Journal of Applied Fluid Mechanics, Vol. 6, No. 3, pp. 443-451, 2013.
Available online at www.jafmonline.net, ISSN 1735-3572, EISSN 1735-3645.

Unsteady MHD Radiative and Chemically Reactive Free Convection Flow near a Moving Vertical Plate in Porous Medium

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(Received February 1, 2012; accepted August 20, 2012)

ABSTRACT

We have investigated an unsteady flow of a viscous, incompressible electrically conducting, laminar free convection boundary layer flow of a moving infinite vertical plate in a radiative and chemically reactive medium in the presence of a transverse magnetic field. The equations governing the flow are solved by Laplace transform technique. The expressions for velocity, temperature, concentration are derived and based on these quantities the expressions for skin friction; rate of heat transfer and the rate mass transfer near the plate are derived. The effects of various physical parameters on flow quantities, wise magnetic parameter, Grashof number, modified Grashof number, heat source parameter, the chemical reaction parameter, Schmidt number and radiation parameter are studied numerically and the results are discussed with the help of graphs. Some important applications of physical interest for different type motion of the plate like case (i) when the plate is moving with uniform velocity, case (ii) when the plate is moving with single acceleration and case (iii) when the plate is moving with periodic acceleration, are discussed.

Keywords: Heat source or sink, Chemical reaction, MHD, Radiation, Porous medium, Heat and mass transfer.

NOMENCLATURE

B_0	external magnetic field
C	dimensionless concentration
C^*	specifies concentration in the Fluid
C_p	specific heat at constant pressure
C_w^*	fluid concentration near the plate
C_∞^*	fluid concentration far away from the plate
D	chemical molecular Diffusivity
erf	error function
$erfc$	complementary error function
F	radiation parameter
G_m	mass Grashof number
G_r	thermal Grashof number
g	acceleration due to gravity
H	heat absorption Parameter
k	non- dimensional permeability coefficient of a porous medium
K_C	non- dimensional rate of chemical reaction
k^*	permeability of porous medium
K_c^*	rate of chemical reaction
S_c	Schmidt number
S_0	Soret number
T^*	fluid temperature
T_w^*	temperature of the plate
T_∞^*	temperature of the fluid far away from the plate
t	dimensionless time
t^*	time
u	non dimensional velocity
u^*, v^*	velocity components in x and y directions
y	dimensionless Co-ordinate axis normal to the plate
y^*	co-ordinate axis normal to the plate
β_T	coefficient of volume expansion
β_c	coefficient of volume expansion with concentration
κ	thermal conductivity of the fluid
μ	dynamic viscosity
ν	kinematic viscosity

M	magnetic parameter
Nu	Nusselt number
P_r	Prandtl number
q_r	radiative heat flux in y-direction
Sh	non-dimensional Sherwood number
θ	dimension less temperature
ρ	fluid density
σ	electrical conductivity
τ	non-dimensional skin friction
ω	non-dimensional frequency of oscillations
ω^*	frequency of oscillations

1. INTRODUCTION

MHD free convection flows occur frequently in nature. Flows of fluids through porous medium are of principal interest now a days and have been attracting the attention of many researchers due to their applications in the fast growing fields of science and technology viz. in the fields of agricultural engineering to study the ground water resources, in petroleum technology to study the moment of natural gas, oil, and water through the oil reservoirs. The applications of hydro magnetic incompressible viscous flow in science and engineering involving heat and mass transfer under the influence of chemical reaction is of great importance to many areas of science and engineering. This frequently occurs in petro-chemical industry, power and cooling systems, chemical vapor deposition on surfaces, cooling of nuclear reactors, heat exchanger design, forest fire dynamics and geophysics as well as in magneto-hydrodynamic power generation systems. Heat transfer by thermal radiation is becoming of greater importance when we are considered with space applications, higher operating temperature and also power engineering. Moreover, considerable interest has been evinced in radiation interaction with convection and chemical reaction for heat and mass transfer in fluids. This is due to the significant role of thermal radiation in the surface heat transfer when convection heat transfer is small, particularly, in free convection problems involving absorbing emitting fluids. Das and Das (2009) studied MHD free convection near a moving a vertical plate in the presence of thermal radiation. Rebhi *et al.* (2009) have investigated combined effect of heat generation or absorption and first-order chemical reaction on micro polar fluid flows over a uniformly stretched permeable surface. Ibrahim and Makinde (2010) considered chemically reacting MHD boundary layer flow of heat and mass transfer over a moving vertical plate with suction. Rajesh and Varma (2009) investigated radiation and mass transfer effects on MHD free convection flow past an exponentially accelerated vertical plate with variable temperature. Recently, Chandrakala (2011) studied radiation effects on flow past an impulsively started vertical oscillating plate with uniform heat flux. Deka and Neog (2009) considered unsteady MHD flow past a vertical oscillating plate with thermal radiation and variable mass diffusion. Prasad *et al.* (2010) studied mass transfer effects on unsteady MHD free convection flow past a vertical porous plate embedded in a porous medium. Srinivas and Muthuraj (2010) considered Effects of thermal radiation and space porosity on MHD mixed convection flow in a vertical channel using homotopy analysis method. Again, Srinivas and Muthuraj (2010) considered a MHD flow with slip effects and temperature-dependent heat source in a vertical wavy porous space. Unsteady MHD free convection flow and mass transfer near a moving a vertical plate in the presence of thermal radiation is investigated by Abzal *et al.* (2011). Sharma and Singh (2009) have studied the effects of variable thermal conductivity and heat source/sink on MHD flow near a stagnation point on a linearly stretching sheet. Effects of varying viscosity and thermal conductivity on steady free convective flow and heat transfer along an isothermal vertical plate in the presence of heat sink was considered by Mahanti and Gaur (2009). Recently variable heat and mass transfer, radiation and heat source or sink effects are considered by Chamkha and Ahmed (2011), Seth *et al.* (2011), Das *et al.* (2011) , Singk *et al.* (2011) and Raju *et al.* (2011).

