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EFFECT OF CHEMICAL REACTION ON UNSTEADY MHD FREE CONVECTIVE FLOW PAST A SEMI-INFINITE VERTICAL POROUS PLATE WITH HEAT GENERATION

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ABSTRACT

This work is focused on the effects of variable viscosity and thermal conductivity on unsteady two-dimensional laminar flow of a viscous incompressible electrically conducting fluid past a semi-infinite vertical plate taking into account the chemical reaction with heat generation. The fluid viscosity is assumed to vary as a linear function of temperature. The governing equations for the flow are transformed into a system of non-linear ordinary differential equations are solved by a perturbation technique. The effects of the various parameters on the velocity, temperature, concentration, Skin friction number, Nusselt number and sheer wood number are computed in graphical and tabular form.

Keywords: Radiation parameter, Thermal conductivity, MHD, porous medium, viscosity and Heat generation.

INTRODUCTION:

Magnetohydrodynamics (MHD) is the branch of continuum mechanics which deals with the flow of electrically conducting fluids in electric and magnetic fields. Many natural phenomena and engineering problems are worth being subjected to an MHD analysis. Magneto-hydrodynamic equations are ordinary electromagnetic and hydrodynamic equations modified to take into account the interaction between the motion of the fluid and the electromagnetic field. Elabashbeshy[1] studied heat and mass transfer along a vertical plate in the presence of magnetic field. Chamkha[2] analyzed an unsteady, MHD convective, viscous incompressible, heat and mass transfer along a semi-infinite vertical porous plate in the presence of transverse magnetic field, thermal and concentration buoyancy effects.

Muthucumaraswamy et al. [3] have studied the effect of homogenous chemical reaction of first order and free convection on the oscillating infinite vertical plate with variable temperature and mass diffusion. Sharma [4] investigate the effect of periodic heat and mass transfer on the unsteady free convection flow past a vertical flat plate in slipflow regime when suction velocity oscillates in time. Chaudhary and Jha [5] studied the effects of chemical reactions on MHD micropolar fluid flow past a vertical plate in slip-flow regime. Anjalidevi et al. [6] have examined the effect of chemical reaction on the flow in the presence of heat transfer and magnetic field. Muthucumaraswamy et al. [7] have investigated the effect of thermal radiation effects on flow past an impulsively started infinite isothermal vertical plate in the presence of first order chemical reaction.

The study of heat generation or absorption effects in moving fluids is important in the view of several physical problems, such as fluids undergoing exothermic or endothermic chemical reactions. Vajravelu and Hadjinicolaou[8] studied the heat transfer characteristics in the laminar boundary layer of a viscous fluid over a stretching sheet with viscous dissipation or frictional heating and internal heat generation. Hossain *et al.*[9] studied problem of the natural convection flow along a vertical wavy surface with uniform surface temperature in the presence of heat generation/absorption. Alam *et al.*[10] studied the problem of the free convection heat and mass transfer flow past an inclined semi-infinite heated surface of an electrically conducting and steady viscous incompressible fluid in the presence of magnetic field and heat generation. Chamkha[11] investigated unsteady convective heat and mass transfer past a semi-infinite porous moving plate with heat absorption. Bala Anki Reddy and Bhaskar Reddy [12] found that the finite difference analysis of radiation effects on unsteady MHD flow of a chemically reacting fluid with timedependent suction. The opposing buoyancy effects on simultaneous heat and mass transfer by natural convection in a fluid saturated porous medium investigated by Angirasa et al.[13]. Ahmed [14] investigates the effects of unsteady free convective MHD flow through a porous medium bounded by an infinite vertical porous plate. Ahmed

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Sahin [15] studied the Magneto hydrodynamic and chemical reaction effects on unsteady flow, heat and mass transfer characteristics in a viscous, incompressible and electrically conduction fluid over a semi-infinite vertical porous plate in a slip-flow regime.

The objective of the present study is to investigate the effect of various parameters like chemical Reaction parameter, thermal Grashof number, mass Grashof number, magnetic field parameter, radiation parameter, Heat generation on convective heat transfer along an semi-infinite vertical plate in porous medium. The governing non-linear partial differential equations are first transformed into a dimensionless form and thus resulting non-similar set of equations has been solved using the perturbation technique. Results are presented graphically and discussed quantitatively for parameter values of practical interest from physical point of view.

