - \varepsilon e^{i\omega t}A_{17}B_5 \end{array}\right]$$

Nusselt Number:

The rate of heat transfer in terms of Nusselt number at the plate is given by:

$$Nu = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0} = A_1 + \varepsilon e^{i\omega t}B_1\left(1 - B_2\right) + \varepsilon e^{i\omega t}A_1B_2$$

Sherwood Number:

The of mass transfer in terms of Sherwood number at the plate is given by:

$$Sh = -\left(\frac{\partial C}{\partial y}\right)_{y=0} = B_3\left(1 + B_4\right) - B_4A_1 - \varepsilon e^{i\omega t}B_5\left(A_2 + A_3 - A_4 - A_5 + A_6 - A_7\right) + \varepsilon e^{i\omega t}B_3A_2 +$$

$$\varepsilon e^{i\omega t}B_3A_3 - \varepsilon e^{i\omega t}A_4A_1 - \varepsilon e^{i\omega t}A_5B_1 + \varepsilon e^{i\omega t}B_1A_6 - \varepsilon e^{i\omega t}A_7A_1$$

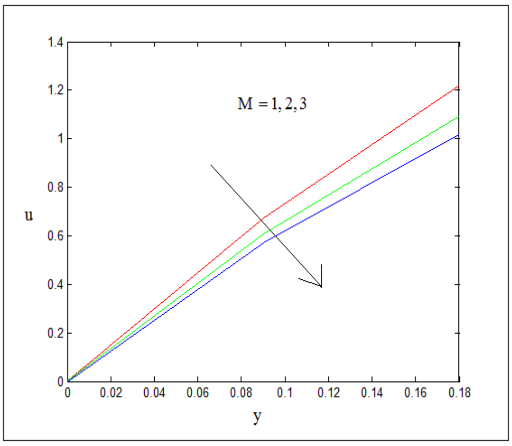

Figure 1: Velocity versus y for K=1, Kr=1, Gr=5,Gm=5,Pr=.71, A=0.5, Sc=.60, ε =0.002, ω =1, Sr=1, N=1, t=1

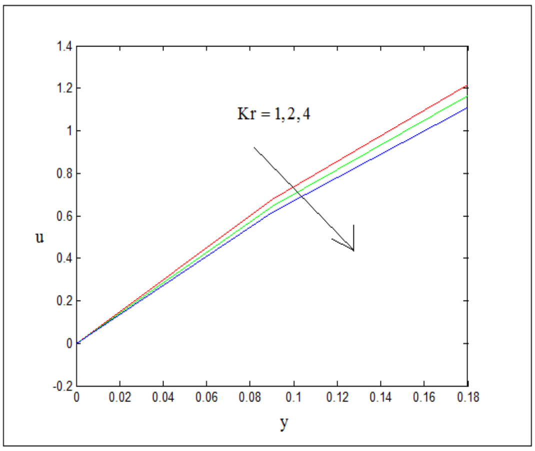

Figure 2: Velocity versus y for K=1, M=1, Gr=5, Gm=5, Pr=.71, A=0.5, Sc=.60, ε =0.002, ω =1, Sr=1, N=1, t=1

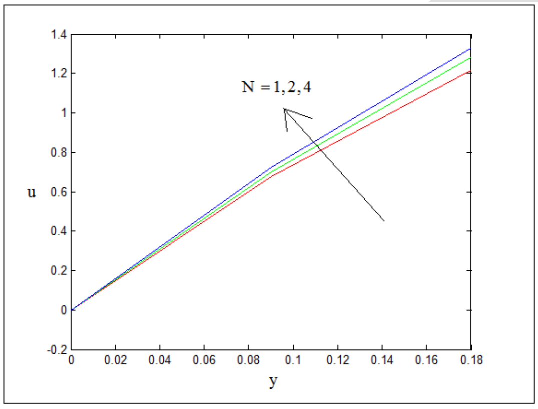

Figure 3: Velocity versus y for K=1, M=1, Gr=5, Gm=5, Pr=.71, A=0.5, Sc=.60, ε =0.002, ω =1, Sr=1, Kr=1, t=1

