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UNSTEADY MHD ROTATING AND CHEMICALLY REACTING FLUID FLOW OVER AN OSCILLATING VERTICAL SURFACE IN A DARCIAN POROUS REGIME

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ABSTRACT

An unsteady mixed convection flow of an electrically conducting, viscous, incompressible fluid over an oscillating vertical surface in a Darcian porous regime in presence of heat generation/absorption and thermal radiation have been studied. The liquid and the surface is moving with constant angular velocity as a rigid body about an axis. The fluid is taken here to be gray, absorbing/emitting radiation but non scattering medium. Here first-order chemical reaction and a transverse magnetic field have been considered. The presence of Hall current and Soret effect are considered. The governing coupled partial differential equations are solved by using Laplace transform technique for velocity, temperature and concentration profiles. The effect of relevant parameters on velocity, temperature and concentration profiles are discussed and presented graphically. It is noticed that fluid velocity enhances due to rising Soret number, while Schmidt number, Prandtl number and radiation parameter reduces the velocity adjacent to the vertical surface. Prandtl number reduces the rate of heat transfer, while it increases the rate of mass transfer inside the boundary layer.

Keywords: MHD, rotating fluid, Soret effect, Hall current, Laplace transform.

1. INTRODUCTION

The study of heat and mass transfer of an unsteady magnetohydrodynamic flow with porous and non-porous medium is prevalent in many natural phenomena and industrial applications. Due to its application in diverse field of science and technology several authors have studied in this line. The heat and mass transfer effects on the flow along a vertical plate in the presence of magnetic field was investigated by Elbashbeshy (1997). Acharya et al. (2000) studied the magnetic field effect on the free convection and mass transfer flow. Jaiswal and Soundalgekar (2001) obtained an approximate solution to the problem of an unsteady flow past an infinite vertical porous plate with constant suction and embedded in a porous medium. Electrically conducting, rotating flow of fluid in presence of magnetic field is an important branch in solar physics dealing with the sunspot development, the solar cyclic and the structure of rotating magnetic stars. Takhar et al. (2002), The applications of the effect of Hall current on the fluid flow with variable concentration have seen in MHD power generators, astrological and metrological studies as well as plasma physics. The effects of Hall current on MHD convection flow past a semi-infinite vertical plate with mass transfer have been studied by Aboldahab et al. (2001). Muthucumarswamy et al. (2003) reveals chemical reaction effect on the flow over an infinite vertical plate with uniform heat flux and variable mass diffusion. Kim (2004)) studied heat and mass transfer effects in MHD micropolar fluid over a vertical moving porous plate in a porous medium. Chen (2004) investigated the effects of heat and mass transfer in MHD free convection from a vertical surface. Rapist (2004) studied an unsteady flow through highly porous medium in presence of thermal radiation. Heat transfers on MHD oscillatory flow in asymmetric wavy channel have studied by Muthuraj et al. (2010). Several authors (Sengupta and Karmakar (2018a), Sengupta and Karmakar (2018b), Sharma et al. (2019),) Mohammad (2020) studied in this line.

In many situations Hall current was ignored during the application of Ohm's law because it has no significant impact for small values of the strength of magnetic field. For strong magnetic field the electromagnetic forces are prominent and Hall current in this case is very important (Crammer et al. (1973)). The effect of Hall current is encountered in some engineering applications of heat transfer on MHD flows such as MHD pumps and power generators, Hall accelerators, plasma actuator control of hypersonic flows, flight MHD, oil extraction, flow through filtering devices, thermal energy storage and heat exchangers in porous material. The importance of Hall effect on MHD fluid flow over a vertical surface with different geometry and conditions have been carried out by several researchers. The authors (Pop and Watanabe (1994), Aboeldahab and Elbarbary (2001), Deka (2008), Singh and Gorla (2009), Seth et al. (2013, 2017), Sreedevi et al. (2016), Veera Krishna (2018) are investigated the impact of Hall effect on MHD flow near a vertical plate by considering various conditions of the problem. Recently, Krishna (Krishna and Chamkha (2019)) studied the effects of Hall and ion slip on MHD boundary layer flow of a nanofluid past an infinite vertical plate. Ramzan (Ramzan et al. (2020)) studied the significance of Hall current in a three-dimensional bioconvective tangent hyperbolic nanofluid flow subject to Arrhenius activation energy. Ganesh and Sridhar (2021) studied the Hall effect for Casson fluid in presence of chemical reaction.