The present study is an analytical solution of combined effect of heat generation or absorption and homogeneous chemical reaction on unsteady MHD free convection flow near a moving vertical plate through a porous medium in presence of thermal radiation. A general exact solution for the partial differential equations governing the flow is obtained with the aid of the usual Laplace transform technique. Also the applications of general solution for the important cases of the flow are discussed.

2. FORMULATION OF THE PROBLEM

We consider an unsteady free convection flow of a viscous incompressible electrically conducting and radiating fluid along an infinite non conducting vertical flat plate or (surface) in the presence of Magnetic field B_0 applied in the direction of the flow. On this plate, an arbitrary point has been chosen as the origin of a co-ordinate system with x^* -axis along the plate in the upward direction and the y^* -axis normal to the plate. Initially for time $t^* \le 0$, the plate and the fluids are at the same constant temperature T_∞^* in a stationary condition. Subsequently ($t' > 0$), the plate is assumed to be accelerating with a velocity $U_0 f\ (t')$ in its own plane along the x' -axis; instantaneously, the temperature of the plate is raised to T_w^* , which is here after regarded as constant. For free convection flows, here so the physical variables are functions of the space co-ordinate y' and time t^* only. Under the above assumptions, the fully developed flow of a radiating gas is governed by the following set of equations.

$$\frac{\partial u^*}{\partial t^*} = \nu \frac{\partial^2 u^*}{\partial y^{*2}} + g B_T (T^* - T_\infty) + g B_C (C^* - C_\infty) - \frac{\sigma B_0^2}{\rho(1+m^2)} u^* - \frac{\vartheta}{K_p} u^* \quad (1)$$

$$\frac{\partial T^*}{\partial t^*}=\frac{K}{\rho C_P}\frac{\partial^2 T^*}{\partial y^{*2}}-\frac{1}{\rho C_P}\frac{\partial q_r}{\partial y^*}-\frac{Q}{\rho C_P}\left(T^*-T_\infty^*\right) \tag{2}$$

$$\frac{\partial C^*}{\partial t^*}=D\frac{\partial^2 C^*}{\partial y^{*2}}-K_c^*(C^*-C_\infty^*) \tag{3}$$

The initial and boundary conditions are

$$\begin{aligned}
&u^*=0, T^*=T_\infty^*, C^*=C_\infty^* \quad \text{for all } \ y^*\geq 0, t^*\leq 0\\
&u^*=U_0 f(t^*), T^*=T_w^*, C^*=C_w^* \ \text{ at } y=0, t^*>0\\
&u^*=0, T^*=T_\infty^*, C^*=C_\infty^* \ \text{ as } \ y\to\infty, t^*>0
\end{aligned} \tag{4}$$

In the optically thick limit, the fluid does not absorb its own emitted radiation in which there is no self absorption, but it does absorb radiation emitted by the bounadries. Cogly *et al.* (1968) showed that in the optically thick limit for a non gray gas near equilibrium as given below.

$$\begin{aligned}
\frac{\partial q_r}{\partial y^*}&=4(T^*-T_w^*)\int_0^\infty K\lambda_w w\left(\frac{de_{b\lambda}}{dT^*}\right)/d\lambda\\
&=4I_1(T^*-T_w^*)
\end{aligned} \tag{5}$$

The reduce the above equations in to non-dimensional form, let us introduce the following dimensionless variables and parameters

$$\begin{aligned}
&y=\frac{U_0 y^*}{\nu}, u=\frac{u^*}{U_0}, \theta=\frac{T^*-T_\infty^*}{T_W^*-T_\infty^*}, t=\frac{t^* U_0^2}{\nu}\\
&C=\frac{C^*-C_\infty^*}{C_W^*-C_\infty^*}, \Pr=\frac{\mu c_P}{K} \ \ K_C=\frac{\nu K_C^*}{U_0^2},\\
&S_c=\frac{\nu}{D}, F=\frac{4I_1\nu}{kU_0^2}, Gr=\frac{\nu g\beta_T(T_W^*-T_\infty^*)}{U_0^3},\\
&Gm=\frac{\nu g\beta_c(C_W^*-C_0^*)}{U_0^3}, M=\frac{\sigma B_0^2\nu}{\rho U_0^2}, K=\frac{U_0^2 K_P}{\nu}
\end{aligned} \tag{6}$$

