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First Order Chemical Reaction on Parabolic flow past an Infinite Vertical Plate with Variable Temperature and Mass Diffusion in the Presence of External Magnetic Field and Thermal Radiation

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ABSTRACT: The present paper is on study of the influence of thermal radiation effects on parabolic flow past an impulsively started infinite vertical plate with variable temperature and uniform mass diffusion in the presence of transverse applied magnetic field in the presence of homogeneous chemical reaction is studied. Using the appropriate variables, the basic governing equations are reduced to non-dimensional equations valid with the imposed initial and boundary conditions. The exact solutions are obtained by using Laplace transform technique. A magnetic field of uniform strength is applied normal to the direction to the flow. The numerical computations are carried out for various values of the physical parameters such as velocity, temperature, skin friction, Sherwood number and Nusselt number and presented graphically

KEYWORDS: Radiation, MHD, Homogenous chemical reaction, Heat and Mass Transfer, Vertical Plate.

1 INTRODUCTION

The experimental and theoretical studies of magnetohydrodynamics flows are important from a technological point of view, because they have many applications, as for examples in magnetohydrodynamics electrical power generation and geophysics etc. The influence of a magnetic field on viscous incompressible flow of electrically conducting fluid is of importance in many applications such as extrusion of plastics in the manufacture of Rayon and Nylon, purification of crude oil, magnetic materials processing, glass manufacturing control processes and the paper industry in different geophysical cases etc., In many process industries, the cooling of threads or sheets of some polymer materials is of importance in the production line. Magneto convection plays an important role in various industrial applications including magnetic control of molten iron flow in the steel industry and liquid metal cooling in nuclear reactors.

The heat transfer from different geometries embedded in porous media has many engineering and geophysical applications such as geothermal reservoirs, drying of porous solids, thermal insulation, enhanced oil recovery, packed-bed catalytic reactors, cooling of nuclear reactors, and underground energy transport. A very significant area of research in radiative heat transfer, at the present time is the numerical simulation of combined radiation and convection /conduction transport processes. The effort has arisen largely due to the need to optimize industrial system such as furnaces, ovens and boilers and the interest in our environment and in non-conventional energy sources such as the use of salt-gradient solar ponds for energy collection and storage. In particular, natural convection induced by the simultaneous action of buoyancy forces resulting from thermal diffusion is of considerable interest in nature and in many industrial applications such as geophysics, oceanography, drying processes and solidification of binary alloy. Convective heat transfer in porous media has received considerable attention in recent years owing to its importance in various technological applications such as fibre and granular insulation, electronic system cooling, cool combustors, oil extraction, thermal energy storage and flow through filtering devices, porous material regenerative heat exchangers.

Many transport processes exist in nature and industrial application in which the transfer of heat and mass occurs simultaneously as a result of combined buoyancy effects of thermal diffusion and diffusion of chemical species. In the last few decades several efforts have been made to solve the problems on heat and mass transfer in view of their application to astrophysics, geophysics and engineering. Chemical reaction can be codified either heterogeneous or homogeneous processes. Its effect depends on the nature of the reaction whether the reaction is heterogeneous or homogeneous. A reaction is of order n, if the reaction rate is proportional to the nth power of concentration. In particular, a reaction is of first order, if the rate of reaction is directly proportional to concentration itself. In nature, the presence of pure air or water is not possible. Some foreign mass may be present naturally mixed with air or water. The presence of foreign mass in air or water causes some kind of chemical reaction. The study of such type of chemical reaction processes is useful for improving the number of chemical technologies, such as food processing, polymer production and manufacturing of ceramics or glassware.

MHD effects on impulsively started vertical infinite plate with variable temperature in the presence of transverse magnetic field were studied by Soundalgekar et al. [11]. The effects of transversely applied magnetic field, on the flow of an electrically conducting fluid past an impulsively started infinite isothermal vertical plate were also studied by Soundalgekar et al. [10]. The dimensionless governing equations were solved using Laplace transform technique. The radiative free convection flow of an optically thin gray-gas past semi-infinite vertical plate studied by Soundalgekar and Takhar[12]. Hossain and Takhar have considered radiation effects on mixed convection along an isothermal vertical plate [5]. In all above studies the stationary vertical plate considered. Raptis and Perdikis [9] studied the effects of thermal-radiation and free convection flow past a moving vertical plate. The governing equations were solved analytically. Das et al [4] have considered radiation effects on flow past an impulsively started infinite isothermal vertical plate. The governing equations were solved by the Laplace transform technique. Muthucumaraswamy and Janakiraman [8] have studied MHD and radiation effects on moving isothermal vertical plate with variable mass diffusion. Alam and Sattar [3] have analyzed the thermal diffusion effect on MHD free convection and mass transfer flow. Jha and Singh [6] have studied the importance of the effects of thermal-diffusion (mass diffusion due to temperature gradient). Alam et al[1] studied the thermal-diffusion effect on unsteady MHD free convection and mass transfer flow past an impulsively started vertical porous plate. Recently, Alam et al [2], studied combined free convection and mass transfer flow past a vertical plate with heat generation and thermal-diffusion through porous medium. Rajesh and Varma [13] studied thermal diffusion and radiation effects on MHD flow past a vertical plate with variable temperature and mass diffusion. Recently, Kumar and Varma [14] investigated thermal diffusion and radiation effects on unsteady MHD flow through porous medium with variable temperature and variable mass diffusion.