Mathematical Formulation

In a situation of two dimensional unsteady laminar natural convection flows of a viscous, incompressible, electrically conducting, radiating fluid past an impulsively started semi-infinite vertical plate in the presence of transverse magnetic field with chemical reaction is considered. The fluid is assumed to be gray, absorbing emitting but non-scattering. The x - axis is taken along the plate in the upward direction and the y- axis is taken normal to it. The fluid is assumed to be slightly conducting and hence the magnetic Reynolds number is much less than unity and the induced magnetic field is negligible in comparison with the transverse applied magnetic field. Initially, it is assumed that the plate and the fluid are at the same temperatureT_∞^1 and concentration level C_∞^1everywhere in the fluid. At time $t^1>0$, the plate starts moving impulsively in the vertical direction with constant velocity u_0 against the gravitational field. Also, the temperature of the plate and the concentration level near the plate are raised to T_w^1 and C_w^1, respectively and are maintained constantly thereafter. It is assumed that the *concentration* C^1 of the diffusing species in the binary mixture is very less in the comparison to the other chemical species, which are present and hence the Soret and Dufour effects are negligible. It is also assumed that there is no chemical reaction between the diffusing species and the fluid. Then, under the above assumptions, in the absence of an input electric field, the governing boundary layer equations with Boussinesq's approximation are

Continuous equation:

$$\frac{\partial u}{\partial x}+\frac{\partial u}{\partial y}=0 \qquad (1)$$

Momentum conservation:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=g\beta(T-T_\infty)+g\beta^*(C-C_\infty)+v\frac{\partial^2 u}{\partial y^2}-\frac{\sigma\beta_0^2}{\rho}u-\frac{v}{k^1}u \qquad (2)$$

Energy conversation:

$$\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}-\frac{1}{\rho c_p}\frac{\partial q_r}{\partial y}+\frac{v}{cp}\left(\frac{\partial u}{\partial y}\right)^2+\frac{Q}{\rho C_p}(T-T_\infty) \qquad (3)$$

Species conservation:

$$\frac{\partial C}{\partial t}+u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D\frac{\partial^2 C}{\partial y^2}-K_r^1(C-C_\infty) \qquad (4)$$

The initial and boundary conditions are as follows:

$$\left.\begin{array}{l} t\le 0, u=0, v=0, T=T_\infty, C=C_\infty\ \forall y \\ t>0, u=u_0, v=0, T=T_w, C=C_w\ at\ y=0 \\ u\to 0, T\to T_\infty, C\to C_\infty\ as\ y\to\infty \end{array}\right\} \qquad (5)$$

Thermal radiation is assumed to be present in the form of a unidirectional flux in the y -direction i.e., q_r(transverse to the vertical surface). By using the Roseland approximation, the radioactive heat flux q_r is given by

$$q_r=-\frac{4\sigma_s}{3k_c}\frac{\partial {T^1}^4}{\partial y} \qquad (6)$$

where $\sigma_s$is the Stefan-Boltzmann constant and $\mathrm{k_c}$ – the mean absorption coefficient. In the Roseland approximation, the present analysis is limited to optically thick fluids. If temperature differences within the flow are sufficiently small, then equation (6) can be linear zed by expanding T^{1^4} into the Taylor series about T^1_∞ , which after neglecting higher order terms takes the form

$T^{1^4} = 4\, T^{1^3}_\infty - T^{1^4}_\infty$ (7)

In view of equations (6) and (7), equation (3) reduces to

$$\frac{\partial T^1}{\partial t} + u\frac{\partial T^1}{\partial x} + v\frac{\partial T^1}{\partial y} = \alpha\frac{\partial^2 T^1}{\partial y^2} + 16\frac{\sigma_s T^{1^3}}{3k_c\, c_p \rho c_p}\frac{\partial^2 T^1}{\partial y^2} + \frac{v}{cp}\left(\frac{\partial u}{\partial y}\right)^2 \quad (8)$$

