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Chemical Reacgtion Effects On Unsteady Magneto Hydrodynamic Convctive Flow Through A Porous Medium In The Prasence Of Heat Generation

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ABSTRACT:

In this analysis, unsteady free convection flow of an electrically conducting fluid past an exponentially accelerated infinite vertical plate with constant heat flux through a porous medium is examined under the influence of uniform magnetic field fixed to the fluid or to the plate in the presence of chemical reaction and heat generation or absorption. The governing partial differential equations have been solved analytically with the aid of Laplace transform technique and the expression for the velocity, temperature and concentration were obtained. Results are presented to illustrate the influence of system parameters such as magnetic parameter, heat generation or absorption parameter, permeability parameter, Prandtl number, Grashof number, modified Grashof number, chemical reaction parameter.

Key words: MHD, porous medium, chemical reaction, heat generation or absorption etc.

INTRODUCTION:

The study of convection heat and mass transfer phenomenon through porous media has played a significant role due to its important and engineering applications. Underground spreading of chemical wastes and other pollutants, gram storage, evaporation cooling and solidification are the flow other applications areas where the combined thermosolutal convection in porous media is investigated. References of complete literature surveys regarding the subject of porous media can be had in most recent books by Ingham and Pop (1), Neild and Bejan (2), Vafai (3), Pop and Ingham (4) and Ingham et al. (5). Bejan and Khair (6) studied the heat and mass transfer by natural convection in porous medium.

The problem of magnetohydrodynamics (MHD) convective flow in a porous medium have drawn considerable attention of several researchers owing to its importance in various scientific and technological applications. (7-9).

The study of heat generation/absorption effects in moving fluids is important in view of several physical problems, such as fluids undergoing chemical reaction with exothermic or endothermic. Due to the important applications in electronic technology effective cooling of electronic equipment has become warranted. The cooling of electronic equipment ranges from individual transistors to main frame computers, from energy suppliers to telephone switch boards and thermal diffusion effects has been utilized for isotopes separation in the mixture between gases with vary light molecule weight (hydrogen and helium) and medium molecular weight.

Vajravelu (10) studied the natural convection at a heated semi-infinite vertical plate with internal heat generation. Crpeass and Clarksean (11) discussed the similarity solution of natural convection with internal heat generation. Narahari and Debnath (12) analyzed the unsteady magnetohydrodynamic free convection flow past an accelerated vertical plate with constant heat flux and heat generation or absorption. Chamka (13) investigated unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat generation. Sharma et al. (14) examined heat and mass transfer effects on unsteady MHD free convective flow along a vertical porous plate with internal heat generation and variable suction. Jha and Prasad (15) contributed the MHD free convection and mass transfer flow through porous medium with heat source. Sharma and Sharma (16) studied the effect oscillatory suction and heat source on heat and mass transfer in MHD flow along a vertical moving porous plate bounded by porous medium.

The study of heat and mass transfer to chemical reacting MHD free convection past a vertical plate through porous medium has received a growing interest during the last decays. Gireesh Kumar et al. (17) pointed out the effects of chemical reaction and mass transfer on MHD unsteady free convection flow past an infinite vertical plate with constant suction and heat sink. Tripathy et al. (18) studied the chemical reaction effect on MHD free convective surface over a moving vertical plate through porous medium.

Moreover, the unsteady free convection flow of an electrically conducting fluid past an exponentially accelerated infinite vertical plate with constant heat flux through a porous medium is examined under the influence of uniform magnetic field fixed to the fluid or to the plate in the presence of chemical reaction reaction and heat generation or absorption is analyzed. The governing coupled linear partial differential equations are solved analytically using the Laplace transform technique. The present problem finds typical applications in aeronautics spacecraft design and the study of the thermal plumes into atmosphere which are responsible for atmospheric pollution.

FORMULATION OF THE PROBLEMS:

Consider the unsteady free convection flow of an electrically conducting fluid past an exponentially accelerated infinite vertical plate with constant heat flux through a porous medium is examined under the influence of uniform magnetic field fixed to the fluid or to the plate in the presence of chemical reaction and heat generation or absorption. The x'- axis is taken along the plate in the upward direction and the y'- axis perpendicular to the plate into the fluid by choosing an arbitrary point on this plate as the origin. A uniform magnetic field of strength B_0 is applied in the horizontal direction that is in the y' - direction. Initially, at time $t' \le 0$, the plate and the fluid are at rest and at the same temperature $T_\infty^{'}$ and the concentration $C_\infty^{'}$. At time $t' > 0$, suddenly the pate accelerated with velocity $u_0 f(t')$ in its own plane along the x' - axis against the gravitational field and heat is supplied to the plate at a constant rate in the presence of temperature dependent heat generation (or absorption). All the physical properties of the fluid are assumed to be constant except the density variations with temperature in the body force term. The magnetic Reynolds number of the flow is assumed to be small so that the induced magnetic field is neglected in comparison with applied magnetic field (B_0). As the plate is infinite extent in x' direction, all the physical quantities are functions of the space coordinate y' and time t' only and therefore the inertia terms are negligible. Then under usual Boussinesq's approximation, neglecting viscous dissipation and Joule heating in the energy equation, the flow can be shown to be governed by the following system of equations:

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

$$\rho C_p \frac{\partial T'}{\partial t'} = \kappa \frac{\partial^2 T'}{\partial y'^2} - Q'\left(T' - T_\infty^{'}\right) \tag{2}$$

$$\frac{\partial C'}{\partial t'} = D \frac{\partial^2 C'}{\partial y'^2} - K_r^{'}\left(C' - C_\infty^{'}\right) \tag{3}$$

where u', T' and C' are velocity, temperature and concentration of the fluid, respectively, g is acceleration due to gravity, β is thermal expansion coefficient, β^* is concentration expansion coefficient, ν is kinematic viscosity, ρ is density, σ is electrical conductivity, C_p is specific heat at constant pressure, κ is thermal conductivity, and Q' is dimensional heat generation (or absorption) coefficient, D is mass diffusivity, $K_r^{'}$ is rate of chemical reaction, k' is permeability coefficient of porous medium. Equation (1) is valid when the magnetic lines of force are fixed relative to the fluid. If the magnetic field relative to the plate, the momentum equations (1) is replaced by (sec [7, 8, 19])

$$\frac{\partial u'}{\partial t'} = \nu \frac{\partial^2 u'}{\partial y'^2} + g\beta\left(T' - T_\infty^{'}\right) + g\beta^*\left(C' - C_\infty^{'}\right) - \frac{\sigma B_0^2}{\rho}\left[u' - u_0 f\left(t'\right)\right] - \frac{\nu}{k'} u' \tag{4}$$

Note that the velocity $u_0 f\left(t'\right)$ of magnetic field B_0 in equation (4) appears because of the magnetic lines of force are fixed relative to the plate, which accelerates with velocity $u_0 f\left(t'\right)$. Equations (1) and (4) can be combined as

$$\frac{\partial u'}{\partial t'}=\nu\frac{\partial^2 u'}{\partial y'^2}+g\beta\left(T'-T'_\infty\right)+g\beta^*\left(C'-C'_\infty\right)-\frac{\sigma B_0^2}{\rho}\left[u'-Ku_0\,f\left(t'\right)\right]-\frac{\nu}{k'}u' \qquad (5)$$

Where $K=\begin{cases}0 & if\ B_0\ is\ fixed\ relative\ to\ the\ fluid\\ 1 & if\ B_0\ is\ fixed\ relative\ to\ the\ plate\end{cases}$

The corresponding initial and boundary conditions are

$$t'\le 0:\quad u'=0,\quad T'=T'_\infty,\quad C'=C'_\infty\quad for\ all\ y'\ge 0$$

$$t'>0:\begin{cases}u'=u_0\,f\left(t'\right),\ \dfrac{\partial T'}{\partial y'}=-\dfrac{q}{\kappa},\ C'=C'_w & at\ \ y'=0\\ u'\to 0,\quad T'\to T'_\infty,\quad C'\to C'_\infty & as\ \ y'\to\infty\end{cases} \qquad (6)$$

Where u_0 is dimensional constant and q is the constant heat flux per unit area at the plate.