The aim of the present study is to investigate thermal radiation effects on parabolic flow past an impulsively started infinite vertical plate with variable temperature and uniform mass diffusion in the presence of transverse applied magnetic field in the presence of a homogenous chemical reaction of first order. The dimensionless governing equations are solved using Laplace-transform technique. The solutions for velocity, temperature and concentration fields are derived in terms of exponential and complementary error functions.

2 MATHEMATICAL ANALYSIS

In this paper, we consider a homogeneous first order chemical reaction between the fluid and species concentration to study thermal radiation and the chemical reaction effects on unsteady MHD free convection flow of a viscous incompressible, electrically, conducting, radiating parabolic fluid past an infinite vertical plate with variable temperature in the presence of transverse applied magnetic field. The x'-axis is taken along the plate in vertical upward direction and y-axis is taken normal to it in the direction of applied transverse magnetic field initially, it is assumed that the plate and the surrounding fluid are maintaining a temperature in stationary condition with concentration levels at all the points in entire flow region. At time $t' \leq 0$, the plate and fluid are at the same temperature T_∞ and concentration C'_∞. At time $t' > 0$, the plate is started with a velocity $u = u_0 t'^2$ in its own plane against gravitational field. A magnetic field of uniform strength against to the gravitational field. And at the same time the plate temperature is raised to is assumed to be applied normal to the flow. And at the same time the plate temperature is raised linearly with time t and also the mass is diffused from the plate to the fluid is linearly with time. A transverse magnetic field of uniform strength B_0 is assumed to be applied normal to the plate. The viscous dissipation and induced magnetic field are assumed to be negligible. The fluid considered here is gray, absorbing/emitting radiation but a non-scattering medium. Then under by usual Boussinesq's approximation, the unsteady flow is governed by the following equations.

$$\frac{\partial u}{\partial t'} = g\beta(T - T_\infty) + g\beta^*(C' - C'_\infty) + \nu \frac{\partial^2 u}{\partial y^2} - \frac{\sigma B_0^2}{\rho} u \qquad (1)$$

$$\rho C_p \frac{\partial T}{\partial t'} = k\frac{\partial^2 T}{\partial y^2} - \frac{\partial q_r}{\partial y} \tag{2}$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y^2} - k_l(C' - C'_\infty) \tag{3}$$

With the following initial and boundary conditions:

$$\left.\begin{array}{ll} u = 0, \quad T = T_\infty, \quad C' = C'_\infty & \text{for all } y, t' \le 0 \\ t' > 0: u = u_0 . t'^2, \; T = T_\infty + (T_W - T_\infty)At', \; C' = C'_\infty + (C'_W - C'_\infty)At' & \text{at } \; y = 0 \\ u \to 0 \quad T \to T_\infty, \; C' \to C'_\infty & \text{as } \; y \to \infty \end{array}\right\} \tag{4}$$

Where, $A = \left(\frac{u_0^2}{\nu}\right)^{\frac{1}{3}}$

The local radiant for the case of an optically thin gray gas is expressed by

$$\frac{\partial q_r}{\partial y} = -4a^*\,\sigma(T_\infty^4 - T^4) \tag{5}$$

It is assumed that the temperature differences with in the flow are sufficiently small such that T^4 may be expressed as a linear function of the temperature. This is accomplished by expanding T^4 in a Taylor series about T_∞ and neglecting higher-order terms, thus

$$T^4 \cong 4T_\infty^3\,T - 3T_\infty^4 \tag{6}$$

By using equations (5) and (6), equation (2) reduces to

$$\rho\, C_p \frac{\partial T}{\partial t'} = k\frac{\partial^2 T}{\partial y^2} + 16\,a^*\sigma T_\infty^3\,(T_\infty - T) \tag{7}$$

On introducing the following non-dimensional quantities:

$$\left.\begin{array}{l} U = u\left(\frac{u_0}{\nu^2}\right)^{1/3}, \; t = \left(\frac{u_0{}^2}{\nu}\right)^{1/3} t', \quad Y = y\left(\frac{u_0}{\nu^2}\right)^{1/3}, \theta = \frac{T - T_\infty}{T_w - T_\infty}, \; C = \frac{C' - C'_\infty}{C'_w - C'_\infty}, Gr = \frac{g\beta(T_w - T_\infty)}{(\nu . u_0)^{1/3}}, \\ Gc = \frac{g\beta(C'_w - C'_\infty)}{(\nu . u_0)^{1/3}}, \; R = \frac{16a^*\sigma . T_\infty{}^3}{k}\left(\frac{\nu^2}{u_0}\right)^{\frac{2}{3}}, K = K_l\left(\frac{\nu}{u_0^2}\right)^{\frac{1}{3}}, M = \frac{\sigma B_0^2}{\rho}\left(\frac{\nu}{u_o^2}\right)^{\frac{1}{3}}, \Pr = \frac{\mu C_p}{k}, \; Sc = \frac{\nu}{D} \end{array}\right\} \tag{8}$$

The equations (1),(3) and (7) reduces to the following dimensionless form

$$\frac{\partial U}{\partial t} = Gr\theta + GcC + \frac{\partial^2 U}{\partial Y^2} - MU \tag{9}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial Y^2} - \frac{R}{\Pr}\theta \tag{10}$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial Y^2} - KC \tag{11}$$