The non-dimensionless quantities introduced in these equations are defined as

$$\left.\begin{aligned} X &= \frac{xu_0}{v}, Y = \frac{xu^0}{v}, t = \frac{t1\, u_0^2}{v}, k_r = \frac{k_r^1}{u_0^2}, U = \frac{u}{u_0}, \\ V &= \frac{v}{u_0}, r = \frac{vg\beta\,(T_w^1 - T_\infty^1)}{u_0^3}, G_m = \frac{vg\beta^*(C_w^1 - C_\infty^1)}{u_0^3}, \\ N &= \frac{k_c k}{4\sigma_s T_\infty^{1^3}}, M = \frac{\sigma\beta_0^2 v}{u_0^2}, T = \frac{T^1 - T_\infty^1}{(T_w^1 - T_\infty^1)}, C = \frac{C^1 - C_\infty^1}{C_w^1 - C_\infty^1} \\ k &= \frac{k^1 u_0^2}{v_0^2},\ p_r = \frac{v}{\alpha}, s_c = \frac{v}{D}, \end{aligned}\right\} \quad (9)$$

In a situation where only one dimensional flow is considered, the above set of equations (1), (2), (8) and (4) are reduced to the following non-dimensional form:

$$\frac{\partial V}{\partial Y} = 0 \Longrightarrow V = -V_0 \ (where\ V_0=1) \quad (10)$$

$$\frac{\partial U}{\partial t} - \frac{\partial U}{\partial Y} = G_r T + GmC + \frac{\partial^2 U}{\partial y^2} - (M + \frac{1}{k})U \quad (11)$$

$$\frac{\partial T}{\partial t} - \frac{\partial T}{\partial Y} = \frac{1}{p_r}(1 + \frac{4}{3N})\frac{\partial^2 T}{\partial Y^2} + QT \quad (12)$$

$$\frac{\partial C}{\partial t} - \frac{\partial C}{\partial Y} = \frac{1}{s_C}\frac{\partial^2 C}{\partial Y^2} - k_r \quad (13)$$

The corresponding initial and boundary conditions are as follows

$$\left.\begin{aligned} &t \le 0, U = 0, T = 0, C = 0\ \forall y \\ &t > 0, U = 1,\ T = 1, C = 1\ at\ Y = 0 \\ &U \to 0, T \to 0, C \to 0\ as\ Y \to \infty \end{aligned}\right\} \quad (14)$$

Solution of The Problem

In order to solve equations (11) - (13) with respect to the boundary conditions (14) for the flow, let us take

$U(y,t) = U_0(y) + U_1(y)\, e^{\omega t}$ (15)

$T(y,t) = T_0(y) + T_1(y)\, e^{\omega t}$ (16)

$C(y,t) = C_0(y) + C_1(y)\, e^{\omega t}$ (17)

Substituting the Equations (15) - (17) in Equations (11) – (13), we obtain:

$$u_0'' + u_o' - (M + \frac{1}{K})\, u_0 = -[\, G_r T_0 + G_m C_0\,] \quad (18)$$

$$u_1'' + u_1' - (M + \frac{1}{K+\omega})\, u_1 = -[\, G_r T_1 + G_m C_1\,] \quad (19)$$

$$T_0'' + T_0^1 K_1\, QTK_1 = 0 \quad (20)$$

$$T_1'' + K_1 T_1' - \omega K_1 T_1 = 0 \quad (21)$$

$$C_0'' + S_c C_0^1 - S_c K_r C_0 = 0 \quad (22)$$

$$C_1'' + S_c C_1^1 - S_c (K_r + \omega) C_1 = 0 \quad (23)$$

where prime denotes ordinary differentiation with respect to y. The corresponding boundary conditions can be written as

$u_0 = 0,\ T_0 = 1, T_1 = 1,\ C_0 = 1,\ C_1 = 0\ at\ y = 0,$ (24)

$u_0 = 0,\ T_0 = 0, T_1 = 0,\ C_0 = 1,\ C_1 = 1\ as\ y \to \infty$

Solving equations (19) – (23) under the boundary conditions (24), we obtain the velocity, temperature and concentration distribution in the boundary layer as:

Solving equations (19) – (23) under the boundary conditions (24) ,we obtain the velocity, temperature and concentration distribution in the boundary layer as:

$U(y,t) = (1 + A_1 + A_2)\, e^{-m_3 y} - A_1\, e^{-m_1 y} - A_2\, e^{-m_2 y}$

$T(y,t) = \quad e^{-m_1 y}$

$C(y,t) = e^{-m_3 y}$

Where $m_1 = \frac{k_1+\sqrt{K_1^2-4QTk_1}}{2}$ $\qquad A_1 = \frac{G_r}{m_1^2-m_1-\left(M+\frac{1}{k}\right)}$