For an exponentially accelerated plate, $f\left(t'\right)=\exp(a'_0\,t')$, where a'_0 is dimensional accelerating parameter. Upon introducing the following non-dimensional quantities

$$\left.\begin{aligned}&u=\frac{u'}{u_0},\ t=\frac{u_0^2\,t'}{\nu},\ y=\frac{u_0^2\,y'}{\nu},\ \theta=\frac{T'-T'_\infty}{\left(\dfrac{q\nu}{\kappa u_0}\right)},\ Gr=\frac{g\,\beta\nu^2\,q}{\kappa u_0^2}\\ &M=\frac{\sigma B_0^2\,\nu}{\rho u_0^2},\ a_0=\frac{a'_0\,\nu}{u_0^2},\ \Pr=\frac{\mu C_p}{\kappa},\ Q=\frac{Q'\,\nu^2}{\kappa u_0^2},k=\frac{k'u_0^2}{\nu^2}\\ &C=\frac{\left(C'-C'_\infty\right)u_0 D}{m\nu},Kr=\frac{Kr'\nu}{u_0^2},\ Sc=\frac{\nu}{D},\ Gc=\frac{g\,\beta^*\,\nu^2\,m}{u_0^4 D}\end{aligned}\right\} \qquad (7)$$

in Equations (5), (2), (3) and (6), we have

$$\frac{\partial u}{\partial t}=\frac{\partial^2 u}{\partial y^2}+Gr\theta+GcC-M\left[u-K\exp\left(a_0 t\right)\right]-\frac{1}{k}u \qquad (8)$$

$$\Pr\frac{\partial\theta}{\partial t}=\frac{\partial^2\theta}{\partial y^2}-Q\theta \qquad (9)$$

$$Sc\frac{\partial C}{\partial t}=\frac{\partial^2 C}{\partial y^2}-KrSc\,C \qquad (10)$$

With the following initial and boundary conditions:

$$t\le 0:\quad u=0,\quad \theta=0,\quad C=0\quad for\ all\ \ y\ge 0$$

$$t>0:\begin{cases}u=\exp\left(a_0\,t\right),\ \dfrac{\partial\theta}{\partial y}=-1,\quad C=1 & at\ \ y=0\\ u\to 0,\quad \theta\to 0,\quad C\to 0 & as\ \ y\to\infty\end{cases} \qquad (11)$$

Where Gr Grashof number, Gc solutal Grashof number, Pr Prandtl numbers, Sc Schmidt number, respectively, M is magnetic field parameter (Square of the Hartmann number), and θ is the dimensionless temperature, C is the dimensionless concentration.

SOLUTION OF THE PROBLEM:

The equations (8), (9) and (10) subject to the initial and boundary conditions (11) are solved exactly by the usual Laplace transform technique without any restriction and the solutions obtained for different cases are as follows:

$$C(y,t)=\frac{1}{2}\left[e^{-y\sqrt{(Sc)(Kr)}}\,erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{(Kr)t}\right)+e^{y\sqrt{(Sc)(Kr)}}\,erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{(Kr)t}\right)\right]$$

$$\theta(y,t)=\frac{1}{2\sqrt{(\mathrm{Pr})(a_1)}}\left[e^{-y\sqrt{(\mathrm{Pr})(a_1)}}\,erfc\left(\frac{y\sqrt{\mathrm{Pr}}}{2\sqrt{t}}-\sqrt{(a_1)t}\right)-e^{y\sqrt{(\mathrm{Pr})(a_1)}}\,erfc\left(\frac{y\sqrt{\mathrm{Pr}}}{2\sqrt{t}}+\sqrt{(a_1)t}\right)\right]$$

$$u(y,t)=a_5 e^{a_0 t}-a_5 e^{-Mt}+\frac{e^{a_0 t}}{2}\left[e^{-y\sqrt{M+a_0}}\, erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(M+a_0)t}\right)+e^{y\sqrt{M+a_0}}\, erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(M+a_0)t}\right)\right]$$

$$+\frac{a_9}{2}\left[e^{-y\sqrt{M}}\, erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{M\,t}\right)+e^{y\sqrt{M}}\, erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{M\,t}\right)\right]$$

$$+a_4\left[\begin{array}{l}\frac{\sqrt{M}}{2a_1}\left\{e^{-y\sqrt{M}}\, erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{M\,t}\right)-e^{y\sqrt{M}}\, erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{M\,t}\right)\right\}\\ +\frac{i\sqrt{a_1-M}\, e^{-a_1 t}}{2a_1}\left\{e^{iy\sqrt{a_1-M}}\, erfc\left(\frac{y}{2\sqrt{t}}+i\sqrt{(a_1-M)t}\right)-e^{-iy\sqrt{a_1-M}}\, erfc\left(\frac{y}{2\sqrt{t}}-i\sqrt{(a_1-M)t}\right)\right\}\end{array}\right]$$

$$-a_4\left[\begin{array}{l}\frac{\sqrt{a_3+M}\, e^{a_3 t}}{2(a_1+a_3)}\left\{e^{-y\sqrt{a_3+M}}\, erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(a_3+M)t}\right)-e^{-y\sqrt{a_3+M}}\, erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(a_3+M)t}\right)\right\}\\ +\frac{i\sqrt{a_1-a_3}\, e^{-a_1 t}}{2(a_1+a_3)}\left\{e^{iy\sqrt{a_1-M}}\, erfc\left(\frac{y}{2\sqrt{t}}+i\sqrt{(a_1-M)t}\right)-e^{-iy\sqrt{a_1-M}}\, erfc\left(\frac{y}{2\sqrt{t}}-i\sqrt{(a_1-M)t}\right)\right\}\end{array}\right]$$

$$+a_5 e^{-Mt}\, erfc\left(\frac{y}{2\sqrt{t}}\right)-a_5\frac{e^{a_0 t}}{2}\left[e^{-y\sqrt{M+a_0}}\, erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(M+a_0)t}\right)+e^{y\sqrt{M+a_0}}\, erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(M+a_0)t}\right)\right]$$

$$-a_4\left[\frac{1}{2\sqrt{a_1}}\left\{e^{-y\sqrt{(\Pr)(a_1)}}\, erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{(a_1)t}\right)-e^{y\sqrt{(\Pr)(a_1)}}\, erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{(a_1)t}\right)\right\}\right]$$

$$+a_4\left[\frac{e^{a_3 t}}{2\sqrt{a_1+a_3}}\left\{e^{-y\sqrt{(\Pr)(a_1+a_3)}}\, erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{(a_1+a_3)t}\right)-e^{y\sqrt{(\Pr)(a_1+a_3)}}\, erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{(a_1+a_3)t}\right)\right\}\right]$$

$$-\frac{a_9 e^{a_8 t}}{2}\left[e^{-y\sqrt{M+a_8}}\, erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(M+a_8)t}\right)+e^{y\sqrt{M+a_8}}\, erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(M+a_8)t}\right)\right]$$

$$-\frac{a_9}{2}\left[e^{-y\sqrt{(Sc)(Kr)}}\, erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{(Kr)t}\right)+e^{y\sqrt{(Sc)(Kr)}}\, erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{(Kr)t}\right)\right]$$

$$+\frac{a_9 e^{a_8 t}}{2}\left[e^{-y\sqrt{Sc}\sqrt{Kr+a_8}}\, erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{(Kr+a_8)t}\right)+e^{y\sqrt{Sc}\sqrt{Kr+a_8}}\, erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{(Kr+a_8)t}\right)\right]$$

Where $a_1=\frac{Q}{\Pr}$, $a_2=\frac{Gr}{\sqrt{\Pr}(1-\Pr)}$, $a_3=\frac{(\Pr)(a_1)-M}{1-\Pr}$, $a_4=\frac{a_2}{a_3}$, $a_5=\frac{MK}{M+a_0}$, $a_7=\frac{Gc}{1-Sc}$, $a_8=\frac{(Kr)(Sc)-M}{1-Sc}$,