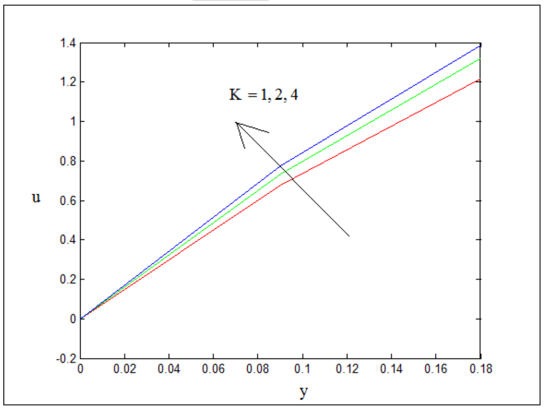

Figure 4: Velocity versus y for N=1, M=1, Gr=5, Gm=5, Pr=.71, A=0.5, Sc=.60, ε =0.002, ω =1, Sr=1, Kr=1, t=1

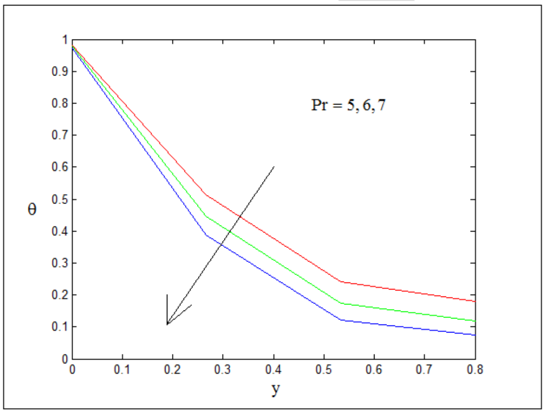

Figure 5: Temperature versus y for K=1, M=1, Gr=5, Gm=5, N=1, A=0.5, Sc=.60, ε =0.002, ω =1, Sr=1, Kr=1, t=1

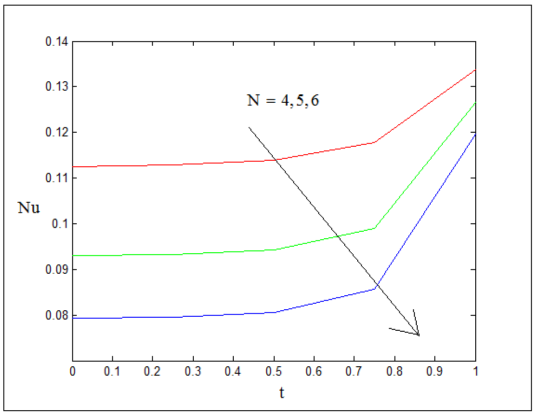

Figure 6: Nusselt number versus t for K=1, M=1, Gr=5, Gm=5, Pr=.71, A=0.5, Sc=.60, ε = 0.002, ω =1, Sr=1, Kr=1

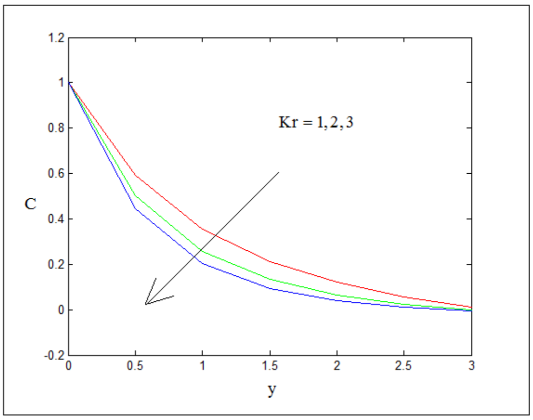

Figure 7: Concentration versus y for Pr=.71, A=0.5, Sc=.60, ε =0.002, ω =1, Sr=1, N=1, t=1