$m_2 = \frac{S_c+\sqrt{S_c^2+4k_r s_c}}{2}$ $\qquad A_2 = \frac{G_m}{m_2^2-m_2-\left(M+\frac{1}{k}\right)}$

$m_3 = \frac{1+\sqrt{1+4(M+\frac{1}{k})}}{2}$ $\qquad A_3 = A_1+A_2$ $\qquad K_1 = \frac{p_r}{1+\frac{4}{3N}}$ $\qquad n_1 = 1+\frac{4}{3N}$

Skin-friction: The dimensionless shearing stress on the surface of a body, due to the fluid motion, is known as skin-friction and is defined by the Newton's law of viscosity. The skin-friction is

$\tau = \left(\frac{\partial U}{\partial y}\right)_{y=0} = -(1+A_1+A_2)m_3+A_1m_1+A_2m_2$

Nusselt number: The rate of heat transfer in terms of nusselt number at the surface is given by $N_u = \left(\frac{\partial T}{\partial y}\right)_{y=0} = -m_1$

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

$S_h = \left(\frac{\partial C}{\partial y}\right)_{y=0} = -m_2$

RESULTS AND DISCUSSION:

In order to study the physical insight in to the problem the effects of various governing parameters on the physical quantities are computed and represented in Figures 1-13 and discussed in detail.

The formulation of the effects of chemical reaction and heat absorption on MHD convective flow and mass transfer of an incompressible, viscous fluid along a semi infinite vertical porous moving plate in a porous medium has been performed in the preceding sections. This enables us to carry out the numerical calculations for the distribution of the velocity, temperature and concentration across the boundary layer for various values of the parameters.

The influence of Magnetic field on the velocity profiles has been studied in Fig .1. It is seen that the increase in the applied magnetic intensity contributes to the decrease in the velocity. Further, it is seen that the magnetic influence does not contribute significantly as we move away from the bounding surface. The influence of the porosity of the boundary on the velocity of the fluid medium has been shown in Fig 2. It is seen that as the porosity of the fluid bed increases, the velocity also increases which is in tune with the realistic situation. Further, the porosity of the boundary does not influence of the fluid motion as we move far away from the bounding surface. The contribution of radiation parameter on the velocity profiles is noticed in Fig.3. It is observed that the radiation parameter increases, the velocity field is an increasing. Further, it is noticed that the velocity decreases as we move away from the plate which is found to be independent of radiation parameter. The effect of Prandtl number on the velocity profiles has been illustrated in Fig.4. It is observed that as the Prandtl number increases, the velocity decreases in general. The dispersion in the velocity profiles is found to be more significant for smaller values of Pr and not that significant at higher values of Prandtl number.

The influence of Schmidt number *Sc* on velocity profiles has been illustrated in Fig.5. It is observed that, while all other participating parameters are held constant and *Sc* is increased, it is seen that the velocity decreases in general. Further, it is noticed that as we move far away from the plate, the fluid velocity goes down. The effect of Grashof number on the velocity profiles as shown in Fig. 6. Increase in *Gr* contributes to an increase in velocity when all other parameters that appear in the velocity field are held constant. Also it is noticed that as we move away from the plate the influence of *Gr* is not that significant. The effect of modified Grashof number *Gc* on the velocity profiles is observed in Fig.7. Increase in *Gc* is found to influence the velocity to increase. Also, it is seen that as we move far away from the plate it is seen that the effect of *Gc* is found to be not that significant. Fig.8 shows that the effect of increasing the chemical reaction parameter on velocity profiles. It is noticed that velocity of flow field are decreasing, as the values of chemical reaction are increasing. The Effect of Prandtl number on the temperature field has been illustrated in Fig.9. It is observed that as the Prandtl number increases, the temperature in the fluid medium decreases. Also, as we move away from the boundary, the Prandtl number has not much of significant influence on the temperature. The dispersion is not found to be significant. Fig.10 illustrates the influence of the radiation parameter on the temperature profiles in the boundary layer. As radiation parameter increases, temperature distributions increase when the other physical parameters are fixed. Fig.11 indicates the effect of heat generation on temperature profiles.as the heat generation increases temperature distributions increase when the other physical parameters are fixed. The influence of Schmidt number on the concentration is illustrated in Fig. 12. It is observed that increase in Sc contributes to decrease of concentration of the fluid medium. Further, it is seen that Sc does not contributes much to the concentration field as we move far away from the bounding surface. Fig.13 shows that the effect of increasing the chemical reaction parameter on concentration profiles. It is noticed that species concentration are decreasing, as the values of chemical reaction are increasing. The effect of chemical reaction on velocity and temperature is less dominant in comparison to concentration. Skin friction for various values of magnetic field strength is portrayed. It is seen that skin friction decreases, as magnetic parameter increases, whereas it is increasing when radiation parameter is increasing.

