

**Research Article****Heat Transfer of a Heat Generation MHD Fluid Flow Over a Vertical Porous Flat Plate in a Rotating System**Md. Mizanur Rahman<sup>1\*</sup>, Md. Asaduzzaman<sup>1</sup>, Md. Anisur Rahman<sup>1</sup>, Shamima Aktar<sup>2</sup><sup>1</sup>Department of Mathematics, Faculty of applied science and Technology, Islamic University, Kushtia-7003, Bangladesh<sup>2</sup>Department of Mathematics and Statistics, Jessore University of Science and Technology, Jessore 7408, Bangladesh**\*Corresponding author**

Md. Mizanur Rahman

Email: [mizan\\_iu@yahoo.com](mailto:mizan_iu@yahoo.com)

**Abstract:** We investigated numerically on MHD Free Convection Fluid Flow over a Vertical Porous Flat Plate in a Rotating System is Presence of Radiation, Soret effect and Heat Transfer of a heat generation. In this study the governing equations of the problem contains the system of partial differential equations. We solve the obtained non-similar, coupled, non-linear, non-dimensional partial differential equations are numerically by technique of finite difference methods. We investigate the effect various physical parameters such as velocity, temperature and concentration within the boundary layer are presented by Numerical results. The effects of thermal radiation entering into the physical problem are observed. The heat transfer as well as rate of transfer are also shown in graphically. Finally, we compare of the present study with previous published work is embodied in tabular form.

**Keywords:** MHD Flow, Rotating System, Heat Generation, Radiation, Soret effect, Finite difference method.

**INTRODUCTION**

In industrial, scientific and engineering application, heat transfer and thermal radiation has play an important role in the boundary layer flow. The mutual heat and mass transfer are increases with the control of buoyancy forces. The characteristic condensing and boiling in separation processes such as drying, evaporation, distillation, condensation, rectification and absorption of chemical engineering has significant role in fluid mechanics. MHD heat transfer and radiation with chemical reaction has influence of liquid metal flows and ionized gas flow into the electrolytes. Sakiadis [1] developed several characters of flow using boundary layer equations for continuous surfaces.

The Hall Current, mass transfer and hydro-magnetic effects of in a rotating system through porous medium studied by Agarwal *et al.* [2], Takhar and Ram [3], Anjali and Uma [4]. Bestman and Adjepong [5] studied heat transfer through the unsteady hydro-magnetic flow into the rotating system. Sharma *et al.* [6], Sarkar *et al.* [7] have studied Hall effects on MHD mixed convective flow of a viscous incompressible fluid past a vertical porous plate as well as rotating system. The Dufour and Soret Effects [8, 9], hydro-

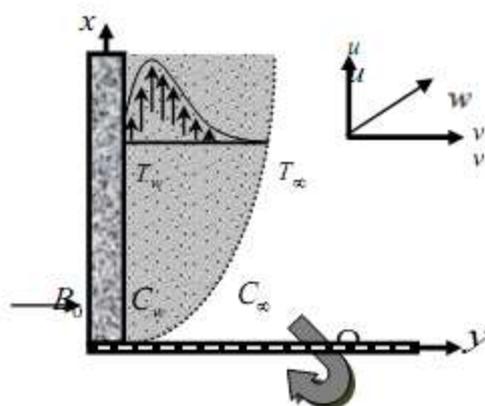
magnetic [10, 14] of heat and mass transfer model, thermal radiations and hall current flow, into the vertical plates are investigated [15].

The effects of chemical reaction and radiation [16], Non-isothermal Turbulent flow [17], Hall Currents and Rotation [18] on MHD flow investigated by a vertical porous flat plate. Postelnica [19] studied numerically of the effect of heat and mass transfer into the magnetic field. The time dependent variation of Rivlin-Ericksen flow into the porous medium investigated by Uwanta *et al.* [20]. In practical of thermal-diffusion and diffusion thermos effect over a stretching sheet studied by Afify [21]. Sandeep and Sugunamma [22] studied the effects of Radiation on Unsteady Hydromagnetic Flow past an Impulsively Moving Vertical Plate with Inclined Magnetic Field. The key objective of the present study is to determine the MHD Free Convection fluid flow over a Vertical Porous Flat Plate in a Rotating System with including the effect of Soret, Heat generation source and radiation. Also our principle aim of the article is to investigate the work of Sivaiah[13] for the case where we consider the fluid in presence of Heat Transfer and Soret effect with porous medium.