The phenomena of chemical reaction and the impact of Soret and dufour effects in various geometrical situations were studied and

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presented by the authors (Hayat et al. (2009), Anjalidevi et al. (2010), Mustafa et al. (2012), Mukhophadhyay et al. (2013), Sengupta (2013), Shehzad et al. (2015), Vedavathi et al. (2015), Karthikeyan et al. (2016), Saidulu and Venkatal (2016), Postelnicu (2020), Kumar et al. (2020).

In this paper our objective is to study the heat and mass transfer effects on an unsteady mixed convective MHD flow of an incompressible rotating fluid over an oscillating vertical surface in a Darcian porous regime incorporating Hall current with heat generation/absorption and thermal radiation. The present paper is an extension of the work done by Sharma et al. (2019) by incorporating the Hall effect with an osculating plate.

2. MATHEMATICL ANALYSIS

Consider an unsteady MHD flow of an incompressible electrically conducting and first-order chemically reacting Newtonian fluid in a rotating system incorporating heat source and Hall current over an oscillating vertical surface in a Darcian porous regime. The x^* - axis is taken vertically upward along the plate and y^*- axis is normal to it as shown in Fig.1. Here it is assumed that the liquid and the sheet is rotating like a rigid body with an angular velocity Ω^* (constant) about y^* -axis and a transverse magnetic field of strength $B_0$is applied. At $t^* > 0$, an oscillatory motion is given in its own plane with a velocity $U_p cos\,(\omega^* t^*)$ and at that time the plate temperature and the diffusion of mass from the plate are raised linearly.

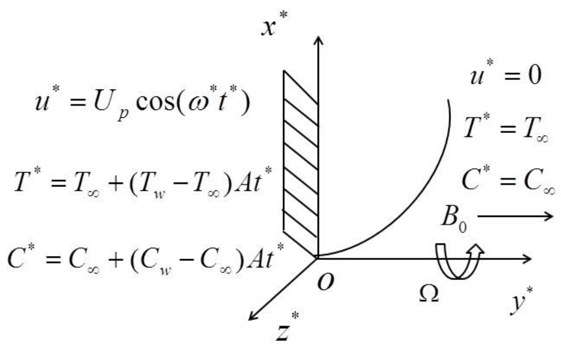

Fig. 1 Physical model of the problem

Then, the governing equations of the motion, following Sharma et al. [2019] become

$$\frac{\partial u^*}{\partial t^*} - 2\Omega^* v^* = \upsilon \frac{\partial^2 u^*}{\partial y^{*2}} + g\beta_T(T^* - T_\infty) + g\beta_C(C^* - C_\infty) - \sigma \frac{\beta_O{}^2(u^* + mv^*)}{\rho(1+m^2)} - \frac{\upsilon}{K^*}u^* \tag{1}$$

$$\frac{\partial v^*}{\partial t^*} + 2\Omega^* u^* = \upsilon \frac{\partial^2 v^*}{\partial y^{*2}} + \sigma \frac{\beta_0{}^2(mu^* - v^*)}{\rho(1+m^2)} - \frac{\upsilon}{K^*}v^* \tag{2}$$

$$\rho C_p \frac{\partial T^*}{\partial t^*} = K \frac{\partial^2 T^*}{\partial y^{*2}} - \frac{\partial q_r}{\partial y^*} - Q_O(T^* - T_\infty) \tag{3}$$

$$\frac{\partial C^*}{\partial t^*} = D_M \frac{\partial^2 C^*}{\partial y^{*2}} + D_1 \frac{\partial^2 T^*}{\partial y^{*2}} - Kr^*(C^* - C_\infty). \tag{4}$$

With boundary condition

$$t^* \le 0: u^* = 0, T^* = T_\infty\,,\ C^* = C_\infty \qquad \forall y^* = 0$$

$$t^* > 0:\ u^* = U_p cos(\omega^* t^*),\ T^* = T_\infty + (T_w - T_\infty)At^*,$$

$$C^* = C_\infty + (C_w - C_\infty)At \qquad at\ \ y^* = 0 \tag{5}$$

$$u^* \to 0, T^* \to T_\infty, C^* \to C_\infty \qquad at\ \ y^* \to \infty$$

The radiative heat flux for optically thin fluid is given as

$$\frac{\partial q_r}{\partial y^*} = 4I(T^* - T_\infty) \tag{6}$$

where $I = \int_0^\infty (K_\lambda)_w \left(\frac{\partial e_{\lambda h}}{\partial T^*}\right)_w^* d\lambda$ (7)