$a_9=\frac{a_7}{a_8}$

Skin-friction

From the velocity field, the expression for skin-friction at an exponentially accellerated plate is derived and is given by

$$\tau=\frac{\tau'}{\rho u_0^2}=-\left(\frac{\partial u}{\partial y}\right)_{y=0}$$

$$\tau = (1-a_8)e^{a_0 t}\left[\sqrt{N+a_0}\, erf\left(\sqrt{(N+a_0)t}\right) + \frac{1}{\sqrt{\pi t}} e^{-(N+a_0)t}\right] + \frac{a_6}{a_1}\left[N + (a_1 - N)e^{-a_1 t}\right]$$
$$-\frac{a_6}{(a_1+a_3)}\left[(N+a_3)e^{a_3 t} + \sqrt{(a_1-a_3)(a_1-N)}\, e^{-a_1 t}\right] + a_7\left[\sqrt{N}\, erf\left(\sqrt{N t}\right) + \frac{1}{\sqrt{\pi t}} e^{-N t}\right]$$
$$-a_7 e^{a_5 t}\left[\sqrt{N+a_5}\, erf\left(\sqrt{(N+a_0)t}\right) - \frac{1}{\sqrt{\pi t}} e^{-(N+a_5)t}\right] + \frac{a_8}{\sqrt{\pi t}} e^{-N t} - a_6\sqrt{\Pr} + a_6\sqrt{\Pr}\, e^{a_3 t}$$
$$-a_7\left[erf\left(\sqrt{(Kr)t}\right) + \sqrt{\frac{Sc}{\pi t}}\, e^{-Kr t}\right] + a_7 e^{a_5 t}\left[\sqrt{Sc(a_5+Kr)}\, erf\left(\sqrt{(a_5+Kr)t}\right) - \sqrt{\frac{Sc}{\pi t}}\, e^{-(a_5+Kr)t}\right]$$

Nusselt number

From the temperature field, the rate of heat transfer in the form of Nusselt number is derived for an exponentially accelerated plate and it is given by

$$Nu = -\frac{\nu}{u_0\left(T' - T'_\infty\right)}\left(\frac{\partial T'}{\partial y'}\right)\Bigg|_{y=0} = -\frac{1}{\theta(0,t)}\left(\frac{\partial \theta}{\partial y}\right)_{y=0}$$
$$= \frac{\sqrt{Q}}{erf\left(\sqrt{\frac{Qt}{\Pr}}\right)}$$

Sherwood number

From the concentration field, the rate of mass transfer in the form of Sherwood number is derived for an exponentially accelerated plate and it is given by

$$Sh = -\left(\frac{\partial C}{\partial y}\right)_{y=0} = -\left(\sqrt{(Kr)(Sc)}\, erf\left(\sqrt{(Kr)t}\right) - \sqrt{\frac{Sc}{\pi t}}\, e^{-Kr t}\right)$$

RESULTS AND DISCUSSIONS:

The problem of unsteadymagnetohydrodynamic free convective flow of a viscous, incompressible fluid past an infinite non-conducting vertical plate through porous medium has been formulated, analyzed and solved analytically using Laplace transform technique. The effects of the flow parameters such as magnetic parameter (M), Grashof number for heat and mass transfer (Gr, Gc), Schmidt number (Sc), Chemical reaction parameter (Kr), Prandtl number (Pr), Heat generation parameter (Q) and permeability parameter (k) on the velocity, temperature and concentration profiles of the flow field are presented with help of graphs.

Fig. 1 reveals the effect of heat absorption parameter Q on the velocity profiles. It is seen from this figure that velocity increases with increaseing heat absorption effects in the vicinity of the plate.

The effect of chemical reaction parameter Kr is shown in Fig. 2, which dipicts that velocity decreases with increasing the rate of chemical reaction parameter Kr. Therefore an increase in Kr leads to a fall in the momentum boundary layer.

Fig. 3 shows that the velocity response to distinct values of Grashof number Gr. It is found than an increase in the Grashof number results to rise in the values of velocity due to enhancement in buoyancy force.

Fig. 4 shows the typical velocity profiles in the boundary layer for distrinct values of the solutal Grashof number Gm. The velocity distribution attains a distinctive maximum value in the region of the plate surface and the decrease properly to approach the free stream value. This is evident in the increase in the value of velocity as solutal Grashof number increases.

Fig. 5 depicts that the Prandlt number effect on velocity profiles. This figure illustrates that the effect of increasing values of Prandtl number results in a decreasing velocity.

The influence of Schmidt number Sc on the velocity profiles is shown in Fig. 6. The Schmidt number is the ration of the momentum to the mass diffusivity. The Schmidt number measures the relative effectiveness of momentum and mass transport by diffusion in the velocity and concentration boundary layers. As the Schmidt number increases the velocity decreases, because the concentration buoyancy effects to decrease yielding a reduction in the fluid velocity.

The influence of the mgnetic field parameter M on the velocity profiles is depict in Fig. 7. It can be seen that the fluid velocity decreases as the magnetic field parameter M increases. Because the presence a transverse magnetic field in an electrically conducting flud introduce a force called the Lorentz force, which acts against the flow if the magnetic field is applied in the perpendicular direction. This force has tendency to slow down the fluid motin in the boundary layer.

In Fig. 8 the profiles of velocity have been plotted for various values of permeability parameter k by keeping other parameter fixed. It is observed that for large values of k, velocity and boundary layer thickness increases which explains the physical situation that as k increases, the resistance of the porous medium is lowered which increase the momentum development of the flow regime, ulimately enhances the velocity field.

The effect of the exponential accelerated parameter a_0 on the velocity profiles is presented in Fig. 9. It is clear that whenever the exponential accelerated parameter increases the velocity also increases.

In Fig. 10 the influence of dimensionless time on the velocity profiles is shown. It is found that the velocity is an increasing function of time t.

The effect of the heat absorption on the temperature field is shown in Fig. 11. It is clear that the presence of heat absorption within the boundary layer produces the opposite effect and thus the temperature of the fluid decreases.

Fig. 12 depicts that the temperature profiles against y taking different values of Prandtl number Pr. The thermal boundary layer thickness is greater for fluids with small Prandtl number. The reason is that smaller values of Prandtl number are equivalent to increasing thermal conductivity and therefore heat is able to diffuse away from the heated surface more rapidly than for higher values of Pr.

Fig. 13 is plotted to show the effects of the dimensionless time t on the tempereture profiles. Four different values of time t = 0.2, t = 0.4, t = 0.6 and t = 0.8 are chosen. Obiviously the temperature increases with increasing time t. The temperature profiles assume a parabolic shape in the vicinity of the plate and this parabolic shape pronounce more as the time progresses.

The chemical reaction parameter Kr effect on species concentration profiles for generative chemical reaction is shown in Fig. 14. It is observed from the figure that there is marked effect with increasing the value of Kr on concentration distribution in the boundary layer. It is easily noticed from this figure that the concentration of species value of 0.2 at vertical plate decreases till it attains the minimum value of zero at the end of the boundary layer and this trend is seen for all the values of Kr. Further, it is evedent that increasing the value of the chemical reaction parameter Kr decreases the concentration of species in the boundary layer, this is due to the fact the boundary layer decreases with increase in the value Kr in this system results in the consumption of the chemical and hence results in concentration profile to decrease.

The effect of Schmidt number Sc on the concentration profiles is noted in Fig. 15. Since Sc is the ration of momentum diffusivity to molecular diffusivity. It is observed that whenever Sc increases the concentration decreases. Physically, the increase in the value of Sc means decrease of molecular diffusion D. Hence the concentration of the species is higher for smaller values of Sc and lower for larger values of Sc.

Table 1 gives the values of the skin-friction for different values of the magnetic parameter *M*. Analysis of the tabular data shows that magnetic field strength enhances the skin friction as highlighted with increases in the absolute values of the skin friction as *M* increases. Physically, this implies that the plate surface exerts a drag force on the fluid.

The effect of heat generation parameter on the Nusselt number is depicted on Table 2. We clearly observe in this table that the absolute values of the Nusselt number are reduced as the heat generation parameter Q increases.

The effect of chemical reaction parameter on the Sherwood number is depicted on Table 3. We clearly observe in this table that the absolute values of the Sherwood number are increase as the chemical reaction parameter Kr increases.