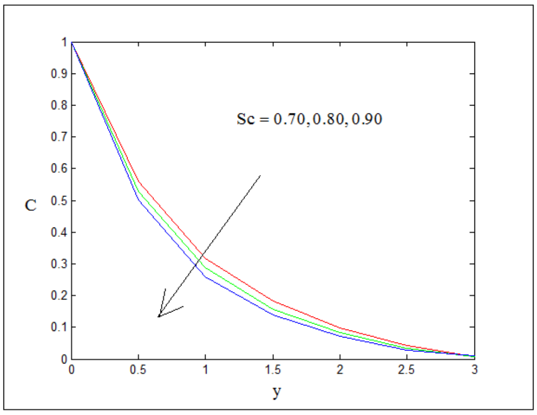

Figure 8: Concentration versus y for Pr=.71, A=0.5, Kr=1, ε =0.002, ω =1, Sr=1, N=1, t=1

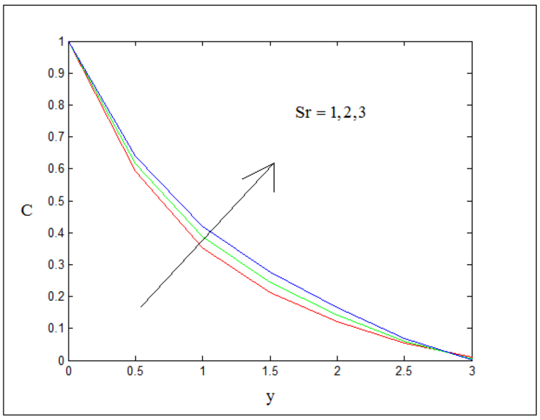

Figure 9: Concentration versus y for Pr=.71, A=0.5, Sc=.60, ε =0.002, ω =1, Kr=1, N=1, t=1

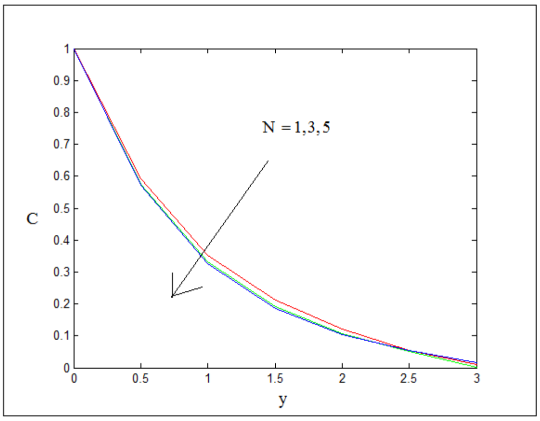

Figure 10: Concentration versus y for Pr=.71, A=0.5, Sc=.60, ε =0.002, ω =1, Sr=1, N=1, t=1

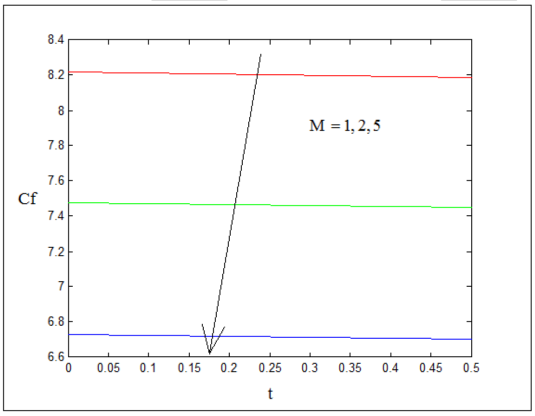

Figure 11: Skin friction versus t for K=1, Kr=1, Gr=5, Gm=5, Pr=.71, A=0.5, Sc=.60, ε =0.002, ω =1. Sr=1. N=1