**Table 1: Nomenclature**

$x, y, z$	Cartesian co-ordinates	$M$	Magnetic Parameter
$u, v, w$	Velocity components	$\sigma^*$	Stefan-Boltzman constant
$K$	Permeability of the porous medium	$\kappa'$	Thermal conductivity
$R'$	Rotational parameter	$\beta_T$	Heat expansion co-efficient
$T_w$	Temperature at the plate	$\beta_C$	Mass expansion co-efficient
$T_\infty$	Temperature outside the boundary layer.	$\beta$	Heat generation quantity
$C_w$	Concentration at the plate	$\nu$	Kinematic viscosity
$C_\infty$	Concentration outside the boundary layer	$\rho$	Density of the fluid
$\Omega$	Rotational velocity component	$q_r$	Radiative heat flux
$U$	Dimensionless primary velocity	$\sigma$	Electrical conductivity
$W$	Dimensionless secondary velocity	$c_p$	Specific heat at constant pressure
$\bar{T}$	Dimensionless fluid temperature	$D$	Co-efficient of mass diffusivity
$\bar{C}$	Dimensionless fluid concentration	$Q$	Heat absorption coefficient
$\mathbf{J}$	Current density	$k_T$	Thermal diffusion ratio
$\mathbf{B}$	Magnetic field	$T_m$	Mean fluid temperature
$B_o$	Magnetic component	$P_r$	Prandtl number
$U_0$	Uniform velocity	$S_0$	Soret number
$G_r$	Grashof number	$S_c$	Schmidt number
$G_m$	Modified Grashof number	$k^*$	Mean absorption coefficient

## MATHEMATICAL FORMULATION



**Fig-1: Physical configuration and coordinate system**

We consider an electrically conducting viscous fluid through a porous medium in a rotating system with infinite vertical porous plate  $y = 0$ . The flow is also assumed to be in the  $x$ -direction and  $y$ -axis is normal to it. We set up the plate is rest into the system and angular velocity  $\Omega$  will be consider the  $y$ -axis i.e.  $\Omega = (0, -\Omega, 0)$ . An identical transverse magnetic field of magnitude  $B_0$  is consider  $y$ -direction and the plate with involving the fluid is present the same temperature  $T(=T_\infty)$  and concentration level  $C(=C_\infty)$ . We see that the temperature  $T_w(>T_\infty)$  of the plate as well as concentration  $C_w(>C_\infty)$  are increases with the flow continuous passes through into the boundary layer. In the

simulation system  $T_w$ ,  $C_w$  are consider temperature and concentration at the wall and  $T_\infty$ ,  $C_\infty$  are consider the temperature and concentration of the outside the boundary layer well-found in Figure 1.

The coupled partial differential equations into the problem given below;

The Continuity equation;

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{1}$$

The Momentum equation in  $x$ -axis ;

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = \nu \frac{\partial^2 u}{\partial y^2} + gB_T(T - T_\infty) + gB_C(C - C_\infty) - \frac{\sigma B_0^2 u}{\rho} + 2\Omega w - \frac{\nu}{\kappa'} u \tag{2}$$

The Momentum equation in  $z$ -axis ;

$$\frac{\partial w}{\partial t} + u \frac{\partial w}{\partial x} + v \frac{\partial w}{\partial y} = \nu \frac{\partial^2 w}{\partial y^2} + \frac{\sigma B_0^2 u}{\rho} - 2\Omega u - \frac{\nu}{\kappa'} u \tag{3}$$

The Energy equation;

$$\frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} = \frac{\kappa}{\rho c_p} \frac{\partial^2 T}{\partial y^2} - \frac{1}{\rho c_p} \frac{\partial q_r}{\partial y} + \frac{Q}{\rho c_p} (T - T_\infty) \tag{4}$$