The radiative heat flux for optically thin fluid is given as

In view of equation (6), equation (3) becomes

$$\rho C_p \frac{\partial T^*}{\partial t^*} = K \frac{\partial^2 T^*}{\partial y^{*2}} - 4I(T^* - T_\infty) - Q_O(T^* - T_\infty) \tag{8}$$

we introduce the following dimensionless variable

$$u = \frac{u^*}{U_p},\ v = \frac{v^*}{U_p},\ t = \frac{t^* U_0{}^2}{v},\ y = \frac{y^* U_0}{v},\quad A = \frac{U_p^2}{v},\ Gr = \frac{g\beta_T v(T_w - T_\infty)}{U_p^3},$$
$$Gm = \frac{g\beta_c v(C_w - C_\infty)}{U_p{}^3},\ \Omega^* = \frac{\Omega^* v}{U_0{}^2},\quad M = B_0\sqrt{\frac{\sigma v}{\rho U_p{}^2}},\quad \theta = \frac{(T^* - T_\infty)}{(T_w - T_\infty)},$$
$$C = \frac{(C^* - C_\infty)}{(C_w - C_\infty)},\ l = \frac{v}{U_{p0}},\ F_1 = \frac{Q_0 l^2}{\rho C_p v},\ Kr = \frac{Kr^* l^2}{v},\ Sc = \frac{v}{D_M},$$
$$Pr = \frac{\rho C_p v}{K}, \omega = \frac{\omega^* v}{U_p^2},\ So = \frac{D_1(T_w - T_\infty)}{(C_w - C_\infty)}, F = \frac{4Iv}{\rho C_p U_0{}^2} \tag{9}$$

Using (9), equation (1) - (4) becomes

$$\frac{\partial u}{\partial t} - 2\Omega u = \frac{\partial^2 u}{\partial y^2} + Gr\theta + GmC - M^2\frac{(u+mv)}{(1+m^2)} - \frac{u}{K} \tag{10}$$

$$\frac{\partial v}{\partial t} + 2\Omega u = \frac{\partial^2 v}{\partial y^2} + M^2\frac{(mu-v)}{(1+m^2)} - \frac{v}{K} \tag{11}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial y^2} - N\theta \tag{12}$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} + So\frac{\partial^2 \theta}{\partial y^2} - KrC \tag{13}$$

The boundary condition (5) becomes

$$t \le 0: u = 0, v = 0 \qquad \forall\, y$$

$$t > 0: u = cos(wt),\ \ \theta = t, C = t \qquad at\ \ y = 0$$

$$u \to 0, \theta \to 0, C \to 0 \qquad at\ y \to \infty \tag{14}$$

Now, simplifying (10) and (11) by introducing $q = u + iv$, the equations (10)-(13) becomes

$$\frac{\partial q}{\partial t} + i2\Omega q = \frac{\partial^2 q}{\partial y^2} + Gr\theta + GmC + M^2\frac{(im-1)}{(1+m^2)}q - \frac{q}{K} \tag{15}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial y^2} - N\theta \tag{16}$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} + So\frac{\partial^2 \theta}{\partial y^2} - KrC \tag{17}$$

where $N = F + F_1$
The boundary condition (14) becomes

$$t \le 0: q = 0, \theta = 0, C = 0, \qquad \forall\, y$$

$$t > 0:\ q = cos(\omega t), \theta = t, C = t \qquad at\ \ y = 0;$$
$$q \to 0, \theta \to 0, C \to 0 \qquad at\ \ y \to \infty \tag{18}$$