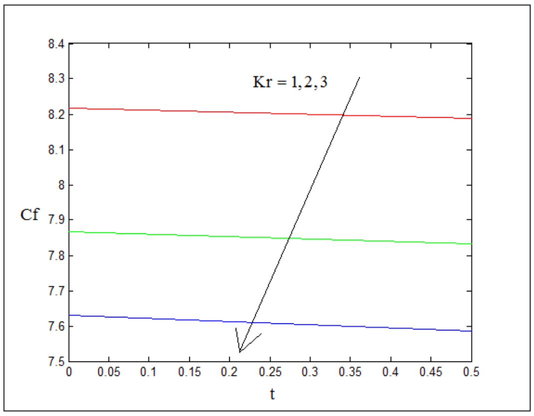

Figure 12: Skin friction versus t for K=1, M=1, Gr=5, Gm=5, Pr=.71, A=0.5, Sc=.60, ε =0.002, ω =1, Sr=1, N=1

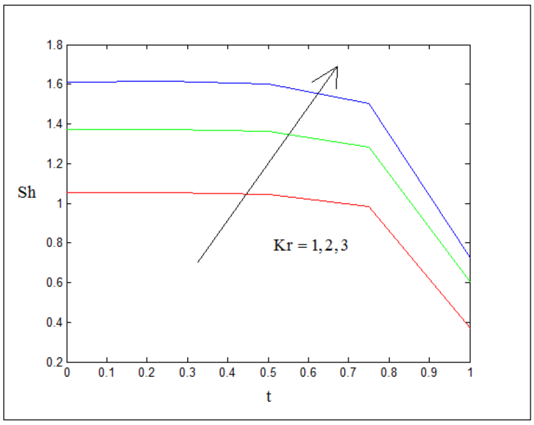

Figure 13: Sherwood number versus t for Pr=.71, A=0.5, Sc=.60, ε =0.002, ω =1, A=0.5, N=1

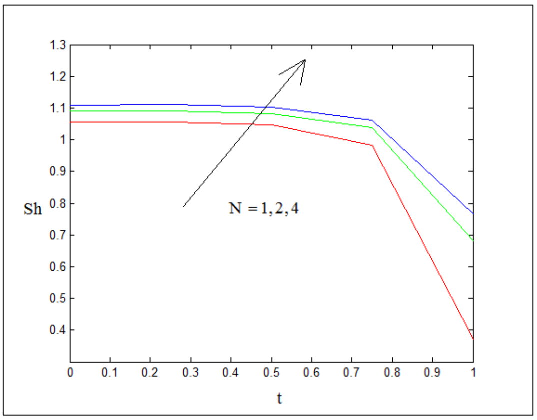

Figure 14: Sherwood number versus t for Pr=.71, A=0.5, Sc=.60, ε =0.002, ω =1, A=0.5, Kr=1

RESULT AND DISCUSSION:

The chemical reaction and thermal radiation effects on an unsteady MHD conducting flow of a viscous incompressible electrically conducting fluid past an infinite vertical porous plate with variable suction under the influence of a uniform transverse magnetic field have been studied. The governing equations are solved by using perturbation technique and approximate solutions are obtained for velocity, temperature and concentration fields. The effects of the flow parameters such as magnetic parameter (M), chemical reaction parameter (Kr), radiation parameter (N), permeability of the porous medium (K), Prandtl number (Pr), Schmidt number (Sc) and Soret number (Sr) on the velocity, temperature and concentration profiles of the flow field are presented with the help of velocity profiles (Figs.1-4), temperature profiles (Fig.5) and concentration profiles (Figs.7-10). We have also analyzed the effects of these physical parameters on skin friction coefficient, Nusselt number and Sherwood number.