The Concentration equation;

$$\frac{\partial C}{\partial t} + u \frac{\partial C}{\partial x} + v \frac{\partial C}{\partial y} = D \frac{\partial^2 C}{\partial y^2} + \frac{Dk_t}{T_m} \frac{\partial^2 T}{\partial y^2} \tag{5}$$

and corresponding boundary conditions are;

$$u = 0, v = 0, w = 0, T = T_w, C = C_w \text{ at } y = 0 \tag{6}$$

$u = 0, v = 0, w = 0, T \rightarrow T_\infty, C \rightarrow C_\infty$  as  $y \rightarrow \infty$

The radiative heat flux  $q_r$  is described by the Rossel and approximation [23] such that  $q_r = -\frac{4\sigma^*}{3k^*} \frac{\partial T^4}{\partial y}$ , where

$\sigma^*$  and  $k^*$  are the Stefan-Boltzman constant and the mean absorption coefficient.. If the temperature differences and magnetic Reynolds number of the flow are consider very small into the fluid flow then  $T^4$  will be  $T^4 \approx 4T_\infty^3 T - 3T_\infty^4$  and current density as  $\mathbf{J} = (J_x, J_y, J_z)$ . Where  $\nabla \cdot \mathbf{J} = 0$  then the current density  $J_y = \text{constant}$  i.e.  $J_y = 0$  . Now we

introduced as non-dimension equation;  $X = \frac{xU_0}{\nu}$ ,  $Y = \frac{yU_0}{\nu}$ ,  $U = \frac{u}{U_0}$ ,  $V = \frac{v}{U_0}$ ,  $W = \frac{w}{U_0}$ ,  $\tau = \frac{tU_0^2}{\nu}$ ,  $\bar{T} = \frac{T - T_\infty}{T_w - T_\infty}$

and  $\bar{C} = \frac{C - C_\infty}{C_w - C_\infty}$ .

Using the dimensionless variables into the equations (1)-(5) and with corresponding boundary conditions (6), we get;

$$\frac{\partial U}{\partial X} + \frac{\partial V}{\partial Y} = 0 \tag{7}$$

$$\frac{\partial U}{\partial \tau} + U \frac{\partial U}{\partial X} + V \frac{\partial U}{\partial Y} = \frac{\partial^2 U}{\partial Y^2} + G_r \bar{T} + G_m \bar{C} - (M + K)U + R'W \tag{8}$$

$$\frac{\partial W}{\partial \tau} + U \frac{\partial W}{\partial X} + V \frac{\partial W}{\partial Y} = \frac{\partial^2 W}{\partial Y^2} + (M - K)W - R'U \tag{9}$$

$$\frac{\partial \bar{T}}{\partial \tau} + U \frac{\partial \bar{T}}{\partial X} + V \frac{\partial \bar{T}}{\partial Y} = \left( \frac{1+R}{Pr} \right) \frac{\partial^2 \bar{T}}{\partial Y^2} + \beta \bar{T} \tag{10}$$

$$\frac{\partial \bar{C}}{\partial \tau} + U \frac{\partial \bar{C}}{\partial X} + V \frac{\partial \bar{C}}{\partial Y} = \frac{1}{S_c} \frac{\partial^2 \bar{C}}{\partial Y^2} + S_0 \frac{\partial^2 \bar{T}}{\partial Y^2} \tag{11}$$

and boundary conditions are;

$$U = 0, W = 0, \bar{T} = 1, \bar{C} = 1 \text{ at } Y = 0 \tag{12}$$

$$U = 0, W = 0, \bar{T} = 0, \bar{C} = 0 \text{ as } Y \rightarrow \infty$$

where  $\tau$  represents the dimensionless time,  $G_r = \frac{gB_T(T_w - T_\infty)\nu}{U_0^3}$  (Grashof Number),  $G_m = \frac{gB_C(C_w - C_\infty)\nu}{U_0^3}$

(Modified Grashof Number),  $M = \frac{\sigma B_0^2 \nu}{\rho U_0^2}$  (Magnetic Parameter),  $R' = \frac{2\Omega \nu}{u_0^2}$  (Rational Parameter),  $K = \frac{\mu \nu}{\rho \kappa' u_0^2}$