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3. METHOD OF SOLUTIONS

The simplified non-dimensional equations (15) to (17) with their boundary conditions (18) are solved through Laplace transform technique to obtain the expression for velocity, temperature and concentrations. The expressions are obtained as

$$\theta(y,t) = \frac{1}{2}[\left(t + \frac{y}{2}\frac{Pr}{\sqrt{N}}\right)\exp\left(y\sqrt{PrN}\right)\operatorname{erfc}\left(\frac{y}{2}\sqrt{\frac{Pr}{t}} + \sqrt{\frac{Nt}{Pr}}\right) + \left(t - \frac{y}{2}\frac{Pr}{\sqrt{N}}\right)\exp\left(-y\sqrt{PrN}\right)\operatorname{erfc}\left(\frac{y}{2}\sqrt{\frac{Pr}{t}} - \sqrt{\frac{Nt}{Pr}}\right)] \quad (19)$$

$$C(y,t) = \frac{B_2}{2}\left[\exp\left(-y\sqrt{ScKr}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Sc}{t}} - \sqrt{Krt}\right) + \exp\left(y\sqrt{ScKr}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Sc}{t}} + \sqrt{Krt}\right)\right] + \frac{B_3}{2}\left[\left(t + \frac{y}{2}\sqrt{\frac{Sc}{Kr}}\right)\exp\left(y\sqrt{ScKr}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Sc}{t}} + \sqrt{Krt}\right) + \left(t - \frac{y}{2}\sqrt{\frac{Sc}{Kr}}\right)\exp\left(-y\sqrt{ScKr}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Sc}{t}} - \sqrt{Krt}\right)\right] + \frac{B_4}{2}\left[\exp\left(-y\sqrt{PrN}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Pr}{t}} - \sqrt{Nt}\right) + \exp\left(y\sqrt{PrN}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Pr}{t}} + \sqrt{Nt}\right)\right] + \frac{B_5}{2}\begin{bmatrix}\left(t + \frac{y}{2}\sqrt{\frac{Pr}{N}}\right)\exp\left(y\sqrt{PrN}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Pr}{t}} + \sqrt{Nt}\right) + \\ \left(t - \frac{y}{2}\sqrt{\frac{Pr}{N}}\right)\exp\left(-y\sqrt{PrN}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Pr}{t}} - \sqrt{Nt}\right)\end{bmatrix} \quad (20)$$

$$q(y,t) = \exp(A_4 t) + \frac{X_1}{2}\left[\exp\left(-y\sqrt{-B_1}\right) erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{-B_1 t}\right) + \exp\left(y\sqrt{-B_1}\right) erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{-B_1 t}\right)\right] - \frac{Z_9}{2}\left[\left(t + \frac{y}{2\sqrt{-B_1}}\right)\exp\left(y\sqrt{-B_1}\right) erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{-B_1 t}\right) + \left(t - \frac{y}{2\sqrt{-B_1}}\right)\exp\left(y\sqrt{-B_1}\right) erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{-B_1 t}\right)\right] + \frac{X_2}{2}\left[\exp\left(-y\sqrt{ScPr}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Sc}{t}} - \sqrt{Krt}\right) + \exp\left(y\sqrt{ScKr}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Sc}{t}} + \sqrt{Krt}\right)\right] + \frac{Z_9}{2}\left[\left(t + \frac{y}{2}\sqrt{\frac{Sc}{Kr}}\right)\exp\left(y\sqrt{ScKr}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Sc}{t}} + \sqrt{Krt}\right) + \left(t - \frac{y}{2}\sqrt{\frac{Sc}{Kr}}\right)\exp\left(-y\sqrt{ScKr}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Sc}{t}} - \sqrt{Krt}\right)\right] + \frac{X_3}{2}\left[\exp\left(-y\sqrt{PrN}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Pr}{t}} - \sqrt{Nt}\right) + \exp\left(y\sqrt{PrN}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Pr}{t}} + \sqrt{Nt}\right)\right] + \frac{Z_{16}}{2}\left[\left(t + \frac{y}{2}\sqrt{\frac{Pr}{N}}\right)\exp\left(y\sqrt{PrN}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Pr}{t}} + \sqrt{Nt}\right) + \left(t - \frac{y}{2}\sqrt{\frac{Pr}{N}}\right)\exp\left(-y\sqrt{PrN}\right) erfc\left(\frac{y}{2}\sqrt{\frac{Pr}{t}} - \sqrt{Nt}\right)\right] \quad (21)$$

where

$A_1 = \frac{SoScPr}{(Pr-Sc)}$

$A_2 = \frac{(PrN-ScKr)}{(Sc-\Pr)}$

$A_3 = \frac{SoScPrN}{(Pr-Sc)}$

$A_4 = \omega^2 + B_1$

$B_1 = (i\frac{imM}{1+m^2} - \left(\frac{M}{1+m^2}\right) - 2i\Omega) - (1/K)$

$B_2 = \left(\frac{A_1}{A_2} + \frac{B_5}{A_2}\right)(e^{A_2 t} - 1)$

$B_3 = 1 - B_5$

$B_4 = \frac{A_1}{A_2}(1 - e^{A_2 t}) + B_5\left(e^{A_2 t} - \frac{1}{A_2}\right)$