With the help of Eq. (6), governing equations are Eq. (1) to Eq. (3) are reduced to

$$\frac{\partial u}{\partial t}=\frac{\partial^2 u}{\partial y^2}-Gr\theta-GmC-M_1U \tag{7}$$

where $M_1=M+\frac{1}{K}$

$$\Pr\frac{\partial\theta}{\partial t}=\frac{\partial^2\theta}{\partial y^2}-F\theta \tag{8}$$

$$S_C\frac{\partial C}{\partial t}=\frac{\partial^2 C}{\partial y}-K_c S_C C \tag{9}$$

The corresponding initial and boundary conditions in non dimensional form are

$$\begin{aligned}
&u=0, \theta=0, C=0 \ \text{ for all } \ y^*\geq 0, t^*\leq 0\\
&u=f(t), \theta=1, C=1 \ \text{ at } \ y=0, t^*>0\\
&u\to 0, \theta\to 0, C\to 0 \text{ as } \ y\to\infty, t^*>0
\end{aligned} \tag{10}$$

3. SOLUTION OF THE PROBLEM

In order to obtain the analytical solution of the system of differential Eq. (7) to Eq. (9) subject to the initial and boundary conditions Eq. (10), we shall use the Laplace transformation technique. Thus, the general solution of the present problem for the temperature $\theta(y,t)$, the velocity $u(y,t)$ and the concentration $C(y,t)$ for $t>0$ are given by

$$\theta(y,t)=\frac{1}{2}\left[\begin{matrix}e^{-y\sqrt{F_1}}erfc\left(\eta\sqrt{\Pr}-\sqrt{\frac{F_1}{\Pr}t}\right)\\+e^{y\sqrt{F_1}}erfc\left(\eta\sqrt{\Pr}+\sqrt{\frac{F_1}{\Pr}t}\right)\end{matrix}\right] \tag{11}$$

where $F_1=F+H$

$$C(y,t)=\frac{1}{2}\left[e^{-y\sqrt{S_cK_c}}erfc\left(\eta\sqrt{S_c}-\sqrt{K_ct}\right)+e^{y\sqrt{S_cK_c}}erfc\left(\eta\sqrt{S_c}+\sqrt{K_ct}\right)\right] \tag{12}$$

but

$$u(y,t)=\phi(y,t)+\psi(y,t) \tag{13}$$

$$\begin{aligned}
&\phi(y,t)=L^{-1}\left[\overline{f(s)}e^{-qy}\right], \ \ \overline{f(s)}=L\left[f(t)\right]\\
&\psi(y,t)=\frac{b}{c}(A+B-C+D)+\frac{e}{f}(E+F-G+H)
\end{aligned} \tag{14}$$

where

$$\begin{aligned}
&A=\frac{e^{-ct}}{2}\left[\begin{matrix}e^{-y\sqrt{M_1-c}}erfc\left(\eta-\sqrt{(M_1-c)t}\right)+\\e^{y\sqrt{M_1-c}}erfc\left(\eta+\sqrt{(M_1-c)t}\right)\end{matrix}\right]\\
&B=\frac{1}{2}\left[\begin{matrix}e^{-y\sqrt{F_1}}erfc\left(\eta\sqrt{\Pr}-\sqrt{\frac{F_1}{\Pr}t}\right)+e^{y\sqrt{F_1}}erfc\\\left(\eta\sqrt{\Pr}+\sqrt{\frac{F_1}{\Pr}t}\right)\end{matrix}\right]\\
&C=\frac{1}{2}\left[\begin{matrix}e^{-y\sqrt{M_1}}erfc\left(\eta-\sqrt{M_1t}\right)+e^{y\sqrt{M_1}}\\erfc\left(\eta+\sqrt{M_1t}\right)\end{matrix}\right]\\
&D=\frac{e^{-ct}}{2}\left[\begin{matrix}e^{-y\sqrt{F_1-c\sqrt{\Pr}}}erfc\left(\eta\sqrt{\Pr}-\sqrt{\left(\frac{F_1}{\Pr}-c\right)t}\right)+\\e^{y\sqrt{F_1-c\sqrt{\Pr}}}erfc\left(\eta\sqrt{\Pr}+\sqrt{\left(\frac{F_1}{\Pr}-c\right)t}\right)\end{matrix}\right]\\
&E=\frac{e^{-ft}}{2}\left[\begin{matrix}e^{-y\sqrt{M_1-f}}erfc\left(\eta-\sqrt{(M_1-f)t}\right)\\+e^{y\sqrt{M_1-f}}erfc\left(\eta+\sqrt{(M_1-f)t}\right)\end{matrix}\right]\\
&F=\frac{1}{2}\left[\begin{matrix}e^{-y\sqrt{S_cK_c}}erfc\left(\eta\sqrt{S_c}-\sqrt{K_ct}\right)+\\e^{y\sqrt{S_cK_c}}erfc\left(\eta\sqrt{S_c}+\sqrt{K_ct}\right)\end{matrix}\right]\\
&G=\frac{1}{2}\left[\begin{matrix}e^{-y\sqrt{M_1}}erfc\left(\eta-\sqrt{M_1t}\right)+\\e^{y\sqrt{M_1}}erfc\left(\eta+\sqrt{M_1t}\right)\end{matrix}\right]
\end{aligned} \tag{15}$$