The corresponding initial and boundary conditions in the dimensionless form are as follows

$$\left.\begin{array}{ll} U=0, \quad \theta=0, \quad C=0 & \text{for all } Y,t\le 0 \\ t>0: \quad U=t^2, \quad \theta=t, \quad C=t & \text{at } \quad Y=0 \\ U\to 0, \quad \theta\to 0, \quad C\to 0 & \text{as } \quad Y\to\infty \end{array}\right\} \tag{12}$$

3 SOLUTION OF THE PROBLEM

The appeared physical parameters are defined in the nomenclature. The dimensionless governing equations from (9) to (11), subject to the boundary conditions (12) are solved by usual Laplace transform technique and the solutions are expressed in terms of exponential and complementary error functions.

$$\theta = \frac{t}{2}\left[\exp\left(2\eta\sqrt{\Pr a t}\right)erfc\left(\eta\sqrt{\Pr}+\sqrt{at}\right)+\exp\left(-2\eta\sqrt{\Pr a t}\right)erfc\left(\eta\sqrt{\Pr}-\sqrt{at}\right)\right]$$
$$-\frac{\eta\sqrt{\Pr}\sqrt{t}}{2\sqrt{a}}\left[\exp\left(-2\eta\sqrt{\Pr a t}\right)erfc\left(\eta\sqrt{\Pr}-\sqrt{at}\right)-\exp\left(2\eta\sqrt{\Pr a t}\right)erfc\left(\eta\sqrt{\Pr}+\sqrt{at}\right)\right] \tag{13}$$

$$C = \frac{t}{2}\left[\exp\left(2\eta\sqrt{Sc K t}\right)erfc\left(\eta\sqrt{Sc}+\sqrt{Kt}\right)+\exp\left(-2\eta\sqrt{Sc K t}\right)erfc\left(\eta\sqrt{Sc}-\sqrt{Kt}\right)\right]$$
$$-\frac{\eta\sqrt{Sc}\sqrt{t}}{2\sqrt{K}}\left[\exp\left(-2\eta\sqrt{Sc K t}\right)erfc\left(\eta\sqrt{Sc}-\sqrt{Kt}\right)-\exp\left(2\eta\sqrt{Sc K t}\right)erfc\left(\eta\sqrt{Sc}+\sqrt{Kt}\right)\right] \tag{14}$$

$$U = 2\left[\begin{array}{l}\frac{\left(\eta^2+Mt\right)t}{4M}\left[\exp\left(2\eta\sqrt{Mt}\right)erfc\left(\eta+\sqrt{Mt}\right)+\exp\left(-2\eta\sqrt{Mt}\right)erfc\left(\eta-\sqrt{Mt}\right)\right] \\ +\frac{\eta\sqrt{t}\,(1-4Mt)}{8M^{3/2}}\left[\exp\left(-2\eta\sqrt{Mt}\right)erfc\left(\eta-\sqrt{Mt}\right)-\exp\left(2\eta\sqrt{Mt}\right)erfc\left(\eta+\sqrt{Mt}\right)\right]-\frac{\eta t}{2M\sqrt{\pi}}\exp(-(\eta^2+Mt)\end{array}\right]$$
$$+d\left(\frac{1}{2}\left[\exp\left(2\eta\sqrt{Mt}\right)erfc\left(\eta+\sqrt{Mt}\right)+\exp\left(-2\eta\sqrt{Mt}\right)erfc\left(\eta-\sqrt{Mt}\right)\right]\right.$$
$$-\frac{\exp(bt)}{2}\left[\exp\left(2\eta\sqrt{(M+b)t}\right)erfc\left(\eta+\sqrt{(M+b)t}\right)+\exp\left(-2\eta\sqrt{(M+b)t}\right)erfc\left(\eta-\sqrt{(M+b)t}\right)\right]$$
$$-\frac{1}{2}\left[\exp\left(2\eta\sqrt{\Pr a t}\right)erfc\left(\eta\sqrt{\Pr}+\sqrt{at}\right)+\exp\left(-2\eta\sqrt{\Pr a t}\right)erfc\left(\eta\sqrt{\Pr}-\sqrt{at}\right)\right]$$
$$\left.+\frac{\exp(bt)}{2}\left[\exp\left(2\eta\sqrt{\Pr(a+b)t}\right)erfc\left(\eta\sqrt{\Pr}+\sqrt{(a+b)t}\right)+\exp\left(-2\eta\sqrt{\Pr(a+b)t}\right)erfc\left(\eta\sqrt{\Pr}-\sqrt{(a+b)t}\right)\right]\right)$$
$$+e\left(\frac{1}{2}\left[\exp\left(2\eta\sqrt{Mt}\right)erfc\left(\eta+\sqrt{Mt}\right)+\exp\left(-2\eta\sqrt{Mt}\right)erfc\left(\eta-\sqrt{Mt}\right)\right]\right.$$
$$-\frac{\exp(ct)}{2}\left[\exp\left(2\eta\sqrt{(M+c)t}\right)erfc\left(\eta+\sqrt{(M+c)t}\right)+\exp\left(-2\eta\sqrt{(M+c)t}\right)erfc\left(\eta-\sqrt{(M+c)t}\right)\right]$$
$$-\frac{1}{2}\left[\exp\left(2\eta\sqrt{Sc K t}\right)erfc\left(\eta\sqrt{Sc}+\sqrt{Kt}\right)+\exp\left(-2\eta\sqrt{Sc K t}\right)erfc\left(\eta\sqrt{Sc}-\sqrt{Kt}\right)\right]$$
$$\left.+\frac{\exp(ct)}{2}\left[\exp\left(2\eta\sqrt{Sc(K+c)t}\right)erfc\left(\eta\sqrt{Sc}+\sqrt{(K+c)t}\right)+\exp\left(-2\eta\sqrt{Sc(K+c)t}\right)erfc\left(\eta\sqrt{Sc}-\sqrt{(K+c)t}\right)\right]\right)$$
$$+d\left(b\left(\frac{t}{2}\left[\exp\left(2\eta\sqrt{Mt}\right)erfc\left(\eta+\sqrt{Mt}\right)+\exp\left(-2\eta\sqrt{Mt}\right)erfc\left(\eta-\sqrt{Mt}\right)\right]\right.\right.$$