$B_5 = \frac{A_3}{A_2}$

$B_6 = \frac{Gr}{(1-Sc)}$

$B_7 = \frac{Gm}{(1-Sc)}$

$B_8 = \frac{A_1}{(1-Sc)}$

$B_9 = Sc\ Kr + \frac{B_1}{(1-Sc)}$

$B_{10} = \frac{(\Pr N + B_1)}{(1-Pr)}$

$B_{11} = \frac{A_3}{(1-Sc)}$

$B_{12} = \frac{A_1}{(Pr-1)}$

$B_{13} = \frac{A_3}{(Pr-1)}$

$Z_1 = U_p\cos(\omega t)$

$Z_2 = \frac{B_7}{B_9} - \frac{B_8}{A_2 B_9} - \frac{B_{12}}{A_2 B_{10}}$

$Z_3 = \frac{B_{11}(A_2+B_9)}{(A_2{}^2 B_9{}^2)}$

$Z_4 = \frac{B_{12}(A_2+B_{10})}{(A_2{}^2 B_{10}{}^2)}$

$Z_5 = \frac{(A_2 B_8 + B_{11})}{A_2{}^2(A_2-B_9)}$

$Z_6 = \frac{(A_2 B_{12} + B_{13})}{(A_2{}^2(A_2-B_{10})}$

$Z_7 = B_6 + \frac{B_7}{B_9} + \frac{(B_8 B_9 + B_{11})}{(B_9{}^2(B_9-A_2)}$

$Z_8 = \frac{(B_{12}B_{10}+B_{13})}{(B_{10}{}^2(B_9-A_2)}$

$Z_9 = \frac{B_{11}}{(A_2 B_9)}$

$Z_{10} = \frac{B_7}{B_9}\left(\frac{B_8}{(A_2 B_9}\right) + \frac{(B_{11}(A_2+B_9))}{(A_2{}^2 B_9{}^2)}$

$Z_{11} = \frac{(B_8 A_2 + B_{11})}{B_7 B_9} + (A_2 - B_9)A_2{}^2$

$Z_{12} = \frac{A_2 B_{10} B_{12} + B_{13}(A_2+B_{10})}{(A_2{}^2 B_9{}^2)}$

$Z_{13} = \frac{(A_2 B_{12} + B_{13})}{(A_2-B_{10})(A_2{}^2)}$

$Z_{14} = \frac{(B_{10}B_{12}+B_{13})}{(B_{10}-A_2)B_{10}{}^2}$

$Z_{15} = \frac{B_{13}}{(A_2 B_{10})}$

$X_1 = Z_1 + Z_2 - Z_3 - Z_4 - (Z_1\exp(A_4 t)) - (Z_5 + Z_6)\exp(A_2) - (Z_7\exp(B_9 t)) - (Z_8\exp(B_{10} t)$

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$X_2 = Z_{10} + (Z_7 \exp(B_9 t)) + (B_{11} \exp(A_2 t))$
$X_3 = Z_{12} + (Z_{13} \exp(A_2 t)) + (B_{14} \exp(B_{10} t))$

NUSSELT NUMBER: The rate of heat transfer at the plate in terms of Nusselt number *(Nu)* is $Nu = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0}$

SHERWOOD NUMBER: Mass transfer coefficient at the plate in terms of Sherwood number *(Sh)* is $Sh = -\left(\frac{\partial C}{\partial y}\right)_{y=0}$

4. RESULTS AND DISCUSSIONS

We study the flow problem for velocity, temperature and concentration profiles. For numerical computation we assign some fixed values to *Sc=0.66*, which represent for oxygen, *Pr*=0.71, which represent for air. The other parameters for numerical calculation are considered as *So=0.01, N=0.2*, *Gr*=1, *Gm*=1, *M=0.001*, *m=0.01, Kr*=0.3, K=0.01, ω=0.01, Ω=0.0001, $U_p = 0.951$ Figures 2-6 represent the velocity profiles for different values of Soret number *(So),* Schmidt number *(Sc),* Prandtl number (*Pr*), resultant of thermal radiation parameter and heat source/sink parameter *(N)*, Grashof number for mass transfer *(Gm)* respectively.