GRAPHS:

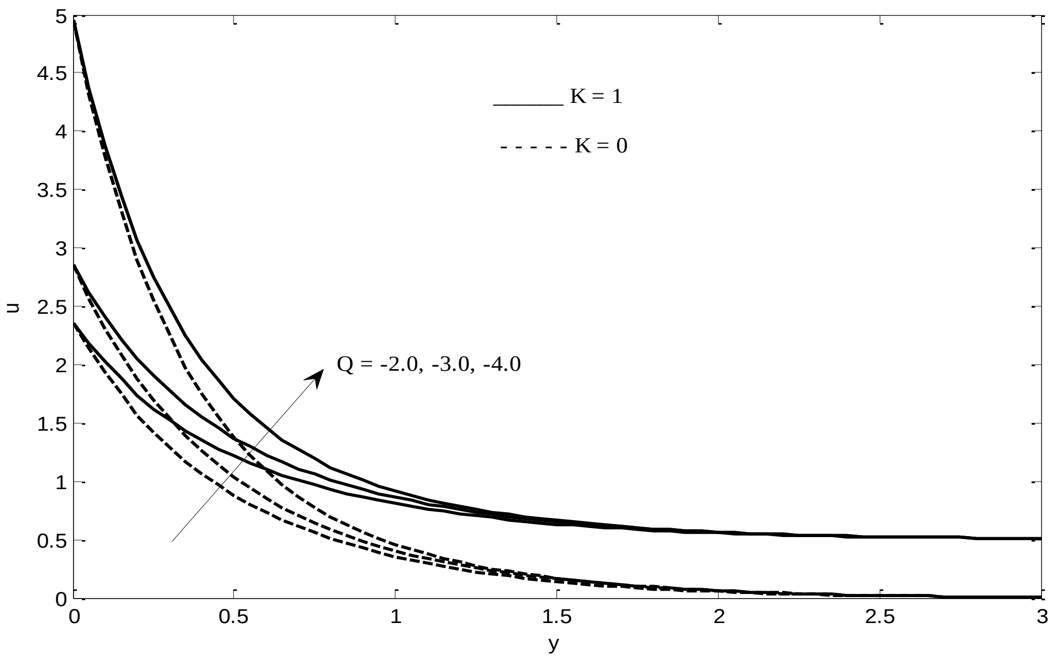

Figure: 1 – Velocity profiles for different vales of heat absorption parameter (Q) when M = 1, Pr = 0.71, Gr = 1, Gm = 1, Sc = 0.6, k = 2, Kr = 0.2, t = 0.4, $a_0 = 0.5$

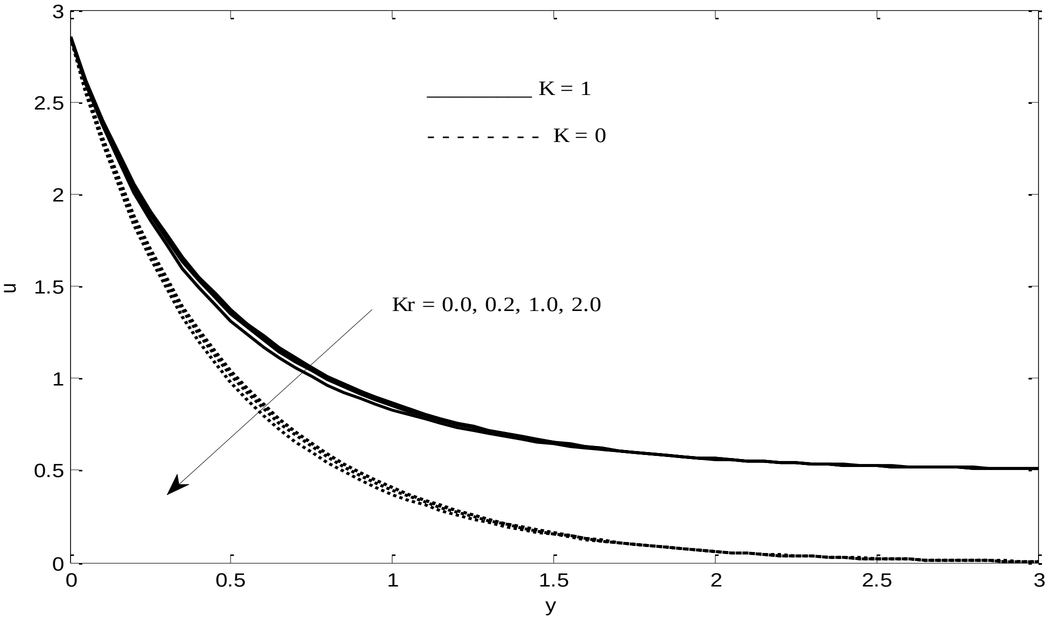

Figure: 2 – Velocity profiles for different vales of chemical reaction parameter (Kr) when M = 1, Pr = 0.71, Gr = 1, Gc = 1, Sc = 0.6, k = 2, $a_0 = 0.5$, t = 0.4.

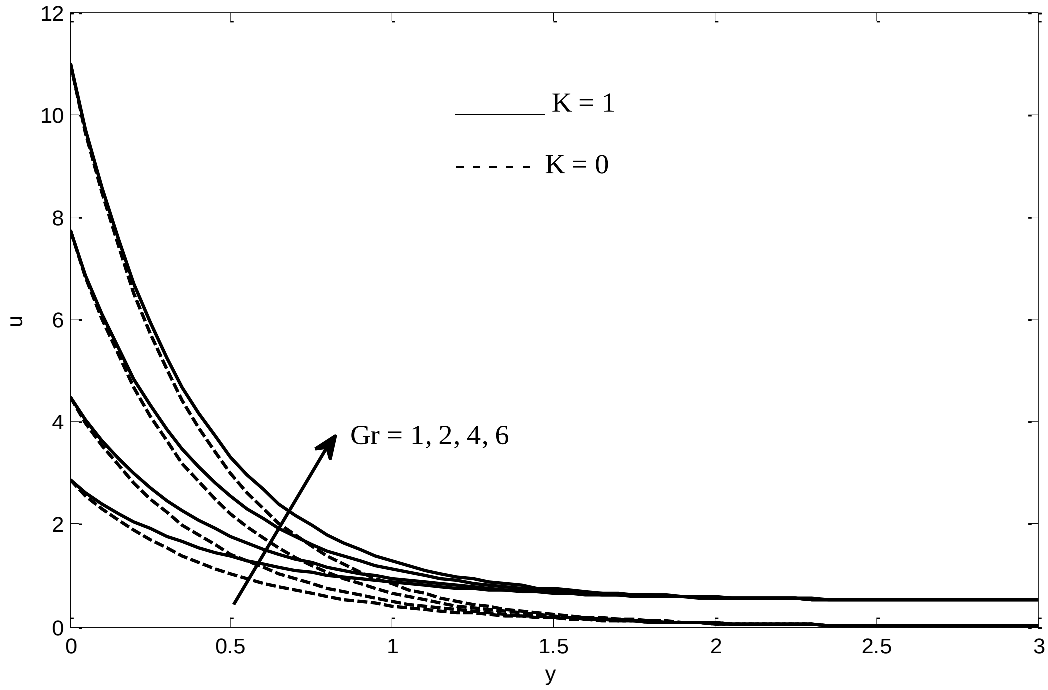

Figure: 3 – Velocity profiles for different vales of Grashof number (Gr) when M = 1, Pr = 0.71, Q = 3, Gm = 1, Sc = 0.6, k = 2, Kr = 0.2, t = 0.4, $a_0 = 0.5$