$$-\frac{\eta\sqrt{t}}{2\sqrt{M}}\left[\exp\left(-2\eta\sqrt{Mt}\right)erfc\left(\eta-\sqrt{Mt}\right)-\exp\left(2\eta\sqrt{Mt}\right)erfc\left(\eta+\sqrt{Mt}\right)\right]$$

$$-\frac{t}{2}\left[\exp\left(2\eta\sqrt{\Pr at}\right)erfc\left(\eta\sqrt{\Pr}+\sqrt{at}\right)+\exp\left(-2\eta\sqrt{\Pr at}\right)erfc\left(\eta\sqrt{\Pr}-\sqrt{at}\right)\right]$$

$$+\frac{\eta\sqrt{\Pr}\sqrt{t}}{2\sqrt{a}}\left[\exp\left(-2\eta\sqrt{\Pr at}\right)erfc\left(\eta\sqrt{\Pr}-\sqrt{at}\right)-\exp\left(2\eta\sqrt{\Pr at}\right)erfc\left(\eta\sqrt{\Pr}+\sqrt{at}\right)\right]\Bigg)\Bigg)$$

$$+e\Bigg(c\Bigg(\frac{t}{2}\left[\exp\left(2\eta\sqrt{Mt}\right)erfc\left(\eta+\sqrt{Mt}\right)+\exp\left(-2\eta\sqrt{Mt}\right)erfc\left(\eta-\sqrt{Mt}\right)\right]$$

$$-\frac{\eta\sqrt{t}}{2\sqrt{M}}\left[\exp\left(-2\eta\sqrt{Mt}\right)erfc\left(\eta-\sqrt{Mt}\right)-\exp\left(2\eta\sqrt{Mt}\right)erfc\left(\eta+\sqrt{Mt}\right)\right]$$

$$-\frac{t}{2}\left[\exp\left(2\eta\sqrt{ScKt}\right)erfc\left(\eta\sqrt{Sc}+\sqrt{Kt}\right)+\exp\left(-2\eta\sqrt{ScKt}\right)erfc\left(\eta\sqrt{Sc}-\sqrt{Kt}\right)\right]$$

$$+\frac{\eta\sqrt{Sc}\sqrt{t}}{2\sqrt{K}}\left[\exp\left(-2\eta\sqrt{ScKt}\right)erfc\left(\eta\sqrt{Sc}-\sqrt{Kt}\right)-\exp\left(2\eta\sqrt{ScKt}\right)erfc\left(\eta\sqrt{Sc}+\sqrt{Kt}\right)\right] \quad (15)$$

Where $a=\frac{R}{\Pr}$, $b=\frac{R-M}{1-\Pr}$, $c=\frac{ScK-M}{1-Sc}$, $d=\frac{Gr}{b^2(1-\Pr)}$, $e=\frac{Gc}{c^2(1-Sc)}$ and $\eta=\frac{y}{2\sqrt{t}}$

3.1 NUSSELT NUMBER

From temperature field, now we study Nusselt number (rate of change of heat transfer) which is given in non-dimensional form as

$$Nu=-\left(\frac{\partial\theta}{\partial y}\right)_{y=0} \quad (16)$$

From equations (13) and (16), we get Nusselt number as follows

$$Nu=t\left[\sqrt{R}\,erf(\sqrt{at})+\frac{\sqrt{\Pr}}{\sqrt{\pi t}}e^{-at}\right]+\frac{\sqrt{\Pr}}{2\sqrt{a}}erf(\sqrt{at})$$

3.2 SHERWOOD NUMBER

From concentration field, now we study Sherwood number (rate of change of mass transfer) which is given in non-dimensional form as

$$Sh=-\left(\frac{\partial C}{\partial y}\right)_{y=0} \quad (17)$$

From equations (14) and (17), we get Sherwood number as follows

$$Sh=t\left[\sqrt{ScK}\,erf(\sqrt{Kt})+\frac{\sqrt{Sc}}{\sqrt{\pi t}}e^{-Kt}\right]+\frac{\sqrt{Sc}}{2\sqrt{K}}erf(\sqrt{at})$$