From Table.1 shows the increase in magnetic field parameter increase in the skin friction, indicates the increase in radiation parameter shows the increase in the skin friction and Nusselt number also shows the increase in Schmidt number shows the increase in sherwood number and Displays the increase in Prandtl number displays the increase in skin friction and Nusselt number And also the Effects of heat generation shows the decrease in skin friction and Nusselt number.

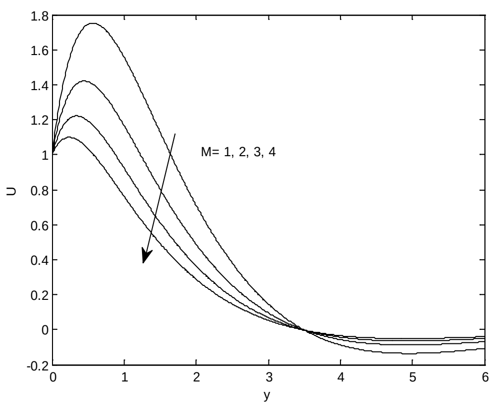

Fig1. Effects of magnetic parameter on velocity Profiles.

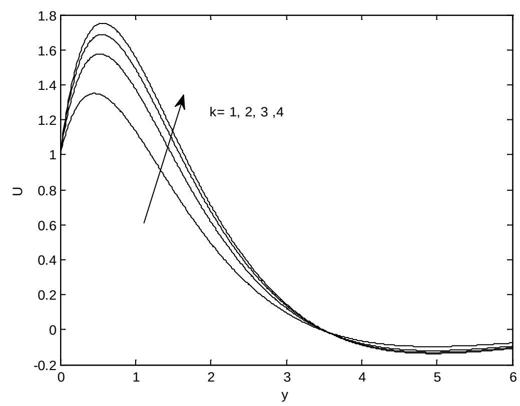

Fig2: Effects of permeability parameter on velocity profiles.

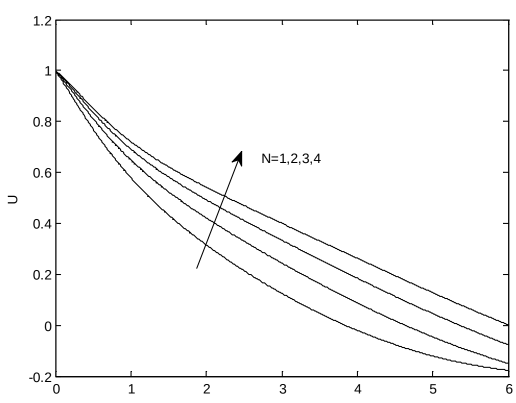

Fig3: Effects of radiation parameter on velocity profiles.

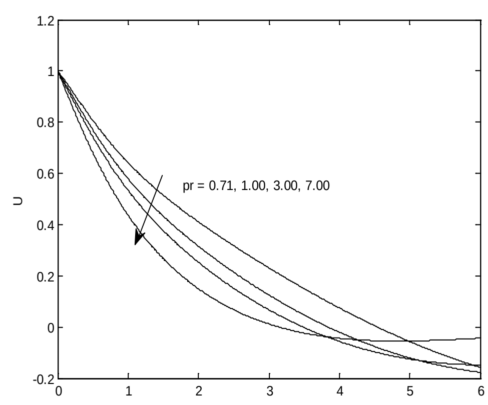

Fig4: Effects of Prandtl number of velocity profiles.

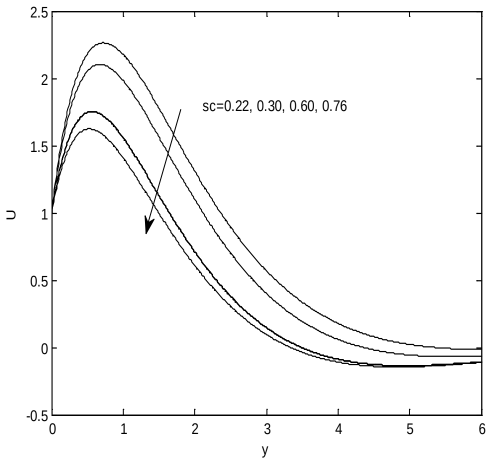

Fig.5: Effects of Schmidt number on velocity profiles.