From Fig. 2, it is observed that velocity increases sharply in vicinity of the plate and then gradually decreases to zero with an increasing value of Soret number for *So*=0.01 to *So*=1.01 through *So*=0.06. From Fig. 3, it is observed that fluid velocity reduces due to a reduction in Schmidt number. As Schmidt number represent the ratio of momentum diffusivity to mass diffusivity, and so the reduction in Schmidt number reduces the momentum diffusivity. Consequently, reduces the velocity and momentum boundary layer. Fig. 4 shows that the decreasing Prandtl number reduced the velocity of the fluid. Fig. 5 shows that the total impact of thermal heat radiation and heat/source parameter on fluid is to reduce the velocity. To distinctly observe the variation in velocity for figures 3-5, a magnified view of each figure has been drawn inside the figures. Fig.6 shows that the velocity of the fluid increases with the increasing values of solutal Grashof number.

Fig. 7 and 8 represents the concentration profile for various values of Schmidt number and chemical reaction parameter respectively. Fig.7 shows that the concentration profile decreases for increasing values of Schmidt number. Also, Fig.8 shows that the concentration profile decreases for increasing values of chemical reaction parameter from $Kr = 0.5$ to $Kr = 1.5$ through $= 1$.

Fig. 9 depicts that the fluid temperature decreases with increasing value of Prandtl number. This might be due to the fact that thermal conductivity of fluid decreases with increasing Prandtl number, resulting in decrease in thermal boundary layer thickness.

For the tables we assigned the following default values to the parameters

t=1, Pr=0.71, Sc=0.66, So=0.01, K=0.01, M=0.001, m=0.01, N=0.2, Kr=0.3, Gr=1, Gm=1, $w = 0.01,\ \Omega = 0.0001$

Table 1 shows the variation on Nusselt number. It is observed that Nusselt number decreases with a decrease in *Pr* while it increases with an increasing in radiation parameter.