3.3 SKIN-FRICTION

Now we study skin-friction from velocity field. It is given in non-dimensional form as

$$\tau=-\left(\frac{\partial U}{\partial y}\right)_{y=0} \quad (18)$$

From equations (15) and (18), we get skin-friction as follows:

$$\tau = \left(t^2 + 2B + 2D + 2At - 2Ct\right)\left[\sqrt{M}\, erf(\sqrt{Mt}) + \frac{1}{\sqrt{\pi t}} e^{-Mt}\right] - \left[\frac{1}{4M\sqrt{M}} - \frac{t}{\sqrt{M}} + \frac{A}{2\sqrt{M}} + \frac{C}{2\sqrt{M}}\right] erf(\sqrt{Mt}) + \frac{\sqrt{t}}{2M\sqrt{\pi}} e^{-Mt}$$

$$-2De^{ct}\left[\left(\sqrt{M+c}\right) erf\left(\sqrt{(M+c)t}\right) + \frac{1}{\sqrt{\pi t}} e^{-(M+c)t}\right] -2Be^{bt}\left[\left(\sqrt{M+b}\right) erf\left(\sqrt{(M+b)t}\right) + \frac{1}{\sqrt{\pi t}} e^{-(M+b)t}\right]$$

$$-(2B + 2At)\left[\sqrt{R}\, erf(\sqrt{at}) + \frac{\sqrt{\Pr}}{\sqrt{\pi t}} e^{-at}\right] - \frac{A\sqrt{\Pr}}{2\sqrt{a}} erf(\sqrt{at}) + 2Be^{bt}\left[\left(\sqrt{\Pr(a+b)}\right) erf\left(\sqrt{(a+b)t}\right) + \frac{\sqrt{\Pr}}{\sqrt{\pi t}} e^{-(a+b)t}\right]$$

$$-(2D + 2Ct)\left[\sqrt{ScK}\, erf(\sqrt{Kt}) + \frac{\sqrt{Sc}}{\sqrt{\pi t}} e^{-Kt}\right] - \frac{C\sqrt{Sc}}{2\sqrt{K}} erf(\sqrt{Kt}) + 2De^{ct}\left[\left(\sqrt{Sc(K+c)}\right) erf\left(\sqrt{(K+c)t}\right) + \frac{\sqrt{Sc}}{\sqrt{\pi t}} e^{-(K+c)t}\right]$$

Where $a = \frac{R}{\Pr}$, $b = \frac{R-M}{1-\Pr}$, $c = \frac{ScK-M}{1-Sc}$, $A = \frac{Gr}{2b(1-\Pr)}$, $B = \frac{Gr}{2b^2(1-\Pr)}$, $C = \frac{Gc}{2c(1-Sc)}$ $D = \frac{Gc}{2c^2(1-Sc)}$

4 RESULTS AND DISCUSSION

For physical understanding of the problem numerical computations are carried out for different parameters depends upon the nature of the flow and transport. The value of the Schmidt number Sc is taken to be 0.6 which corresponds to water vapor. Also, the values of Prandtl number Pr are chosen such that they represent air (Pr = 0.71).We have plotted velocity profiles for different values of the physical parameters M(Magnetic field parameter), R(Radiation parameter), K(Chemical reaction parameter), Pr(Prandtl number), Sc(Schmidt number) and t(time) in Figure.1 to Figure.6 for the case of cooling of the plate (Gr > 0, Gc > 0) and heating of the plate (Gr < 0, Gc < 0). The heating and cooling take place by setting up free convection current due to concentration gradient and temperature gradient.

Figure.1 & Figure.2 illustrate the influences of M(Magnetic field parameter) and K (chemical reaction parameter) on the velocity field in cases of cooling and heating of the plate at time t = 0.4 & t = 0.2 respectively. It is found that with the amplification of magnetic field parameter and chemical reaction parameter the velocity diminishes for cooling of the plate but a reverse effect is noticed in the case of heating of the plate. Magnetic field lines act as a string to retard the motion of the fluid are free convection flow as the consequence the rate of heat transfer increases.