Figs.1 depicts the influence of magnetic parameter (M) on the velocity field u. It is evident from Fig.1 that the velocity u decreases on increasing M throughout the boundary layer region. The application of transverse magnetic field to an electrically conducting field gives rise to a resistive type of force called Lorentz force. This force has the tendency to slow down the fluid. This trend is evident from Fig.1. Fig.2 and 7 displays the influence of chemical reaction parameter (Kr) on the velocity field u and concentration profile. It is perceived from Fig. 2 and 7 that, fluid velocity u and concentration profile decreases on increasing the chemical reaction parameter. This implies that, chemical reaction tend to decrease the fluid velocity as well as species concentration of the fluid throughout the boundary layer region. In turn, this causes the concentration buoyancy effects to decrease as Kr increases. Consequently, less flow is induced along the plate resulting in decrease in the fluid velocity in the boundary layer. Fig. 3 depicts the effect of thermal radiation on velocity field. It is clear from Fig. 3 that, fluid velocity increases with the increase of thermal radiation parameter. Fig. 4 exhibits the effect of permeability of the porous medium (k) on fluid velocity. An increase in permeability parameter (k) leads to an increase in fluid velocity. This is due the fact that an increase in k implies that there is a decrease in the resistance of the porous medium which tends to accelerate the fluid velocity in the boundary layer region.

Fig. 5 displays the effect of Prandtl number (Pr) on temperature profile. It is evident from Fig. 5 that, fluid temperature decrease on increasing the Prandtl number. Prandtl number signifies the ratio of momentum diffusivity to thermal diffusivity. In heat transfer problems, the Prandtl number Pr controls the relative thickening of the momentum and thermal boundary layers. Hen Prandtl number Pr is small, heat diffuses quickly compared to the velocity (momentum), which means that for liquid metals, the thickness of the thermal boundary layer is much bigger than the momentum boundary layer. Fluids with lower Prandtl number have higher thermal conductivities (and thicker thermal boundary layer structures) so that heat can diffuse from the sheet faster than for higher Pr fluids (thinner boundary layer). Hence Prandtl number can be used to increase the rate of cooling in conducting flows.

Fig. 8 depicts the effect of Schimdt number (Sc) on species concentration profile. It is noticed that effect of increasing value of Sc is to decrease the concentration profile. This is consistent with the fact that, increase in Sc means decrease of molecular diffusivity those results in decease of concentration boundary layer. Hence species concentration is higher for small values of Sc and lower for large value of Sc. Fig. 9 display the influence of Soret number Sr on concentration profile. It is noticed that an increase in Soret number Sr results an increase in the species concentration of the fluid flow. An increase in Soret number indicates increasing molar mass diffusivity, as seen from definition of Sr. The surge in molecular mass diffusivity causes the concentration to rise. This implies that, Soret number tends to enhance the species concentration of the fluid. Fig. 10 shows the effect of thermal radiation parameter (N) on the concentration profile. It is clear that increasing the thermal radiation parameter tends to decrease the species concentration of the fluid flow. As thermal radiation increase the fluid temperature decreases thereby causing reduced molecular activity. Decrease in fluid temperature lessens the impetus of thermal flux on concentration flux. This reduces the molecular concentration. This implies that the thermal radiation tends to retard the species concentration of the fluid.

Figs. 11-12 exhibit the nature of skin-friction coefficient Cf for different values of magnetic parameter (M) and chemical reaction parameter (Kr). It is found that skin-friction coefficient deceases with the increase of M and Kr. This implies that magnetic parameter and chemical reaction parameter has the tendency to reduce the skin-friction.

Fig. 6 displays the effect of thermal radiation on Nusselt number. It is noticed from Fig. 6 that, Nusselt number decreases on increasing thermal radiation parameter. This implies that, thermal radiation tends to decelerate the rate of heat transfer at the plate.

Figs. 13 and 14 show the effect of chemical reaction parameter (Kr) and thermal radiation parameter (N) on Sherwood number (Sh). It is perceived from Figs.13 and 14 that the rate of mass transfer increases on increasing Kr and N. This implies that, chemical reaction and thermal radiation tends to enhance the rate of mass transfer at the plate.