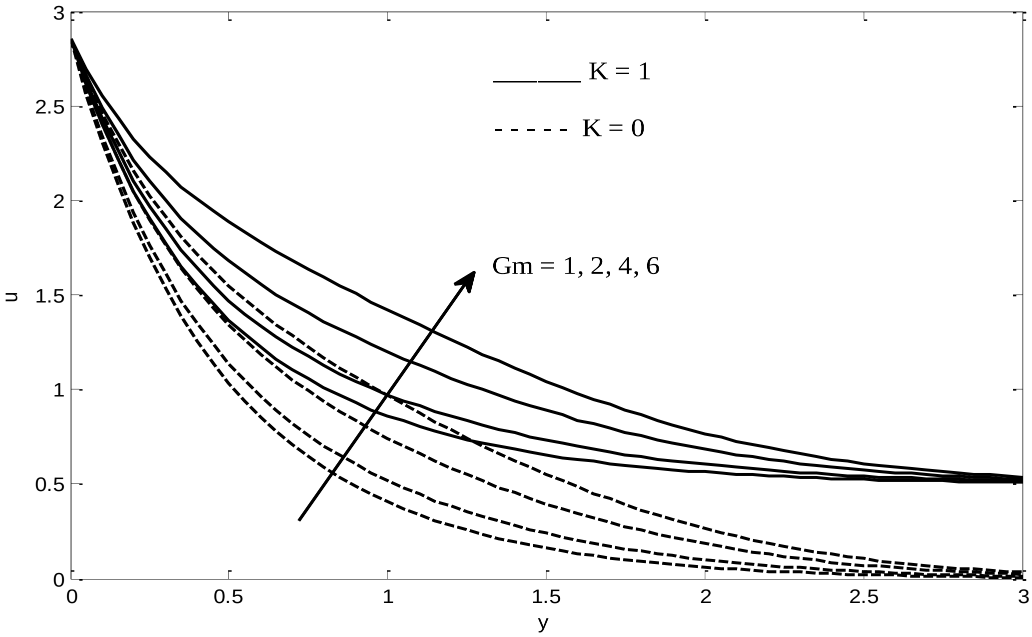

Figure: 4 – Velocity profiles for different vales of solutal Grashof number (Gm) when M = 1, Pr = 0.71, Gr = 1, Q = 3, Sc = 0.6, k = 2, Kr = 0.2, t = 0.4, $a_0 = 0.5$

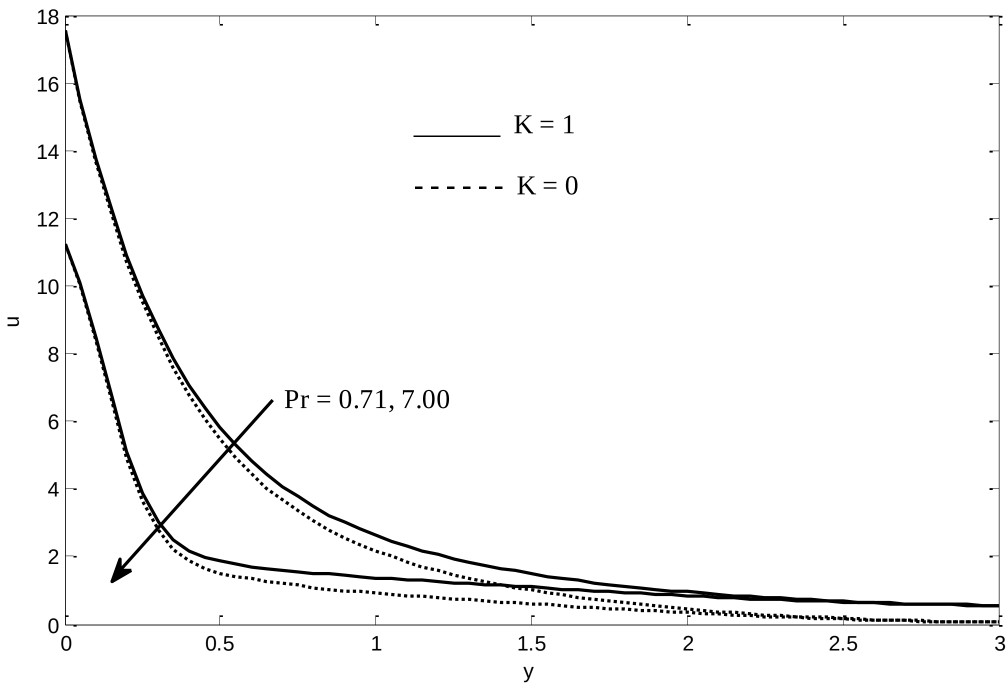

Figure: 5 – Velocity profiles for different vales of Prandtl number (Pr) when M = 1, Gm = 10, Gr = 10, Q = 3, Sc = 0.6, k = 2, Kr = 0.2, t = 0.4, $a_0 = 0.5$

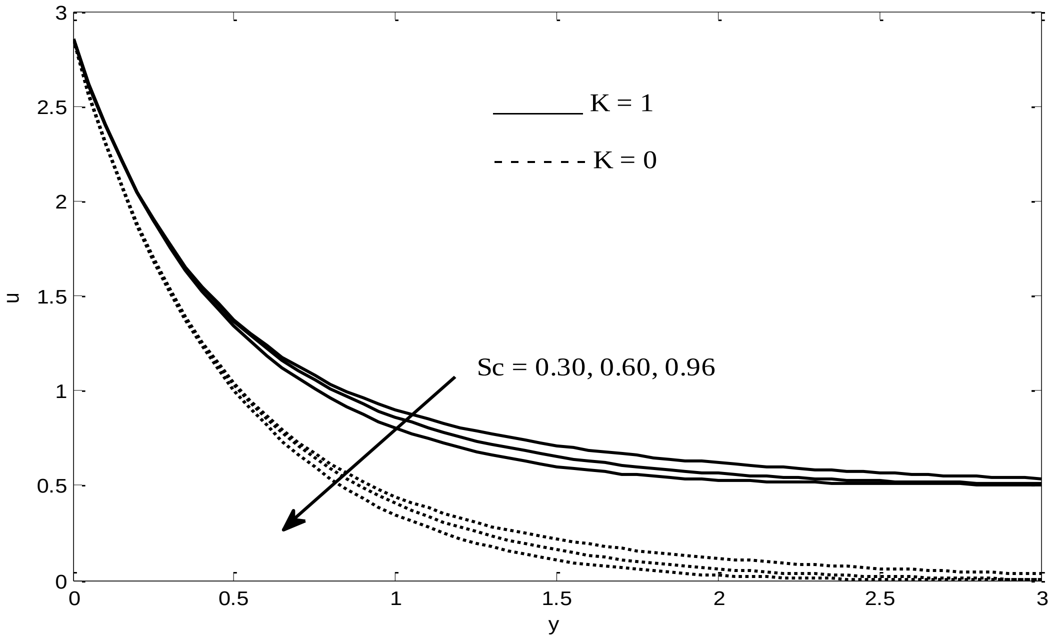

Figure: 6 – Velocity profiles for different vales of Schmidt number (Sc) when M = 1, Pr = 0.71, Gr = 1, Gm = 1, Q = 3, k = 2, Kr = 0.2, t = 0.4, $a_0 = 0.5$

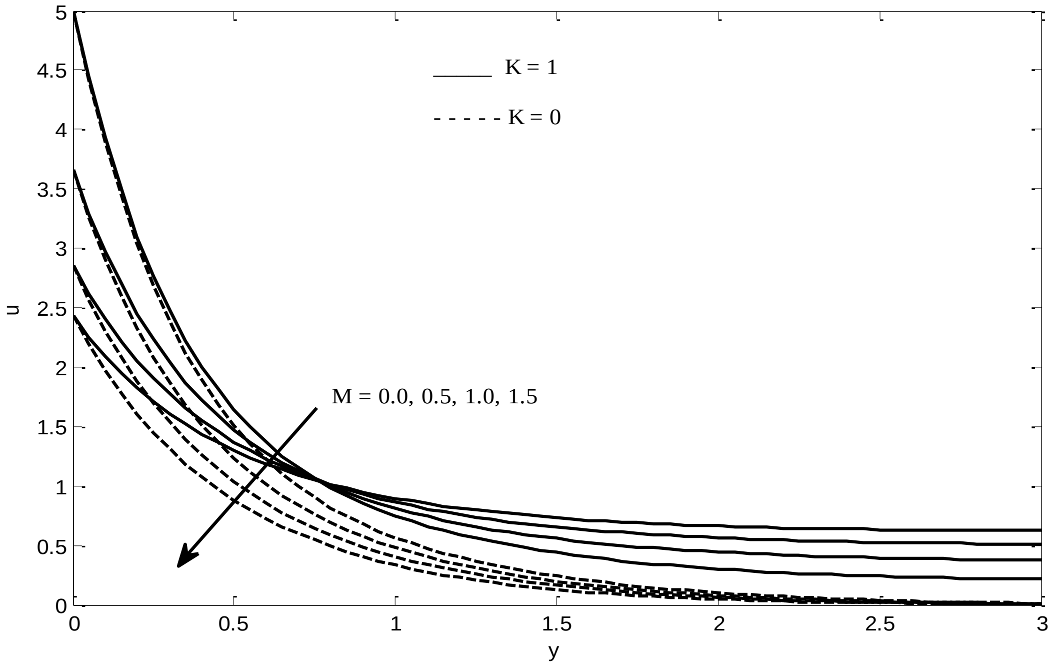

Figure: 7 – Velocity profiles for different vales of magnetic parameter (M) when Q = 3, Pr = 0.71, Gr = 1, Gm = 1, Sc = 0.6, k = 2, Kr = 0.2, t = 0.4, $a_0 = 0.5$