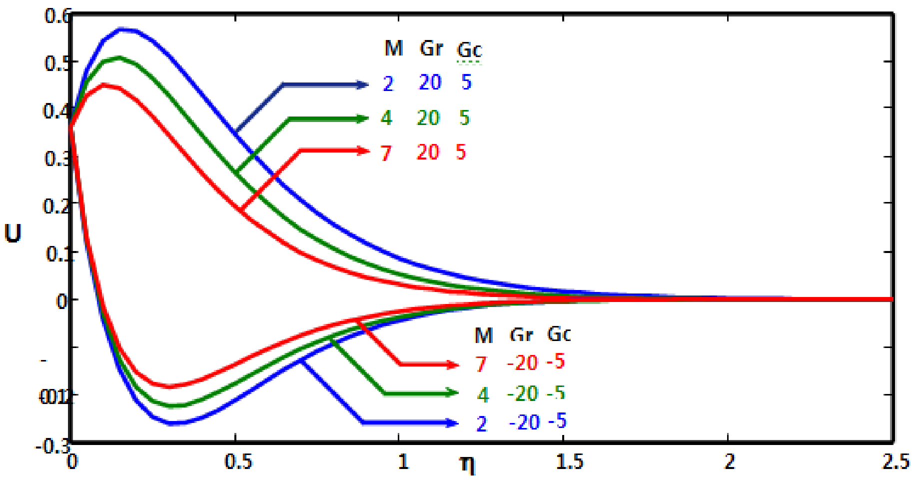

Fig.1. Velocity profiles for different Values of M at t=0.6

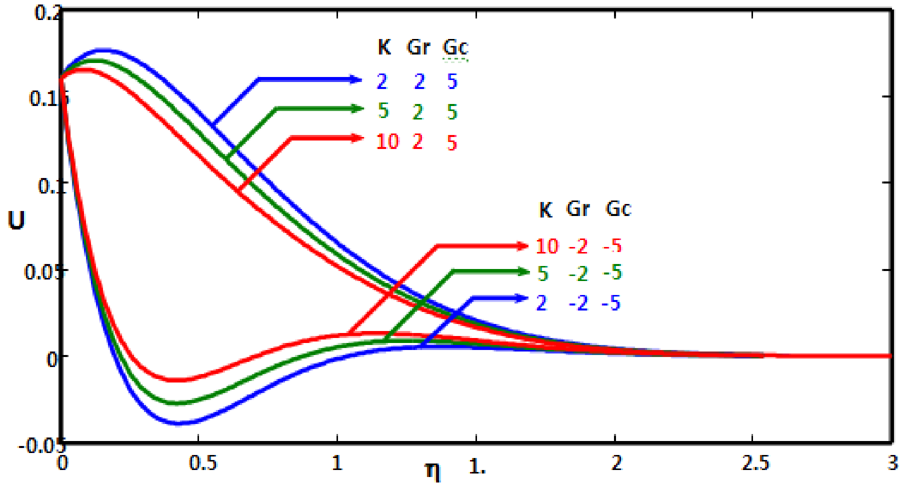

Fig.2. Velocity profiles for different values of K at t=0.4

From Figure.3 & Figure.4, it is observed that with the extension of R (Radiation parameter), Sc (Schmidt number) the velocity distends in the case of cooling of the plate but a reverse effect is noticed in the case of heating of the plate.

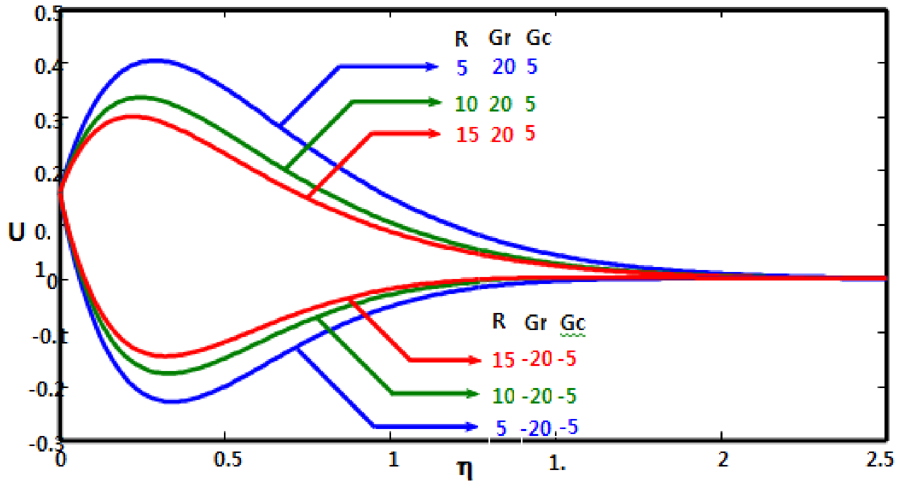

Fig.3. Velocity profiles for different values of R at t =0.4

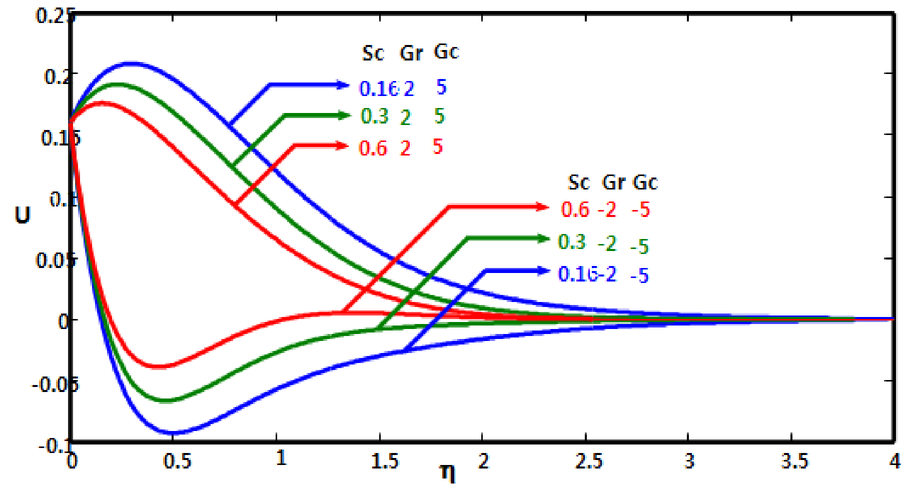

Fig.4. Velocity profiles for different values of Sc at t=0.4

Figure.5 reveals the velocity variation with time t for the cases of both cooling and heating. From this we observed that the velocity augments as time *t* increase for the case of cooling and the trend is just reversed for the case of heating of the plate.

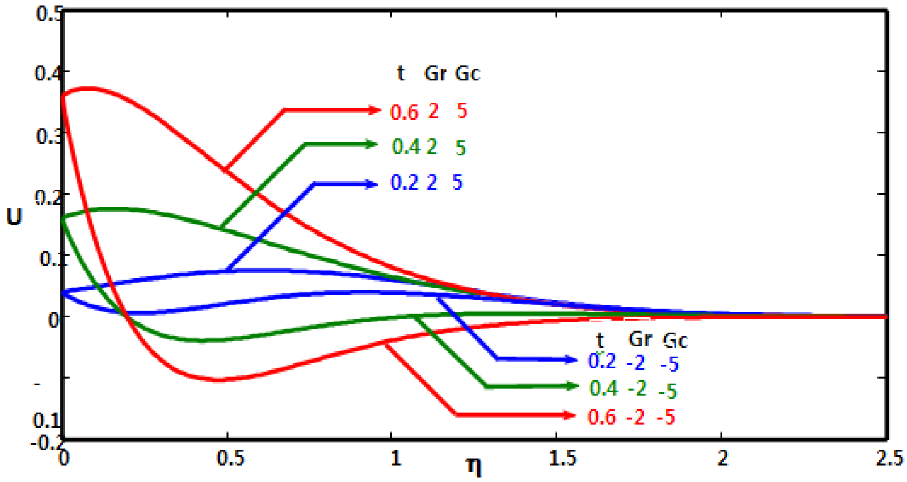

Fig.5. Velocity profiles for different values of t

In Figure.6, we depict the effects of Prandtl number Pr on the velocity field. It is observed that an amplification in the Prandtl number leads to decrease in the velocity and the trend is just reversed for the case of heating of the plate.