(Permeability of the porous medium),  $R = \frac{16\sigma^* T_\infty^3}{3\kappa^* \kappa}$  (Radiation parameter)  $P_r = \frac{\rho c_p \nu}{\kappa}$  (Prandtl Number),  $\beta = \frac{Q\nu}{\rho c_p U_0^2}$

(Heat generation/ Absorption parameter),  $S_c = \frac{\nu}{D}$  (Schmidt Number) and  $S_0 = \frac{D_m k_t (T_w - T_\infty)}{\nu T_m (C_w - C_\infty)}$  (Soret Number)

### NUMERICAL SOLUTIONS

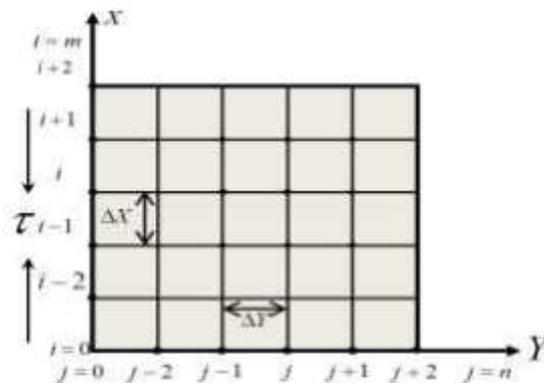


Fig-2: Explicit finite difference system grid

The above partial differential equations (7)-(11) with boundary condition (12) are solve by numerical explicit finite difference method. Now the region of the flow is divided into a grid lines parallel to  $X$  axis consider the plate and  $Y$  axis also consider normal to the plate. We furnished the height of the plate is  $X_{\max}(=100)$  i.e.  $X$  varies from 0 to 100 and assumed  $Y_{\max}(=35)$  as corresponding to  $Y \rightarrow \infty$  i.e.  $Y$  varies from 0 to 35. Moreover, grid spacing in the  $X$  and  $Y$  directions are  $m(=200)$  and  $n(=200)$ , and mesh size  $\Delta X = 0.50(0 \leq X \leq 100)$  and  $\Delta Y = 0.175(0 \leq Y \leq 35)$  with time-step  $\Delta \tau = 0.005$ . Let we consider  $U', W', \bar{T}'$  and  $\bar{C}'$  with the values of  $U, W, \bar{T}$  and  $\bar{C}$  are the end of a time-step. Finally we obtain the equation as;

$$\frac{U'_{i,j} - U'_{i-1,j}}{\Delta X} + \frac{V_{i,j} - V_{i,j-1}}{\Delta Y} = 0 \tag{13}$$

$$\frac{U'_{i,j} - U_{i,j}}{\Delta \tau} + U_{i,j} \frac{U_{i,j} - U_{i-1,j}}{\Delta X} + V_{i,j} \frac{U_{i,j+1} - U_{i,j}}{\Delta Y} = \frac{U_{i,j+1} - 2U_{i,j} + U_{i,j-1}}{(\Delta Y)^2} + G_r \bar{T}'_{i,j} + G_m \bar{C}'_{i,j} - (M + K)U_{i,j} + R'W_{i,j} \tag{14}$$

$$\frac{W'_{i,j} - W_{i,j}}{\Delta \tau} + U_{i,j} \frac{W_{i,j} - W_{i-1,j}}{\Delta X} + V_{i,j} \frac{W_{i,j+1} - W_{i,j}}{\Delta Y} = \frac{W_{i,j+1} - 2W_{i,j} + W_{i,j-1}}{(\Delta Y)^2} + (M - K)W_{i,j} - R'U_{i,j} \tag{15}$$

$$\frac{\bar{T}'_{i,j} - \bar{T}_{i,j}}{\Delta\tau} + U_{i,j} \frac{\bar{T}_{i,j} - \bar{T}_{i-1,j}}{\Delta X} + V_{i,j} \frac{\bar{T}_{i,j+1} - \bar{T}_{i,j}}{\Delta Y} = \frac{(1+R)}{Pr} \frac{\bar{T}_{i,j+1} - 2\bar{T}_{i,j} + \bar{T}_{i,j-1}}{(\Delta Y)^2} + \beta \bar{T} \tag{16}$$