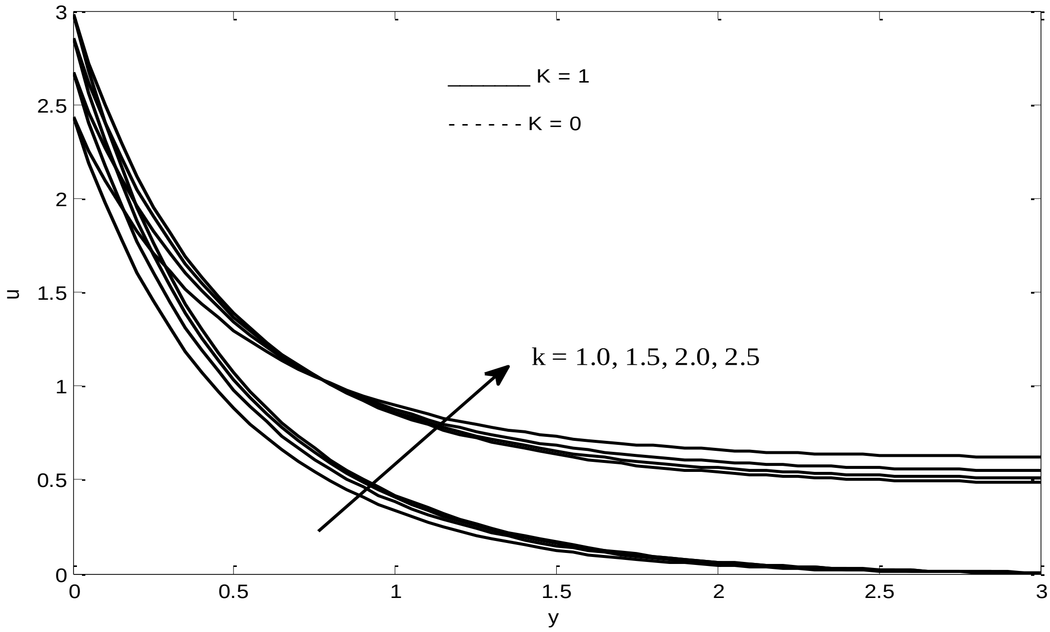

Figure: 8 – Velocity profiles for different vales of permeability parameter (k) when M = 1, Pr = 0.71, Gr = 1, Gc = 1, Sc = 0.6, Q = 3, $a_0 = 0.5$, t = 0.4, Kr = 0.2.

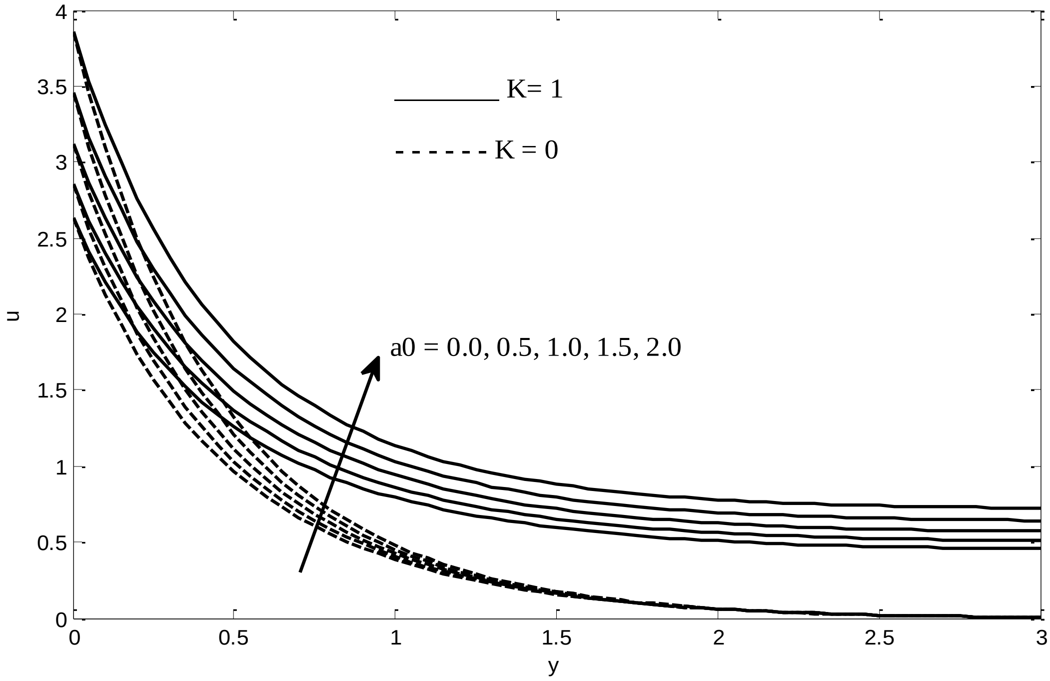

Figure: 9 – Velocity profiles for different vales of exponentially accelated parameter (a_0) when M = 1, Pr = 0.71, Gr = 1, Gc = 1, Sc = 0.6, k = 2, Kr = 0.2, t = 0.4, Pr = 0.71.

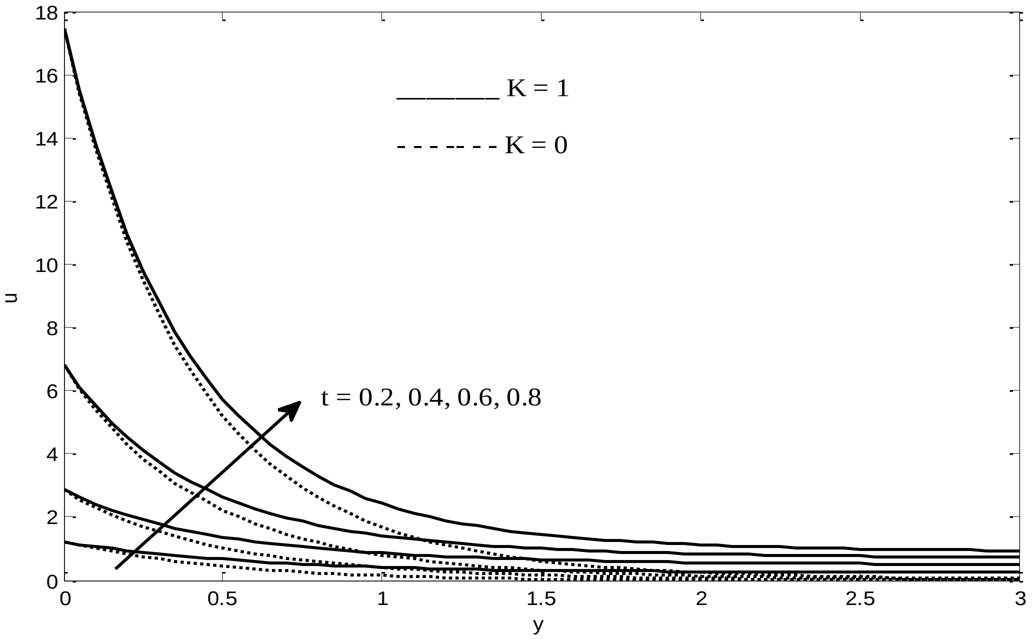

Figure: 10 – Velocity profiles for different time levels (t) when M = 1, Pr = 0.71, Gr = 1, Gc = 1, Sc = 0.6, Q = 3, $a_0 = 0.5$, k = 2, Kr = 0.2