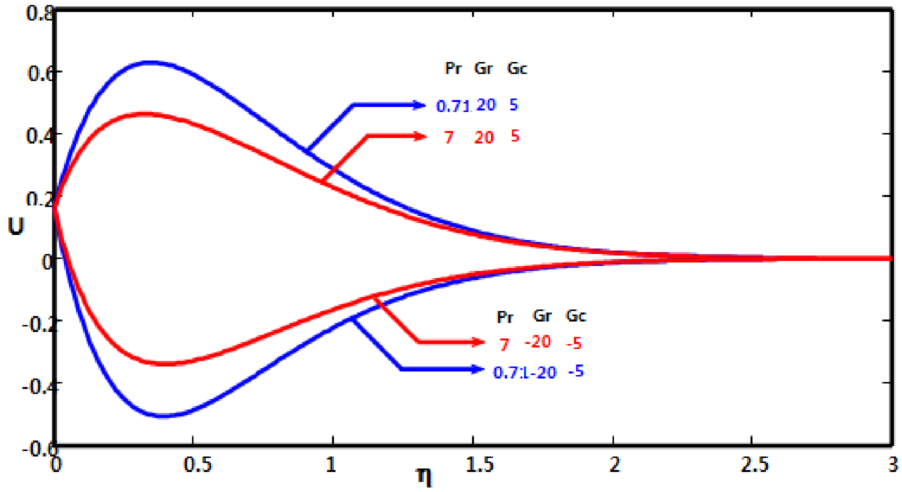

Fig.6. Velocity profiles for different values of Pr at t =0.4

Figure.7 is a graphical representation which depicts the concentration profiles for different values of Sc at t=0.2 and t=0.4. It is clear that the wall concentration lowers with heightened value of Sc (Schmidt number).

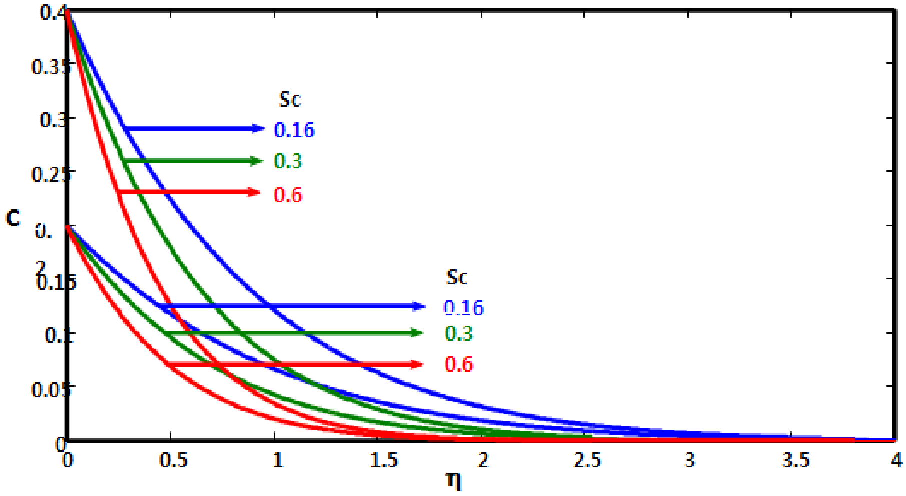

Fig.7. Concentration profiles for different values of Sc at t=0.2 and t=0.4

Figure.8 represents the effect of temperature profiles of different time t in the presence of water vapor. The trend shows that the temperature increasing with increasing value of time t.

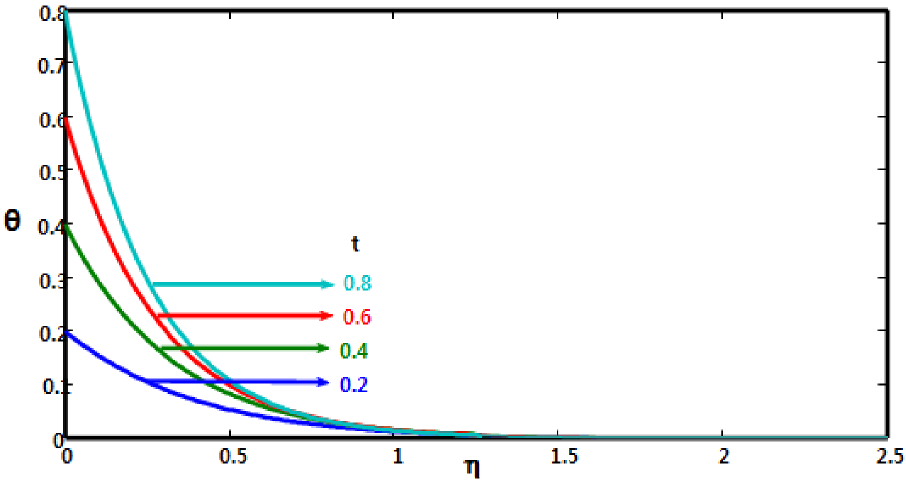

Fig.8. Temperature profiles for different values of t

Figure.9 explains that the Nusselt number increases with decreasing value of Pr (Prandtl number) at time.Figure.10 shows that Sherwood number increases as increasing value of Sc (Schmidt number).