$$\frac{\bar{C}'_{i,j} - \bar{C}_{i-1,j}}{\Delta\tau} + U_{i,j} \frac{\bar{C}_{i,j} - \bar{C}_{i-1,j}}{\Delta X} + V_{i,j} \frac{\bar{C}_{i,j+1} - \bar{C}_{i,j}}{\Delta Y} = \frac{1}{Sc} \frac{\bar{C}_{i,j+1} - 2\bar{C}_{i,j} + \bar{C}_{i,j-1}}{(\Delta Y)^2} + S_0 \frac{\bar{T}_{i,j+1} - 2\bar{T}_{i,j} + \bar{T}_{i,j-1}}{(\Delta Y)^2} \tag{17}$$

with the boundary condition;

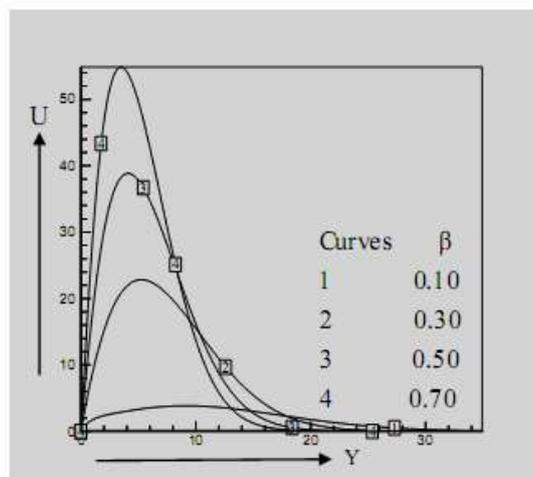
$$U_{i,0}^n = 0, W_{i,0}^n = 0, \bar{T}_{i,0}^n = 1, \bar{C}_{i,0}^n = 1 \tag{18} \quad U_{i,L}^n = 0, W_{i,L}^n = 0, \bar{T}_{i,L}^n = 0, \bar{C}_{i,L}^n = 0 \text{ where } L \rightarrow \infty$$

Here the subscript  $i$  and  $j$  labels will be consider the grid points with  $X$  and  $Y$  coordinates and the superscript  $n$  denotes a value of time,  $\tau = n\Delta\tau$  where  $n = 0, 1, 2, \dots$

### RESULTS AND DISCUSSION

In our investigation of the problem the physical parameters are velocities ( $U$ ) and ( $W$ ), temperature ( $\bar{T}$ ) and concentration ( $\bar{C}$ ) distributions within the boundary layer have been computed for different values of Magnetic parameter ( $M$ ), Rational Parameter ( $R'$ ), Permeability of the porous medium ( $K$ ), Heat generation ( $\beta$ ), Radiation parameter ( $R$ ), Prandtl number ( $Pr$ ), Schmidt number ( $Sc$ ) and Soret number ( $S_0$ ) with the help of a computer programming language Compaq Visual Fortran 6.6a and Tecplot 7. When  $\tau = 80$  the solution will obtain steady-state. But after  $\tau = 50$ , the numerical values of  $U$ ,  $W$ ,  $\bar{T}$  and  $\bar{C}$  shows that little changes. Hence at  $\tau = 50$  for all variables are found steady-state solutions.