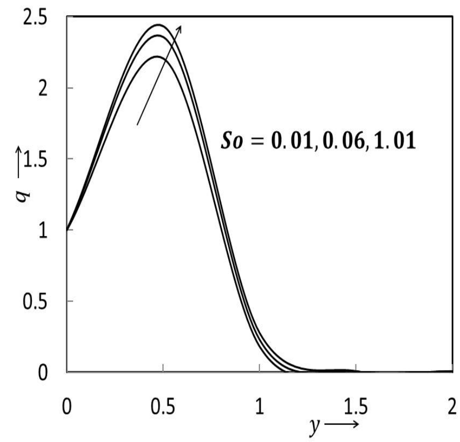

Fig. 2 Velocity profile for Soret number So

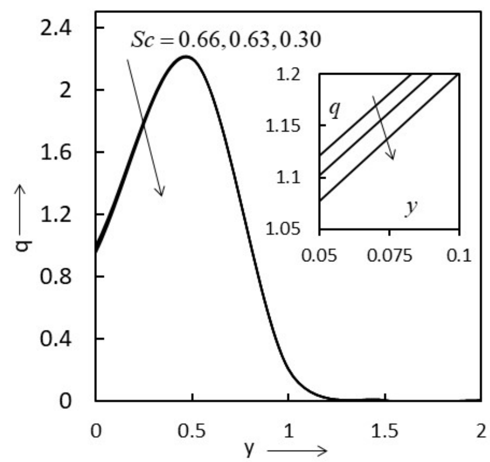

Fig. 3 Velocity profile for Schmidt number Sc

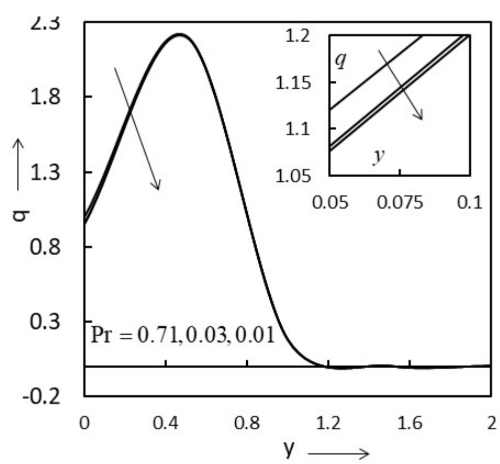

Fig. 4 Velocity profile for Prandtl number Pr

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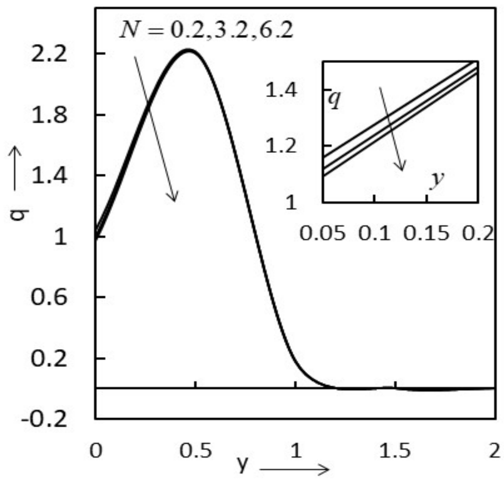

Fig. 5 Velocity profile for thermal radiation parameter *N*.

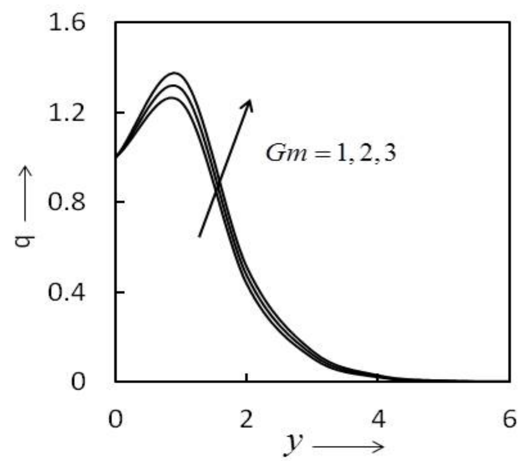

Fig. 6 Velocity profile for Grashof number Gm

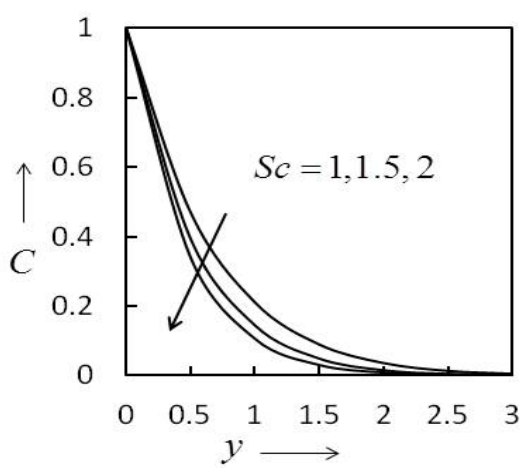

Fig. 7 Concentration profile for Schmidt number Sc with $Kr = 1, t = 1$.

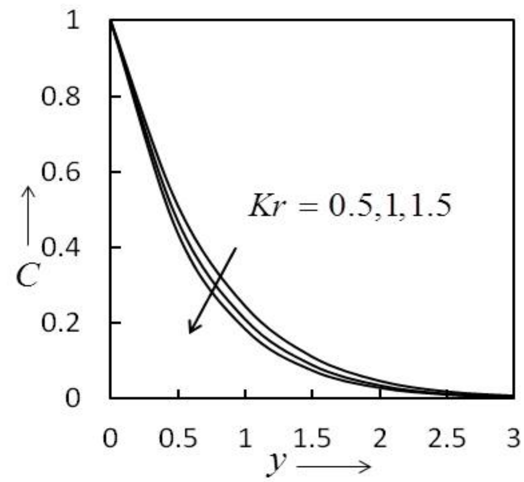

Fig. 8 Concentration profile for Schmidt number $Kr = 1, t = 1$.