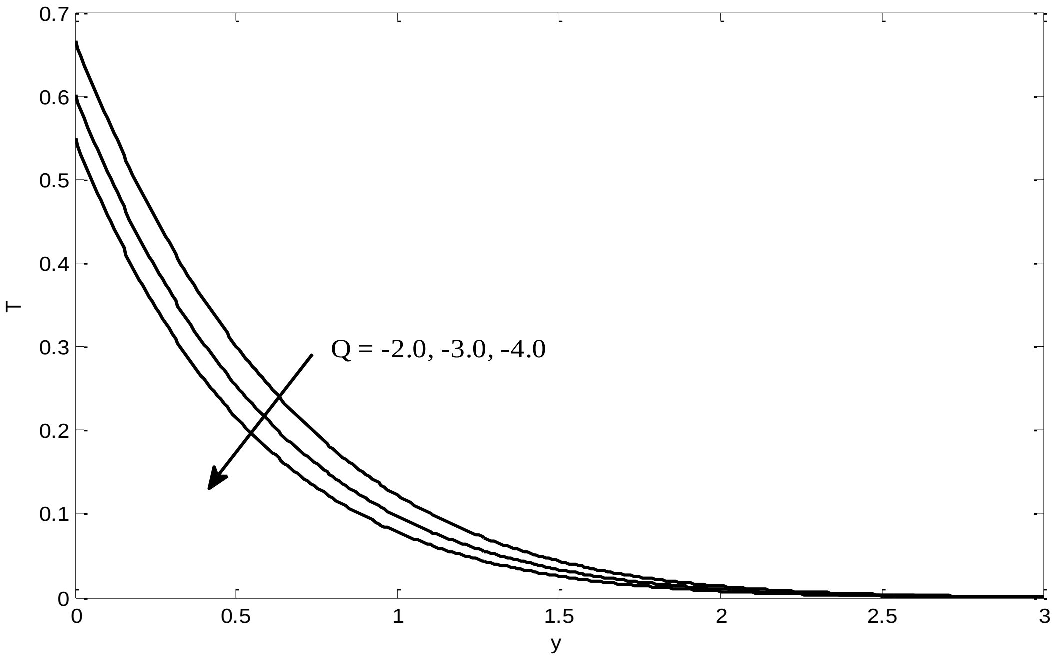

Figure: 11 – Temperature profiles for different values of heat absorption parameter (Q) when t = 0.4, Pr = 0.71.

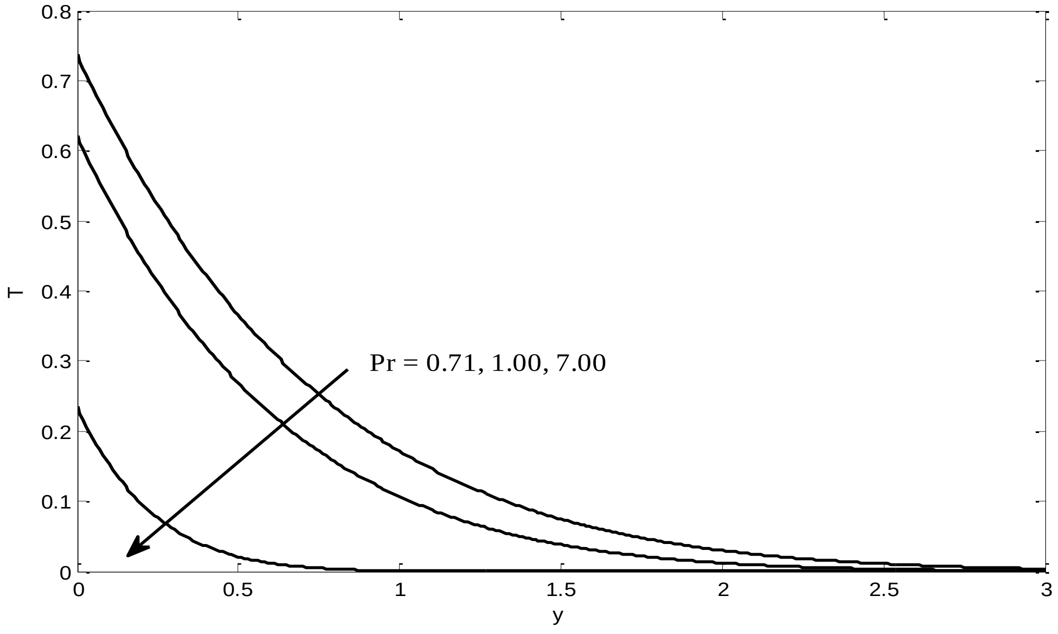

Figure: 12 – Temperature profiles for different values of Prandtl number (Pr) when t = 0.4, Q = 3

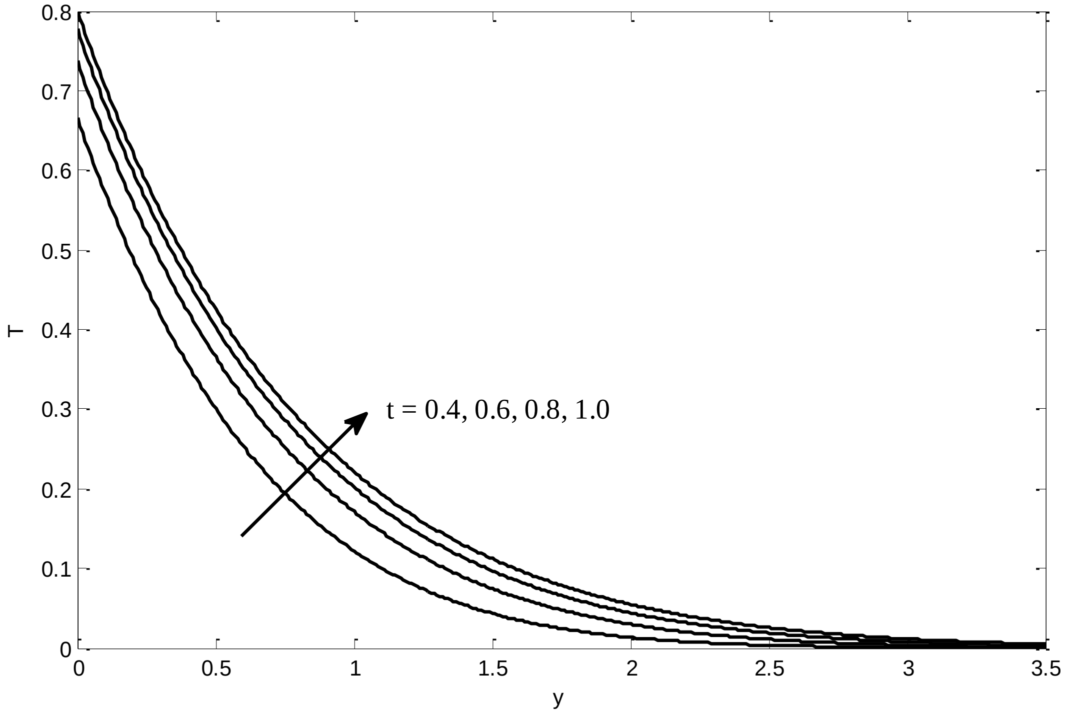

Figure: 13 – Temperature profiles for different time levels when Q = 3, Pr = 0.71.