$$H=\left[\frac{e^{-ft}}{2}\left[\begin{array}{l} e^{-y\sqrt{S_cK_c-fS_c}}\,erfc\left(\eta\sqrt{S_c}-\sqrt{(K_c-f)t}\right)\\ +e^{y\sqrt{S_cK_c-fS_c}}\,erfc\left(\eta\sqrt{S_c}+\sqrt{(K_c-f)t}\right)\end{array}\right]\right] \tag{15}$$

where $a=F-M_1, b=\frac{-Gr}{\Pr-1}, c=\frac{a}{\Pr-1}, d=S_cK_c-M_1, e=\frac{-Gm}{S_c-1}, f=\frac{d}{S_c-1}$.

Since non dimensional temperature $\theta(y,t)$ is clearly described in Eq. (11) and concentration $C(y,t)$ is clearly described in Eq. (12), so we shall confine ourselves to non-dimensional velocity $u(y,t)$ for various types of $f(t)$.

4. Application In Engineering

In this section, we now consider some important cases of flow as given below.

Case I: Motion of the plate with uniform velocity

Let $f(t)=H(t)$, Heaviside unit step function $\therefore \overline{f(s)}=L(f(t))=\frac{1}{s}$.

In this case, we observe that the result of Eq. (11) is an affected and Eq. (13) for $u(y,t)$ becomes

$$u(y,t)=\frac{1}{2}\left[\begin{array}{l} e^{-y\sqrt{M_1}}\,erfc\left(\eta-\sqrt{M_1t}\right)\\ +e^{y\sqrt{M_1}}\,erfc\left(\eta+\sqrt{M_1t}\right)\end{array}\right]+\psi(y,t) \tag{16}$$

where $\psi(y,t)$ is given from Eq. (14).

Case II: Motion of the plate with single acceleration

Let $f(t)=tH(t)$, Heaviside unit step function $\therefore \overline{f(s)}=L(f(t))=\frac{1}{s^2}$.

In this case, we observe that the result of Eq. (11) is an affected and Eq. (13) for $u(y,t)$ becomes

$$u(y,t)=\frac{1}{2}\left[\begin{array}{l} \left(t+\frac{y}{2\sqrt{M_1}}\right)e^{y\sqrt{M_1}}\,erfc\left(\eta+\sqrt{M_1t}\right)\\ +\left(t-\frac{y}{2\sqrt{M_1}}\right)e^{-y\sqrt{M_1}}\,erfc\left(\eta-\sqrt{M_1t}\right)\end{array}\right]+\psi(y,t) \tag{17}$$

Where $\psi(y,t)$ is given from Eq. (14).

Case III: Motion of the plate with periodic acceleration

For this case Let $f(t)=tH(t)$, Heaviside unit step function $\therefore \overline{f(s)}=L(f(t))=\frac{s}{s^2+w^2}$.

In this case, we observe that the result of Eq. (11) is an affected and expression (10) for $u(y,t)$ becomes

$$u(y,t)=\frac{1}{4}e^{i\omega t}\left[\begin{array}{l} e^{-y\sqrt{M_1+i\omega}}\,erfc\left(\eta-\sqrt{(M_1+i\omega)t}\right)+\\ e^{y\sqrt{M_1+i\omega}}\,erfc\left(\eta+\sqrt{(M_1+i\omega)t}\right)\end{array}\right]+ \frac{1}{4}e^{-i\omega t}\left[\begin{array}{l} e^{-y\sqrt{M_1-i\omega}}\,erfc\left(\eta-\sqrt{(M_1-i\omega)t}\right)+\\ e^{y\sqrt{M_1-i\omega}}\,erfc\left(\eta-\sqrt{(M_1-i\omega)t}\right)\end{array}\right]+\psi(y,t) \tag{18}$$

where $\psi(y,t)$ is given from Eq. (15).

It should be noted that our results of case (i) are identical with those of Mazundar and Deka (2007).