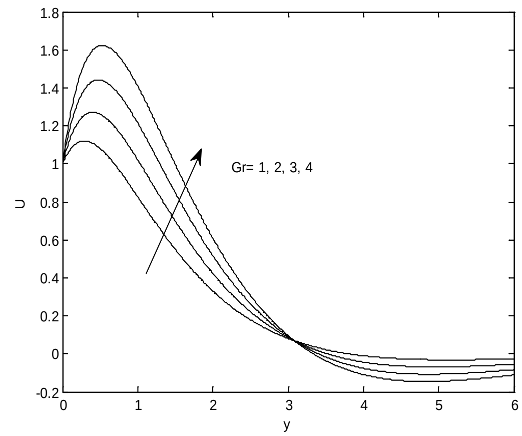

Fig.6: Effects of Grashof number on velocity profiles.

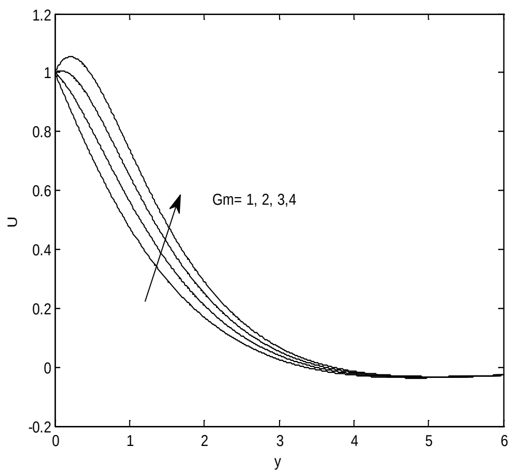

Fig.7: Effects of modified Grashof number on velocity profiles.

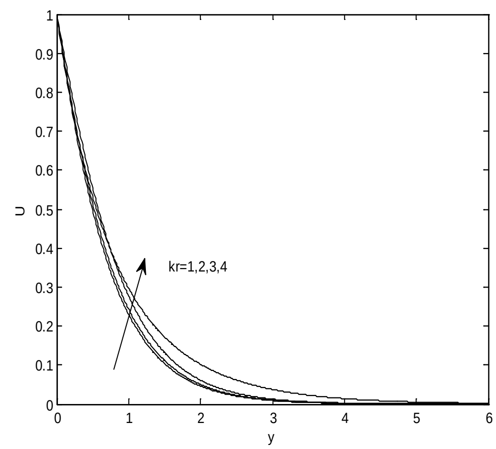

Fig.8: Effects of magnetic parameters on velocity profiles.

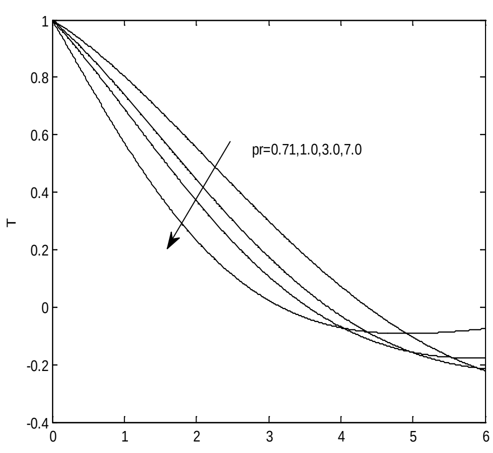

Fig :9 Effects of prandtl number on temperature Profiles.

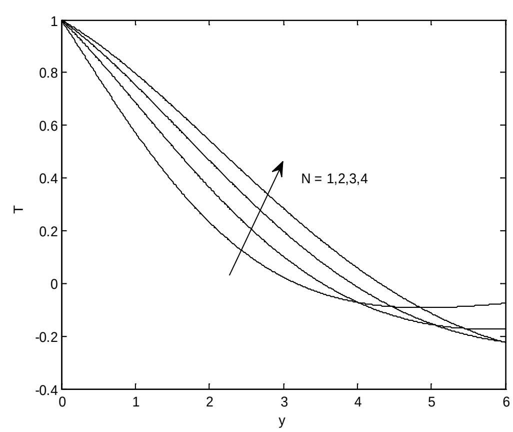

Fig:10 Effects of radiation parameter on temperature Profiles.