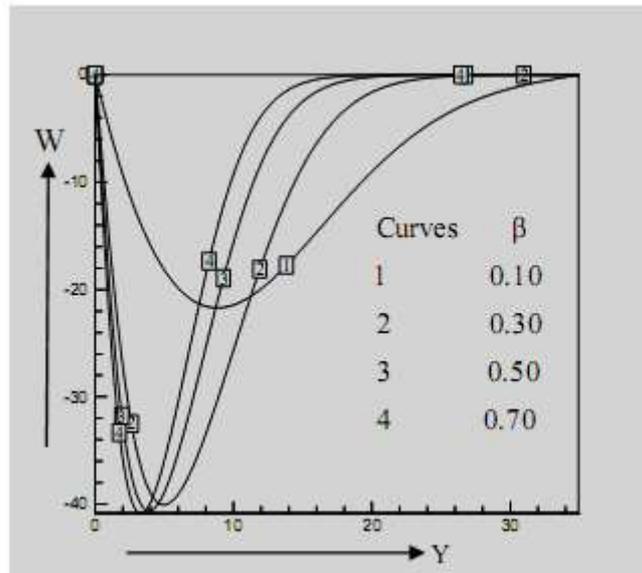
The positive Grashof number ( $G_r > 0$ ) is importance of cooling problem which is application of nuclear engineering. The most important fluids are atmospheric air, water and methanol for that reason we considered  $G_r = 2.00$ ,  $Pr = 0.71$  (Prandtl number is consider for the effect of air at  $20^\circ C$ ),  $Pr = 1.00$  (Prandtl number is consider for the effect of salt at  $20^\circ C$ ) and  $Pr = 7.00$  (Prandtl number is consider for the effect of water at  $20^\circ C$ ) and  $Pr = 11.62$  (Prandtl number is consider for the effect of methanol at  $20^\circ C$ ). Moreover, we consider the modified Grashof number  $G_m = 2.00$  which is effective for mass transfer.



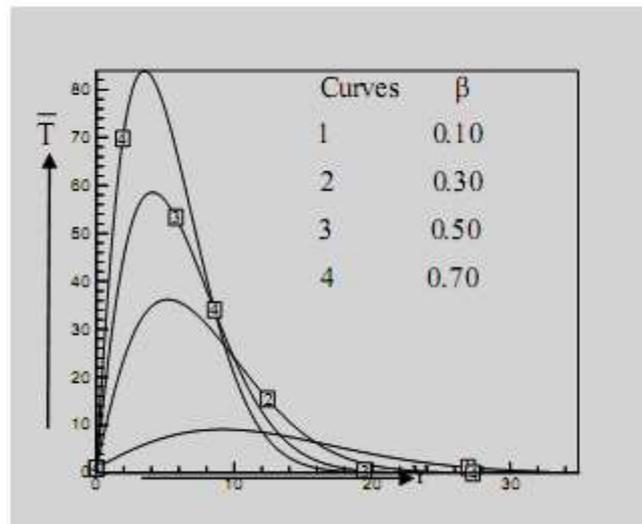
**Fig-3: Primary velocity profile for effects of different values of Heat generation parameter  $\beta$  with**

$$G_R = 2.00, G_m = 2.00, M = 1.00, K = 1.00, R' = 0.5,$$

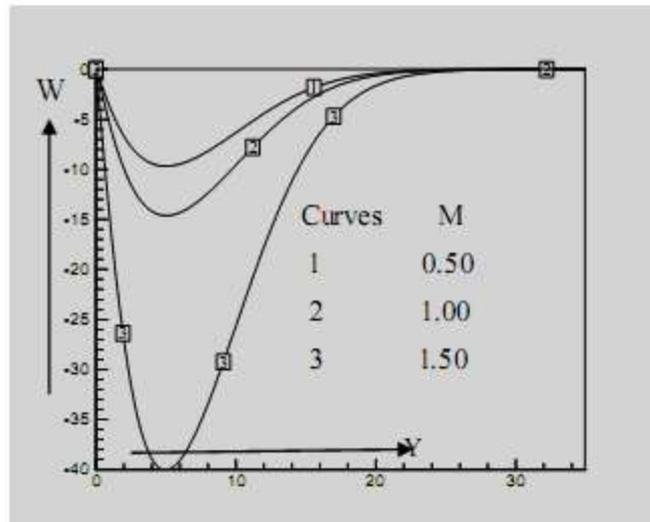
$$R = 0.30, Pr = 1.00, Sc = 0.60, S_0 = 0.10$$