CONCLUSIONS:

An investigation of the effects of chemical reaction, thermal radiation and Soret number on an unsteady MHD conducting flow of a viscous incompressible electrically conducting fluid past an infinite vertical porous plate with variable suction under the influence of a uniform transverse magnetic field is carried out. Exact solutions of the governing equations were obtained using regular perturbation technique. A comprehensive set of graphical for the fluid velocity, fluid temperature and species concentration is presented and their dependence on some physical parameters is discussed. Significant finding are as follows:

1. Chemical reaction and magnetic parameter tend to decrease the fluid velocities whereas radiation and permeability parameter has the reverse effect on it.
2. Chemical reaction and thermal radiation parameter tend to decrease the species concentration of the fluid flow whereas Soret number has the reverse effect on it.
3. Thermal diffusion tends to decrease the fluid temperature throughout the boundary layer region.
4. Radiation parameter tends to accelerate the rate of heat transfer throughout the boundary layer region.
5. Chemical reaction and magnetic parameter has the tendency to reduce the skin-friction co-efficient of the fluid flow throughout the boundary layer region.
6. Chemical reaction and thermal radiation parameter tend to increase the rate of mass transfer of the fluid flow throughout the boundary layer region.

References:

1. Aboeldahab, M. E., (2000) Radiation effect on heat transfer in electrically conducting fluid at a stretching surface with uniform free stream, *J. Phys, D. Appl. Phys.*, 33, pp. 3180-3185.
2. Ahmed, N. and Sinha, S. (2013) Soret effect on an oscillatory MHD mixed convective mass transfer flow past an infinite vertical porous plate with variable suction, Applied Mathematical Sciences, 7(51), pp. 2515-2524.
3. Anjalidevi, S. P. and Kandasamy, R., (1999) Effects of chemical reaction, heat and mass transfer on laminar flow along a semi-infinite horizontal plate, *Heat and Mass Transfer*, 35(6), pp. 465-467.
4. Aydin, O. and Kaya, A., (2008) Radiation effect on MHD mixed convection flow about a permeable vertical plate, *Heat Mass Transfer*, 45, pp. 239-246.
5. Babu, M. S. and Narayana, P. V. S., (2009) Effects of the chemical reaction and radiation absorption on free convection flow through porous medium with variable suction in the presence of uniform magnetic field, *J. P. Journal of Heat and Mass Transfer*, 3, pp.219-234.
6. Chamkha, A. J., (2003) MHD flow of an uniformly stretched vertical permeable surface in the presence of heat generation/absorption and a chemical reaction, *Intl. Comm. in Heat Mass Transfer*, 30(3), pp. 413-422.
7. Cussler, E. L., (1988) Diffusion mass transfer in fluid system, *Cambridge University Press*, London.
8. El-Aziz, M. A., (2009) Radiation effect on the flow and heat transfer over an unsteady stretching sheet", *Int. Comm. in Heat and Mass Transfer*, 36, pp. 521-524.
9. Elbashbeshy, E. M. A., Yassmin, D. M. and Dalia, A. A., (2010) Heat transfer over an unsteady porous stretching surface embedded in a porous medium with variable heat flux in the presence of heat source or sink, *African J. of Mathematics and Computer Science Research*, 3(5), pp. 68-73.
10. El-Fayez, F. M. N., (2012) Effects of chemical reaction on the unsteady free convection flow past an infinite vertical permeable moving plate with variable temperature, *J. of Surface Engineered Materials and Advanced Technolog*y, 2, pp. 100-109.
11. Gururaj, A. D. M. and Anjali Devi, S. P., (2014) MHD boundary layer with forced convection past a nonlinearity stretching surface with variable temperature and nonlinear radiation effects, *Int. Journal of Development Research*, 4(1), pp.75-80.
12. Hiremath, P.S. and Patil, P. M., (1993) Free convection effects on oscillatory flow of couple stress field through a porous medium, *ACTA Mechanica*, Vol. 98, No. 1-4, pp. 143-158.
13. Hossain, M. A. and Takhar, H. S., (1996) Radiation effect on mixed convection along a vertical plate with uniform surface temperature, *Heat Mass Transfer*, 31, pp. 243-248.
14. Hossain, M. M. T. and Khatun, M., (2012) Study of Diffusion-Thermo effect on laminar mixed convection flow and heat transfer from a vertical surface with induced magnetic field, *Int. J. of appl. Math and Mech.*, 8(5), pp. 40-60.
15. Ibrahim, F. S., Elaiw, A. M. and Bakr, A. A., (2008) Effect of the chemical reaction and radiation absorption on the unsteady MHD free convection flow past a semi-infinite vertical permeable moving plate with heat source and suction, *Comm. in Non-Linear Science and Numerical Simulation*, 13(6), pp. 1056-1066.
16. Makinde, O. D., (2011) MHD mixed convection interaction with thermal radiation and n^{th} order chemical reaction past a vertical porous plate embedded in a porous medium, *Chemical Engineering Communication*, 198(4), pp. 590-608.
17. Muthucumarswamy, R. and Ganesan, P., (2001) Effect of the chemical reaction and injection on flow characteristics in an unsteady upward motion of an isothermal plate, *J. Appl. Mech. Tech. Phys.*, 42(4), pp. 665-671.
18. Nield, D. A. and Bejan, A., (1998) *Convection in porous media*, 2nd Edition, Springer-Verlag, Berlin, 1998.
19. Pal, D. and Talukdar, B., (2010) Perturbation analysis of unsteady MHD convective heat and mass transfer in a boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction, *Comm. in Non-Linear Science and Numerical Simulation*, pp. 1813-1830.