5. Skin Friction

Knowing the velocity field, we now study the effect of t, Pr, F, M, etc. on the skin friction. In the non dimensional form, it is given by

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

$$-\left(\frac{\partial\phi}{\partial y}\right)_{y=0}+\frac{b}{c}\left[\begin{array}{l} e^{-ct}\left[\begin{array}{l}\sqrt{(M_1-c)}\,erf\left(\sqrt{(M_1-c)t}\right)\\ +\frac{1}{\sqrt{\pi t}}e^{-(M_1-c)t}\end{array}\right]+\\ \left[\sqrt{F_1}\,erf\left(\sqrt{\frac{F_1}{\Pr}t}\right)+\frac{1}{\sqrt{\pi t}}e^{-\frac{F_1}{\Pr}t}\right]-\\ \left[\left[\sqrt{M_1}\,erf\left(\sqrt{M_1t}\right)+\frac{1}{\sqrt{\pi t}}e^{-M_1t}\right]+ e^{-ct}\left[\begin{array}{l}\sqrt{(F_1-c\sqrt{\Pr})}\,erf\left(\sqrt{\left(\frac{F_1}{\Pr}-c\right)t}\right)\\ +\frac{1}{\sqrt{\pi t}}e^{-\left(\frac{F_1}{\Pr}-c\right)t}\end{array}\right]\right]\end{array}\right]$$

$$\frac{e}{f}\left\{\begin{array}{l} e^{-ft}\left[\begin{array}{l}\sqrt{(M_1-f)}\,erf\left(\sqrt{(M_1-f)t}\right)+\\ \frac{1}{\sqrt{\pi t}}e^{-(M_1-f)t}\end{array}\right]+\\ \left[\sqrt{S_cK_c}\,erf\left(\sqrt{K_ct}\right)+\frac{1}{\sqrt{\pi t}}e^{-K_ct}\right]-\\ \left[\left[\sqrt{M_1}\,erf\left(\sqrt{M_1t}\right)+\frac{1}{\sqrt{\pi t}}e^{-M_1t}\right]+ e^{-ft}\left[\begin{array}{l}\sqrt{(S_cK_c-fS_c)}\,erf\left(\sqrt{(K_c-f)t}\right)\\ +\frac{1}{\sqrt{\pi t}}e^{-(K_c-f)t}\end{array}\right]\right]\end{array}\right\} \tag{19}$$

Case (I): When the plate is moving with uniform velocity, then

$$\left(\frac{\partial\phi}{\partial y}\right)_{y=0}=-\left[\sqrt{M_1}\,erf\left(\sqrt{M_1t}\right)+\frac{1}{\sqrt{\pi t}}e^{-M_1t}\right] \tag{20}$$

Case (II): When the plate is moving with single acceleration, then

$$\left(\frac{\partial\phi}{\partial y}\right)_{y=0} = -\left[\sqrt{M_1}\left(t+\frac{1}{2M_1}\right)erf\left(\sqrt{M_1 t}\right)+\frac{1}{\sqrt{\pi t}}e^{-M_1 t}\right] \quad (21)$$

Case (III): When the plate is moving with periodic acceleration, then

$$\left(\frac{\partial\phi}{\partial y}\right)_{y=0} = -\left\{\begin{array}{l}\left(\frac{1}{2\sqrt{t}}\left[\begin{array}{l}e^{i\omega t}\sqrt{(M_1+i\omega)t}\; erf\left(\sqrt{(M_1+i\omega)t}\right)+\\ e^{-i\omega t}\sqrt{(M_1-i\omega)t}\; erf\left(\sqrt{(M_1-i\omega)t}\right)\end{array}\right]\right)\\ +\sqrt{\frac{t}{\pi}}e^{-M_1 t}\end{array}\right\} \quad (22)$$

6. NUSSELT NUMBER

An important phenomenon in this study is to understand the effect of t, F and H on the Nusselt Number. In non-dimensional form, the rate of heat transfer is given by

$$Nu = -\left(\frac{\partial\theta}{\partial y}\right)_{y=0} = \sqrt{F_1}\, erf\left(\sqrt{\frac{F_1}{\Pr}t}\right)+\frac{1}{\sqrt{\pi t}}e^{-\frac{F_1}{\Pr}t} \quad (23)$$

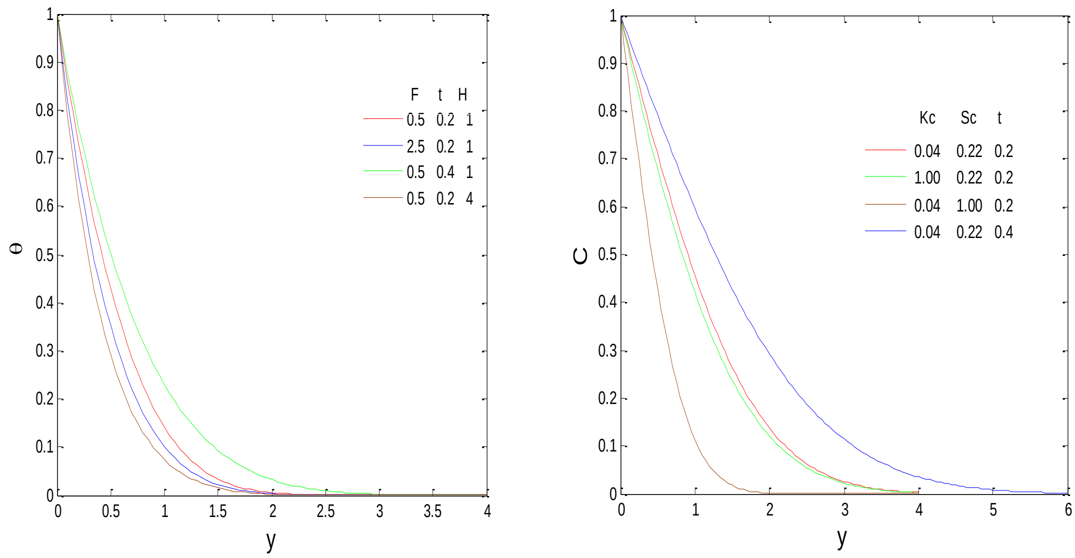
7. SHERWOOD NUMBER

An important phenomenon in this study is to understand the effect of t, S_c *and* K_c on the Sherwood Number. In non-dimensional form, the rate of mass transfer is given by