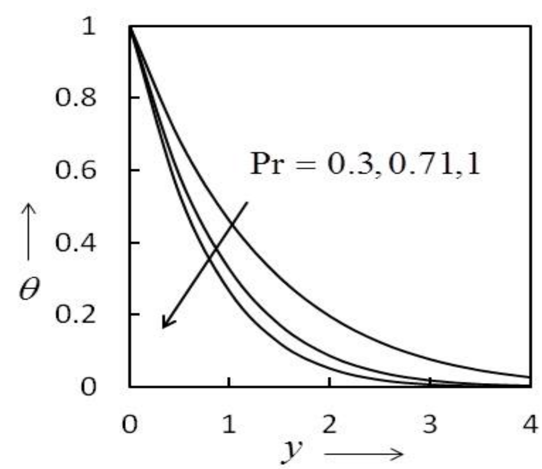

Fig. 9 Temperature profile for Prandtl number with $t = 1$.

Table 2 shows the variation in Sherwood number. It is seen that Sherwood number increases with an increasing in *N, Sc* and *So*, but it decreases with an increasing in *Pr* and Kr.

TABLE: 1 Variation in Nusselt Number (Nu).

Pr	*N*	*Nu*
0.71	0.2	1.4388
0.03	0.2	0.2713
0.01	0.2	0.1565
0.71	3.2	1.7487
0.71	6.2	2.2674

TABLE: 2 Variation in Sherwood Number *(Sh)*

Pr	*N*	*Sc*	*Kr*	*So*	*Sh*
0.71	0.2	0.66	0.03	0.01	0.0021
0.03	0.2	0.66	0.03	0.01	- 0.0722
0.01	0.2	0.66	0.03	0.01	- 0.0885
0.71	3.2	0.66	0.03	0.01	0.0026
0.71	6.2	0.66	0.03	0.01	0.0030
0.71	0.2	0.63	0.03	0.01	0.0044
0.71	0.2	0.30	0.03	0.01	0.0345
0.71	0.2	0.66	3.03	0.01	0.0120
0.71	0.2	0.66	6.03	0.01	- 0.0332
0.71	0.2	0.66	0.03	0.06	0.0022
0.71	0.2	0.66	0.03	1.01	0.0034

5. CONCLUSIONS

Above study led to the following conclusions:

(i) Fluid velocity increases when Soret number Schmidt number, Prandtl number and solutal Grashof number are increases, whereas it decreases with increasing value of thermal radiation parameter.
(ii) Concentration profile can be decreased by increasing Schimdt number and chemical reaction parameter.
(iii) Temperature profile can be increased by decreasing Prandtl number.
(iv) The rate of mass transfer can be decreased by increasing any one of the parameters from Schmidt number and chemical reaction parameter, while it may be increased by increasing Prandtl number, radiation parameter, and Soret number.

NOMENCLATUR

B_O Strength of the applied magnetic field
C_p Specific heat at constant pressure
C^* Dimensional concentration of solute
$C_w{}^*$ Concentration away from the wall
$C_\infty{}^*$ Concentration of solute far away from the plate
D_M coefficient of chemical molecular diffusivity
g Acceleration due to gravity
Gr Grashof number for heat transfer
Gm Grashof number for mass transfer
K Thermal conductivity
Kr Rate of chemical reaction
m Hall parameter
M Magnetic field parameter
N Thermal radiation parameter
Nu Nusselt Number
Pr Prandtl number
q Velocity
q_r Radiative heat flux
Q_o Heat Source
Sc Schmidt number
So Soret number
t Dimensionless time
t^* Time
T^* Fluid temperature
T_w Wall Temperature
T_∞ Free steam dimensional temperature
U_p positive constant
V_O Suction velocity constant
(x, y) Dimensionless Cartesian co-ordinates
(x^*, y^*) Cartesian co-ordinates
(u, v) Components of dimensionless velocities along x, y-axes respectively
(u^*, v^*, w^*) Components of dimensionless velocities along x^*-, y^*- and z^*- axes respectively

GREEK SYMBOLS

β Dimensionless viscosity
β_c Co-efficient of concentration expansion
β_T Coefficient of thermal expansion
μ Co-efficient of viscosity
ϑ Kinamatic viscosity
Ω Angular velocity
ρ Density of the
σ Electrical conductivity
σ^* Stefan- Baltzman constant
θ Dimensionless temperature

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