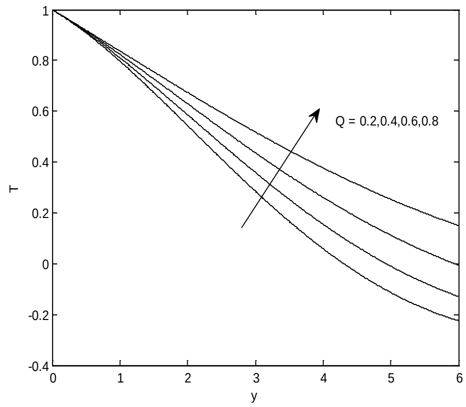

Fig.11: Effects of heat radiation on temperature profiles.

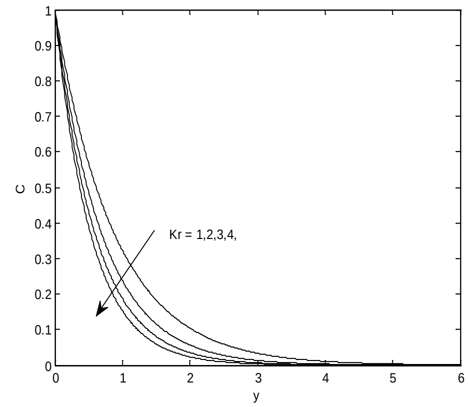

Fig.12: Effects of chemical reaction parameters on concentration profiles.

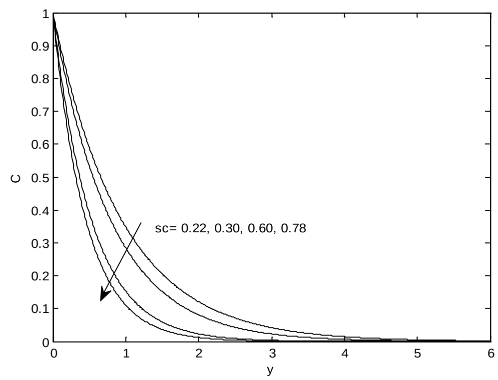

Fig.13: Effects of Schmidt number on concentration profiles.

Table 1: Effects of schmidd number Nusselt number Sharehood Number different values of Gr, Gm, M, Pr, Sc, Kr, N, K.:

Gr	Gm	M	Pr	Sc	Kr	N	K	Cf	Nu	Sh
10	5	10	0.71	0.22	1.0	1.0	1.0	6.1979	-0.1521	-1.3555
2	5	10	0.71	0.22	1.0	1.0	1.0	0.8328	-0.1521	-1.3555
5	5	10	0.71	0.22	1.0	1.0	1.0	2.8447	-0.1521	-1.3555
10	1	10	0.71	0.22	1.0	1.0	1.0	5.2250	-0.1521	-1.3555
10	2	10	0.71	0.22	1.0	1.0	1.0	5.4682	-0.1521	-1.3555
10	2	0.1	0.71	0.22	1.0	1.0	1.0	5.9880	-0.1521	-1.3555
10	2	0.5	0.71	0.22	1.0	1.0	1.0	6.0145	-0.1521	-1.3555
10	2	0.5	0.1	0.22	1.0	1.0	1.0	8.2124	-0.0214	-1.3555
10	2	0.5	0.5	0.22	1.0	1.0	1.0	6.5952	-0.1071	-1.3555
10	2	0.5	0.5	0.1	1.0	1.0	1.0	7.0344	-0.1521	-0.3702
10	2	0.5	0.5	0.2	1.0	1.0	1.0	6.8089	-0.1521	-0.5583
10	2	0.5	0.5	0.2	0.3	1.0	1.0	7.0087	-0.1521	-0.3895
10	2	0.5	0.5	0.2	0.5	1.0	1.0	6.9209	-0.1521	-0.4594
10	2	0.5	0.5	0.2	0.5	0.3	1.0	5.9799	-0.2536	-0.4594
10	2	0.5	0.5	0.2	0.5	0.5	1.0	6.3088	-0.2130	-0.4594
10	2	0.5	0.5	0.2	0.5	0.5	0.3	2.5182	-0.2130	-0.4594
10	2	0.5	0.5	0.2	0.5	0.5	0.5	4.0280	-0.2130	-0.4594