$$Sh = -\left(\frac{\partial C}{\partial y}\right)_{y=0} = \sqrt{S_c K_c}\, erf\left(\sqrt{K_c t}\right)+\frac{1}{\sqrt{\pi t}}e^{-K_c t} \quad (24)$$

8. RESULT AND DISCUSSION

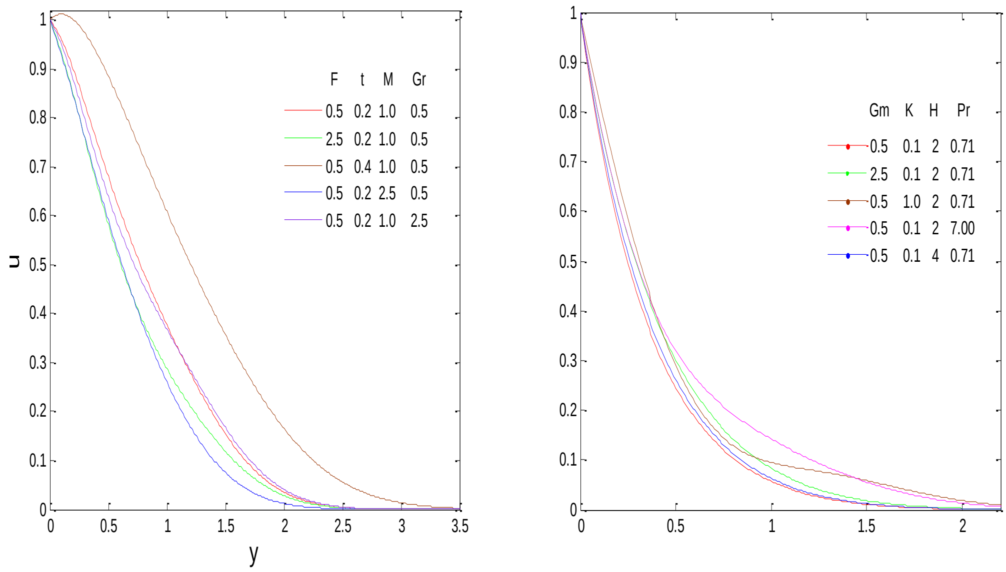
In order to get physical insight into problem, the numerical computations have been carried out and the influence of various physical parameters viz., magnetic parameter M, heat generation / absorption parameter H, time t, Grashof number Gr, modified Grashof number Gm, permeability parameter K, phase angle ωt, the chemical reaction parameter $K_{c,}$ Prandtl number Pr, Schmidt number Sc and Radiation parameter F on flow quantities. The values of Prandtl number are chosen Pr = 7 (water) and Pr = 0.71 (air). The values of Schmidt number are chosen to represent the presence of species by hydrogen (0.22), water vapor (0.60), ammonia (0.78), and Carbon dioxide (1.00). Figure 1(a) depicts the temperature profiles against y for different values of F, t, and H. The magnitude of the temperature is maximum at the plate and then decays to zero asymptotically. From this figure it is noticed that temperature decreases with the increase in F and H where as it shows different effect for t. Figure 1(b) represents the concentration profiles due to the variations in K_c, Sc and t. The concentration decreases with an increase in K_c and Sc and it shows the reverse effect in case of t. further, it is noticed that the concentration is maximum at the surface and falls exponentially.



(a) (b)

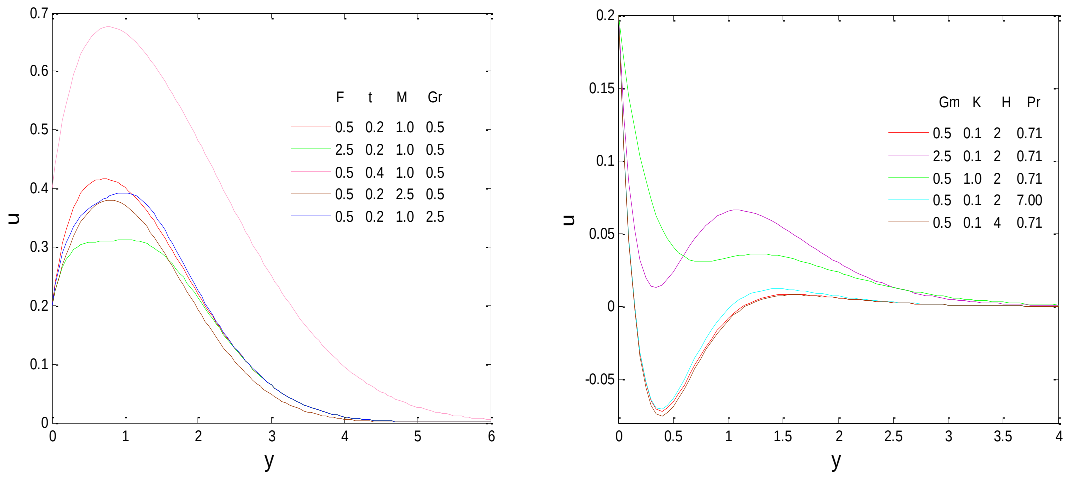
Fig. 1. Temperature (a) and concentration (b) profiles with the variations in F, t, H, Kc, Sc, t and for fixed values of Pr=0.71, M=1,Gr = 0.5, Gm=0.5, K=1.