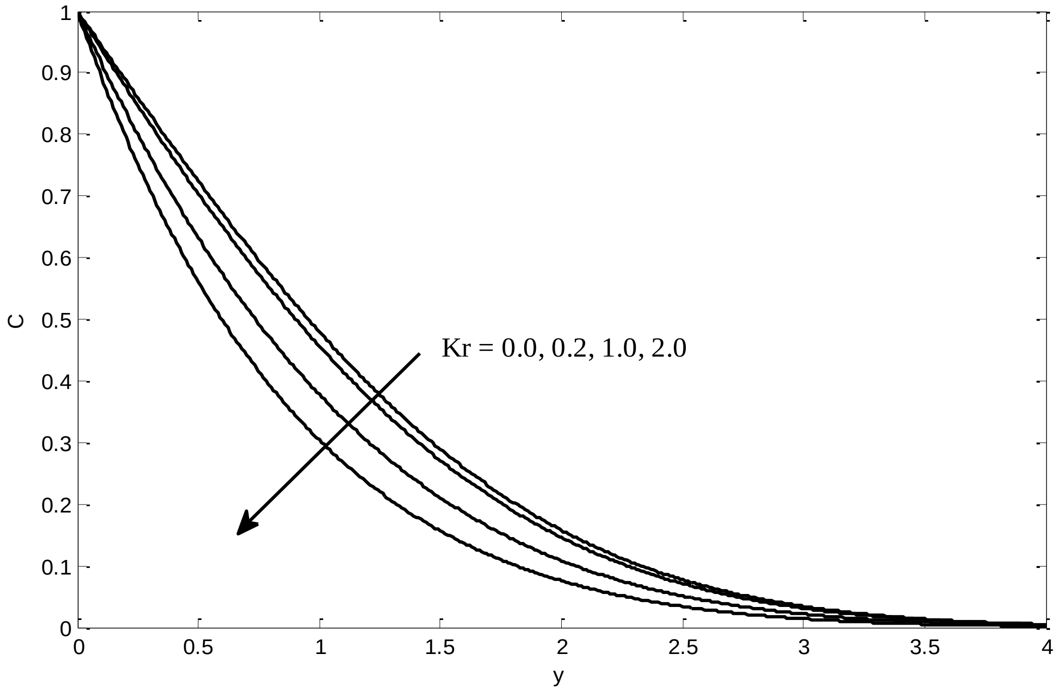

Figure: 14 – Concentration profiles for different vales of Schmidt number (Sc) when Kr = 0.2, t = 0.4

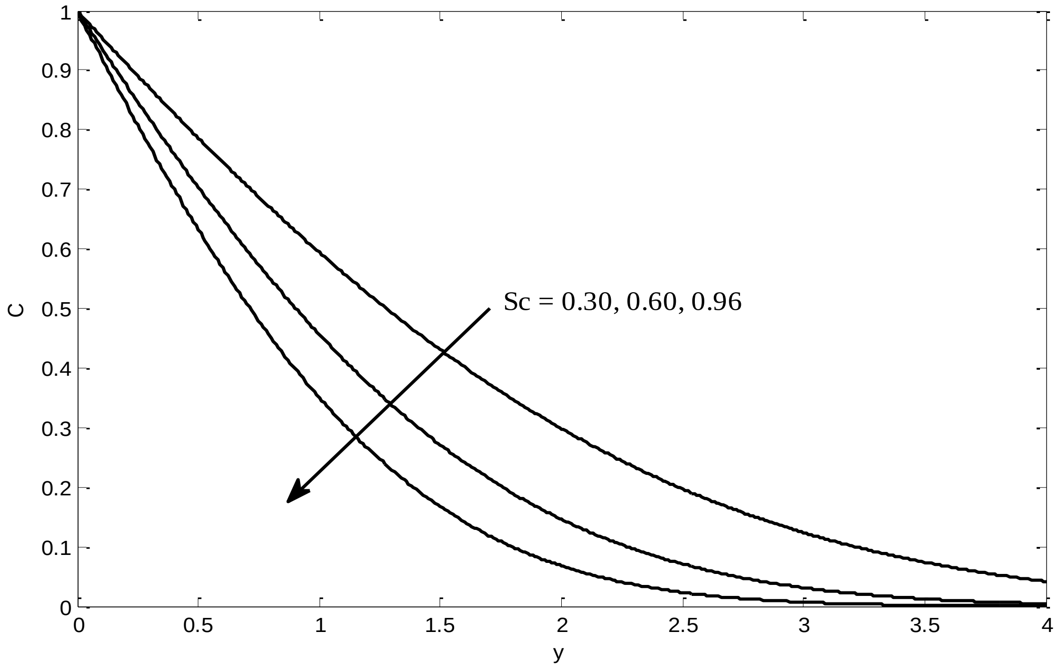

Figure: 15 – Concentration profiles for different vales of chemical reaction (Kr) when Sc = 0.60, t = 0.4.

Table 1– Skin-friction variation for Pr = 0.71 (air)

t	M	K	Skin friction

0.6	1	0	5.8512
0.6	2	0	11.4747
0.6	1	1	5.0125
0.6	2	1	10.0016
0.4	1	0	2.9684
0.4	2	0	7.3271
0.4	1	1	2.2826
0.4	2	1	6.0878

Table 2 – Nusselt number variation for Pr = 0.71 (air)

t	Q	Nusselt Number
0.2	-2.0	1.7722
0.4	-2.0	0.9344
0.6	-2.0	0.5562
0.6	-1.0	0.8859
0.6	-2.0	0.5562
0.6	-3.0	0.3319

Table 3– Sherwood number variation for Sc = 0.6 (water-vapor)

t	Kr	Sherwood number
0.4	0	0.6910
0.4	0.2	0.6691
0.4	1.0	0.7950
0.4	2.0	1.1234
0.6	0	0.5642
0.6	0.2	0.5471
0.6	1.0	0.7774
0.6	2.0	1.1671

REFERENCES:

1. Ingham D.B., and Pop I., Transport Phenomena in Porous Media, Pergamon, Oxford, 1998, vol. II, (2000), vol. III (2005).
2. Neild D.A., and Bejan A. (2006), Convection in Porous Media, 3rd edition, Springer, New York,.
3. Vafai, K (2005), Hand book of Porous Media, Taylor & Francis, Baton Roca, F.L.
4. Pop. I., and Ingham D.B.(2001), Convective Heat Transfer: Mathematical and Computational Modeling of viscous fluids and porous media, Pergamon Oxford,
5. Ingham D.B., Bejan A., Mamut E., Pop. I .(2004), Emerging Technologies and techniques in porous media, Kluwer, Dordrecht,
6. Bejan A and Khair K.R. (1985), Heat and mass transfer by natural convection in porous medium, Int. J. Heat Mass Transfer, vol. 28, no. 5, pp.909-918.
7. Raptis A., and Singh A.K. (1983), MHD free convection flow past an accelerated vertical plate, Int. Commun. Heat Mass, 10, 313-321.
8. Tokis J.N. (1985), A class of exact solutions of the unsteady magnetohydrodynamic free convection flows, Astrophysics Space Sci. 112, 413-422.
9. Chandran P., Sacheti N.R., and Singh A.K. (1998), Unsteady hydromagnetic free convection flow with heat flux and accelerated boundary motion, J. Phys. Soc. Jpn, 67, pp.124-129.
10. Narahari M., and Debnath L. (2013) Unsteady magnetohydro dynamic free convection flow past an accelerated vertical plate with constant heat flux and heat generation or absorption, ZAMM, 93, no. 1, 38-49.
11. Vajravelu K (1979)., Natural convection at a heated semi-infinite vertical plate with internal heat generation, Acta Mech., 34, pp.153-159.
12. Crpean J.C., Clarksean R. (1997), Similarity solution of natural convection with internal heat generation, ASME Journal of Heat Transfer, 119, pp.183-185.
13. Chamkha A.J, (2004), Unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat generation, Int. J. Engg. Science, 42, pp.217-230.
14. Sharma P.R., Dadheech I.K., and Gurminder Singh. (2012), Heat and mass transfer effects on unsteady MHD free convective flow along a vertical porous plate with internal heat generation and variable suction, International Journal of Mathematical Archive, 3(5), pp.2163-2172.
15. Jha B.K., and Prasad R. (1991), MHD free convection and mass transfer flow through a porous medium with heat source, Astrophysics and Space Science, 181, pp.117-123.
16. Sharma P.R., and Sharma K. (2007), Effect of oscillatory suction and heat source on heat and mass transfer in MHD flow along a vertical moving porous plate bounded by porous medium, Mod. Meas. & Control B, AMSE J. France, 76 (5), pp.34-40.

17. Gireesh Kumar J., Sayanarayana P.V. (2009), and Ramakrishna S., Effects of chemical reaction and mass transfer on MHD free convection flow past an infinite vertical plate with constant suction and heat sink, Ultra Science, vol. 21(8), pp.639-650.
18. Tripathy R.S., Dash G.C., Mishra S.R., and Baag S. (2015), Chemical reaction effect on MHD free convective surface over a moving vertical plate through porous medium, Alexandria Engineering Journal, 54, pp.673-679.
19. Cramer K.R., and Pai S.I. (1973), Magno Fluid Dynamics for Engineers and Applied Physics McGraw-Hill Book Company, New York.