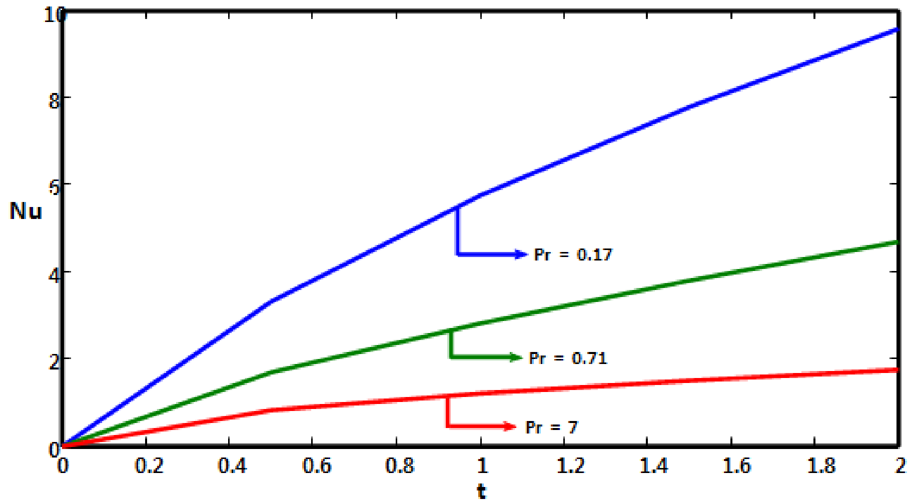

Fig.9. Nusselt Number for different values of Pr

The Skin friction is presented in the table.1 and table.2. From these tables we conclude that the Skin friction heightens with an increase Sc, but lowers with increase Pr and M. Also that skin friction reduced with decrease R and K for cooling of the plate. But the reverse effect is observed in the case of heating of the plate. Again it is found that the Skin friction amplifies in case of cooling of the plate and diminishes in case of heating with an increase in t of the plate.

Table-1(Skin friction for cooling of the plate)

Pr	Sc	M	R	K	Gr	Gc	t	τ
0.71	0.16	2	10	5	2	5	0.2	2.5073
7	0.16	2	10	5	2	5	0.2	1.2013
0.71	0.6	2	10	5	2	5	0.2	3.2412
0.71	0.16	5	10	5	2	5	0.2	0.8860
0.71	0.16	2	5	5	2	5	0.2	1.4399
0.71	0.16	2	10	2	2	5	0.2	1.7014
0.71	0.16	2	10	5	2	5	0.4	7.1694

Table-2(Skin friction for heating of the plate)

Pr	Sc	M	R	K	Gr	Gc	t	τ
0.71	0.16	2	10	5	-2	-5	0.2	-1.2391
7	0.16	2	10	5	-2	-5	0.2	0.0669
0.71	0.6	2	10	5	-2	-5	0.2	-1.9730
0.71	0.16	5	10	5	-2	-5	0.2	0.8730
0.71	0.16	2	5	5	-2	-5	0.2	-0.1717
0.71	0.16	2	10	2	-2	-5	0.2	-0.4332
0.71	0.16	2	10	5	-2	-5	0.4	-5.3656

5 Conclusion

In this paper, the behavior of thermal radiation effects on parabolic flow past an impulsively started infinite vertical plate with variable temperature and uniform mass diffusion in the presence of transverse applied magnetic field in the presence of homogeneous chemical reaction is studied. Some important conclusions that can be obtained from the graphical results are:

- Velocity decreases with increasing values of chemical reaction parameter,
- Velocity decreases with increasing values of radiation parameter
- Temperature increasing with increasing time.

- Skin friction is reduced with decreasing radiation parameter.
- Nusselt number is greater with decreasing Prandtl number.

NOMENCLATURE

A Constants
C' species concentration in the fluid $kg\,m^{-3}$
C dimensionless concentration
C_p specific heat at constant pressure $J.kg^{-1}.k$
D mass diffusion coefficient $m^2.s^{-1}$
Gc mass Grashof number
Gr thermal Grashof number
g acceleration due to gravity $m.s^{-2}$
k thermal conductivity $W.m^{-1}.K^{-1}$
Pr Prandtl number
Sc Schmidt number
T temperature of the fluid near the plate K
t' time s
u velocity of the fluid in the x'-direction $m.s^{-1}$
u_0 velocity of the plate $m.s^{-1}$
u dimensionless velocity
y coordinate axis normal to the plate m
Y dimensionless coordinate axis normal to the plate

Greek symbols

β volumetric coefficient of thermal expansion K^{-1}
β^* volumetric coefficient of expansion with concentration K^{-1}
μ coefficient of viscosity $Ra.s$
ν kinematic viscosity $m^2.s^{-1}$
ρ density of the fluid $kg.m^{-3}$
τ dimensionless skin-friction $kg.m^{-1}.s^2$
θ dimensionless temperature
η similarity parameter
$erfc$ complementary error function

Subscripts

w conditions at the wall
∞ free stream conditions

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