Figures 2(a) and 2(b) correspond to the plates moving uniform velocity, Figs. 3(a) and 3(b) corresponds to plates moving with single acceleration and Figs. 4(a) and 4(b) correspond to the periodic acceleration. From these figures it is evident that the magnitude of the velocity near the plate exceeds and at the plate the velocity shoot occurs. An increase in Gm, t, K, Pr and H results in an increase in the velocity. It is due to fact that increases in the values modified Grashof number has the tendency to increase thermal and mass buoyancy effect. This gives rise to an increase in the induced flow. The reverse effect is observed in case of Gr, M and F, it is because of the application transverse magnetic field which results a Lorentz force similar to drag force that tends to resist fluid flow and thus reduces it velocity. Figures 5(a), 5(b) and 5(c) depict skin friction against time t for different values of physical parameters. It is observed that skin friction decreases with an increase in M and F but it shows reverse effect in the case of Gr and Gm. Variations in Nusselt number against t for different values of F and H are presented in Fig. 6. Nusselt number increases with the increase in both F and H. Effect of chemical reaction on Sherwood number is displayed in Fig. 7. From this figure it is observed that Sherwood number increases with the increase in chemical reaction parameter.



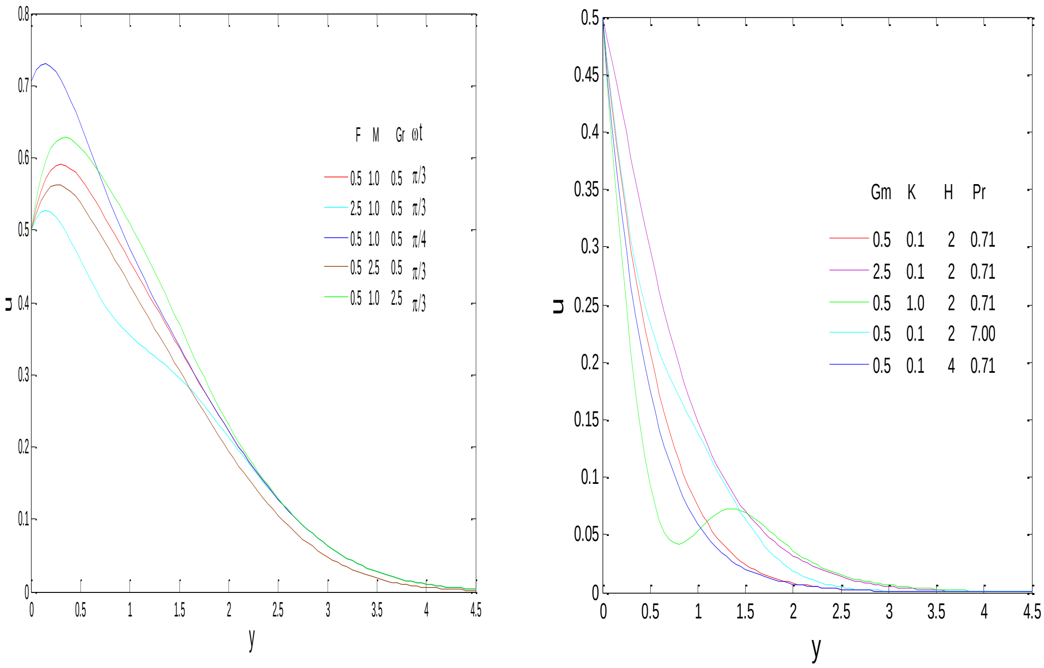
(a) (b)

Fig. 2. Velocity profiles, when the plate is moving with Uniform velocity in variations of F, t, M,Gr ,Gm,K,H and Pr for fixed values of Kc =1, Sc=0.22.