CONCLUSION:

In this paper we considered Unsteady MHD free convective flow past a semi-infinite vertical porous plate with heat generation and chemical reaction. The governing equations for the flow are transformed into a system of non-linear ordinary differential equations are solved by a perturbation technique. The effects of the various parameters on the velocity, temperature, concentration, Schmidt number, Nusselt number skin-friction profiles and heat generation are discussed qualitatively and graphically. It is observed that as the Prandtl number increases, the velocity decreases in general. The dispersion in the velocity profiles is found to be more significant for smaller values of Pr and not that significant at higher values of Prandtl number. . Increase in *Gr* contributes to an increase in velocity when all other parameters that appear in the velocity field are held constant. Also it is noticed that as we move away from the plate the influence of *Gr* is not that significant. . It is noticed that velocity of flow field are decreasing, as the values of chemical reaction are increasing. . It is observed that increase in Sc contributes to decrease of concentration of the fluid medium. Further, it is seen that Sc does not contributes much to the concentration field as we move far away from the bounding surface.

REFERENCES:

1. Elabashbeshy EMA. Heat and mass transfer along a vertical plate with variable temperature and concentration in the presence of magnetic field. International journal of engineering sciences, vol.34,pp.515-522.
2. Chamka AJ . unsteady MHD convective heat and mass transfer past a semi –infinite vertical permeable moving plate with heat absorption. International journal of Engineering sciences, vol.42, pp.217-30.
3. Muthucumaraswamy.R and Meenakshisundaram.S. Theoretical study of chemical reaction effects on vertical oscillating plate with variable temperature. Theoret. Appl. Mech., vol.33, No.3 (2006), pp.245-257.
4. Sharma, P. K. Fluctuating thermal and mass diffusion on unsteady free convective flow past a vertical plate in slip-flow regime, Latin American Applied Research, 35, 313-319,(2005).
5. Anjalidevi, S.P. and R. Kandasamy. Effects of a chemical reaction heat and mass transfer on MHD flow past a semi infinite plate. Z.Angew. Math. Mech.,(2000) 80:697-701.
6. Chaudhary, R. C. and Jha, A. K.,Effects of chemical reactions on MHD micropolar fluid flow past a vertical plate in slip-flow regime, Applied Mathematics and Mechanics, 29 (9), 1179-1194, (2008).
7. Muthucumaraswamy, R. and Chandrakala, P. Radiation heat and mass transfer effects on moving isothermal vertical plate in the presence of chemical reaction. J. of Applied Mechanics and Engineering, vol. 11 NO.3, (2006), pp 639-646.
8. Hossain M.A., Molla M.M. and Yaa L.S. (2004), Natural convection flow along a vertical wary surface temperature in the presence of heat generation/absorption, Int. J. Thermal Science. Vol. 43.pp157-163.
9. Alam M.S., Rahman M.M. and Sattar M.A. (2006) MHD Free convection heatand mass transfer flow past an inclined surface with heat generation, Thamasat. Int.J.J.Sci.Tech. Vol.11 (4).pp.1-8.
10. Chamkha A.J.(2004), Unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption, Int. J.Eng.Sci.Vol.24.pp217- 230.
11. Bala Anki Reddy P and Bhaskar Reddy N (2011), Radiation effects on MHD combined convection and mass transfer flow past a vertical porous plate embedded in a porous medium with heat generation. *Int J . of Appl. Math and Mech* Vol.6(18) pp.33-49.
12. Muthucumaraswamy R. and Ganesan P.(2002), Effects of suction on heat and mass transfer along a moving vertical surface in the presence of chemical reaction, Forsehung Ingemieurwesen, Vol.67,pp.129 -132.
13. Angirasa, D., Peterson, G. P. and Pop, I. Combined heat and mass transfer by natural convection with opposing buoyancy effects in a fluid saturated porous medium, Int. J. Heat Mass Trans., 40(12), 2755-2773,(1997).
14. Ahmed, S. Effects of unsteady free convective MHD flow through a porous medium bounded by an infinite vertical porous plate, Bull.Cal.Math. Soc.,99(5),511-522(2007)
15. Ahmed Sahin. Influence of chemical reaction on transient mhd free Convective flow over a vertical plate in slip-flow Regime. Emirates Journal for Engineering Research, 15 (1), 25-34 (2010).