20. Pandit, K. K. and Sarma, D., (2015) Effects of Thermal Radiation and Chemical Reaction on Steady MHD Mixed Convective Flow over a Vertical Porous Plate with Induced Magnetic Field, Int. J. of Fluid Mechanics Research, 42(4), pp. 315-333.
21. Patil, P. M. and Kulkarni, P. S., (2008) Effects of chemical reaction on free convective flow of a polar fluid through a porous medium in the presence of internal heat generation, *Int. J. of Thermal Sciences*, 47(8), pp. 1043-1054.
22. Prasad, V. R. and Reddy, N. B., (2008) Radiation effects on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium, *J. of Energy Heat and Mass Transfer*, 30, pp. 57-68.
23. Raptis, A. and Perdikis, C., (2006) Viscous flow over a non-linearly stretching sheet in the presence of a chemical reaction and magnetic field, *Int. J. Non-Linear Mech.*, 41, pp. 527-529.
24. Reddy, G. V. R., Murthy, Ch. V. R. and Reddy, N. B., (2010) Mass transfer and radiation effects of unsteady MHD free convective fluid flow embedded in porous medium with heat generation/absorption, *J. of Appl. Mathematics and Fluid Mechanics*, 2, pp. 85-98.
25. Seddeek, M. A., Darwish, A. A. and Abdelmeguid, M. S., (2007) Effects of chemical reaction and variable viscosity on hydro magnetic mixed convection heat and mass transfer for Hiemenz flow through porous media with radiation, *Comm. in Nonlinear Science and Numerical Simulation*, 12(2), pp. 195-213.
26. Sekhar, D. V. and Reddy, G. V., (2012) Effects of chemical reaction on MHD free convective oscillatory flow past a porous plate with viscous dissipation and heat sink, *Advances in Applied Science Research*, 3(5), pp. 3206-3215.
27. Singh, P., Tomer, N. S. and Sinha, D., (2010) Numerical study of heat transfer over stretching surface in porous media with transverse magnetic field, Proceeding in International conference on challenges and application of Mathematics in Sciences and Technology, ISBN 023-032-875-X, pp. 422-430.
28. Sravanthi, C. S., Ratnam, A. L. and Reddy, N. B., (2013) Thermo-Diffusion and Chemical reaction effects on a steady mixed convective heat and mass transfer flow with induced magnetic field, *Int. J. of Innovative Research in Sci., Eng. and Tech.*, 2(9), pp. 4415-4424.