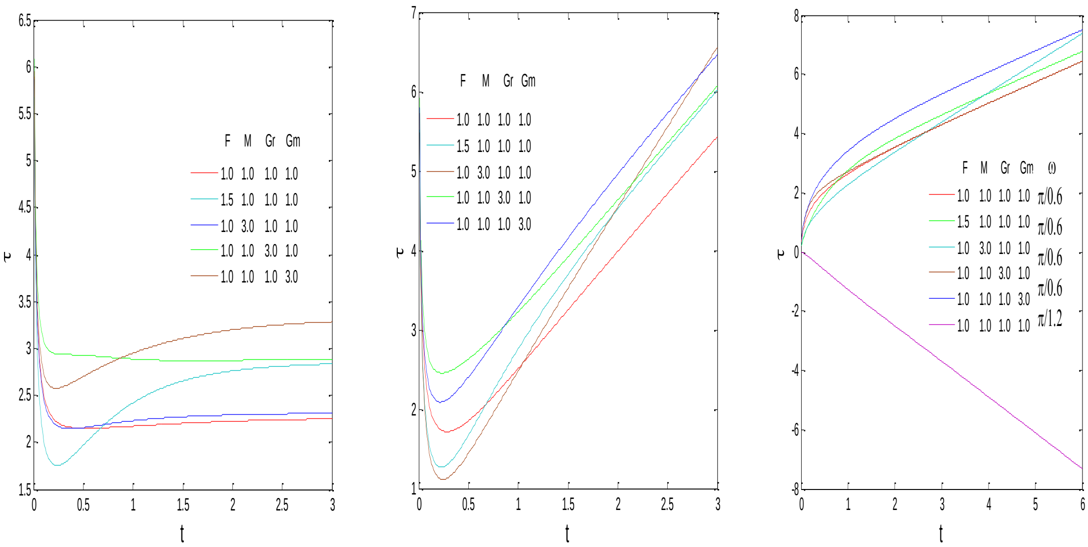
(a) (b)

Fig. 3. Velocity profiles, when the plate is moving with Single acceleration in variations of F, t, M, Gr Gm, K, H, and Pr, for fixed values of Kc =1, Sc=0.22.



(a) (b)

Fig. 4. Velocity profiles, when the plate is moving with periodic acceleration in variations of ωt, F, t, M, Gm, K, H, and Pr for fixed values of Pr=0.71, Kc =1, Sc=0.22.



(a) (b) (c)

Fig. 5. Skin friction for uniform velocity (a),(b) and for single acceleration (c).

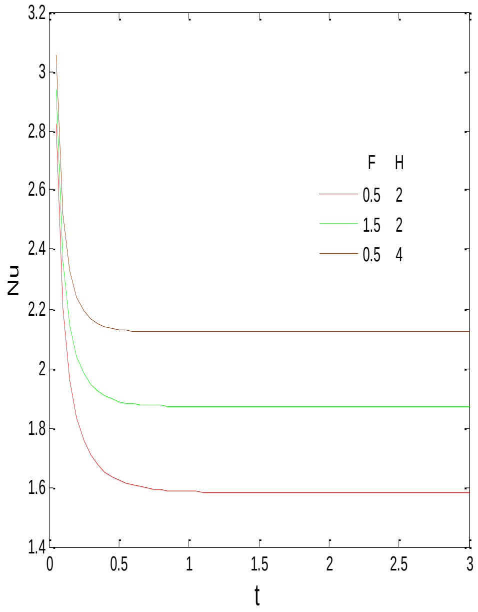


Fig. 6. Nusselt number

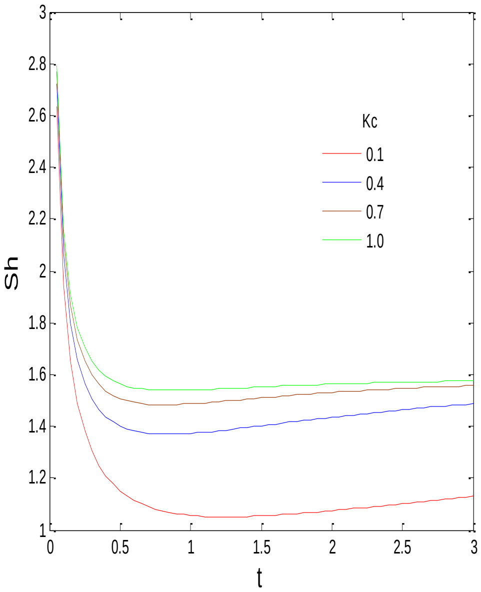


Fig. 7. Sherwood number

9. CONCLUSION

In this paper, an analytical solution of combined effect of heat generation or absorption and homogeneous chemical reaction on unsteady MHD free convection flow near a moving vertical plate through a porous medium in presence of thermal radiation. A general exact solution for the partial differential equations governing the flow is obtained with the aid of the usual Laplace transform technique. Also the applications of general solution for the important cases of the flow are discussed. Also a physical example for evolution of numerical values of the velocity, temperature and concentration is considered. From this study the following conclusions are made

a. The concentration decreases with an increase in K_c and Sc and it shows the reverse effect in case of t.

b. Temperature decreases with the increase in F and H where as it shows different effect for t.

c. Increase in Gm, t, K, Pr and H results in an increase in the velocity and the reverse effect is observed in case of Gr, M and F

d. Skin friction decreases with an increase in M and F but it shows reverse effect in the case of Gr and Gm.

e. Nusselt number increases with the increase in both F and H.

f. Sherwood number increases with the increase in chemical reaction parameter.

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