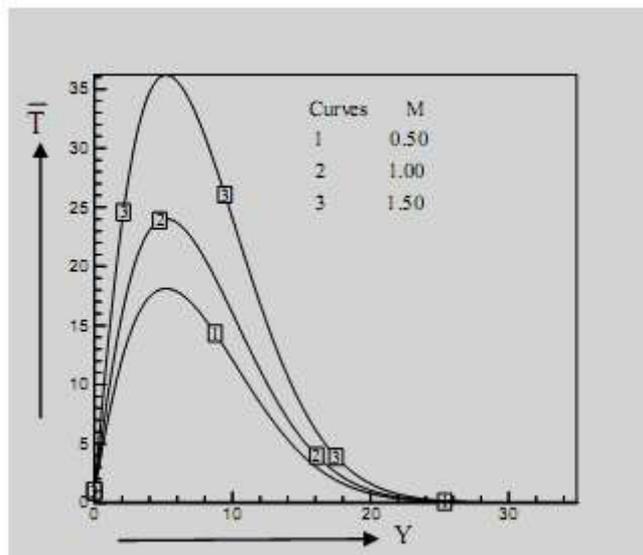
**Fig-4: Secondary velocity profile for effects of different values of Heat generation parameter  $\beta$  with  $G_r = 2.00, G_m = 2.00, M = 1.00, K = 1.00, R' = 0.5,$   
 $R = 0.30, P_r = 1.00, S_c = 0.60, S_0 = 0.10$**



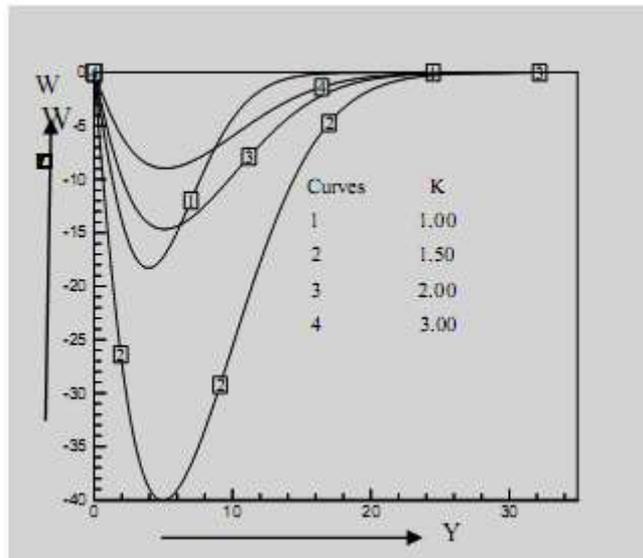
**Fig-5: Temperature profile for effects of different values of Heat generation parameter  $\beta$  with  $G_r = 2.00, G_m = 2.00, M = 1.00, K = 1.00, R' = 0.5,$   
 $R = 0.30, P_r = 1.00, S_c = 0.60, S_0 = 0.10$**



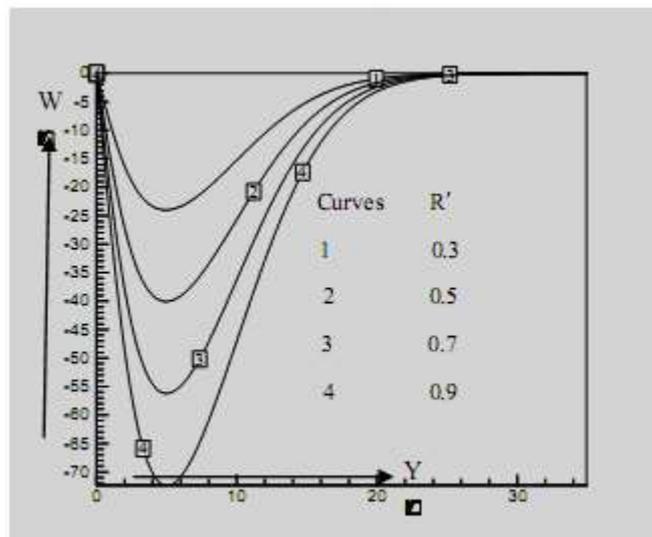
**Fig-6: Secondary velocity profile for effects of different values of Magnetic parameter M with  $G_r = 2.00, G_m = 2.00, \beta = 0.50, K = 1.00, R' = 0.5,$   
 $R = 0.30, P_r = 1.00, S_c = 0.60, S_0 = 0.10$**



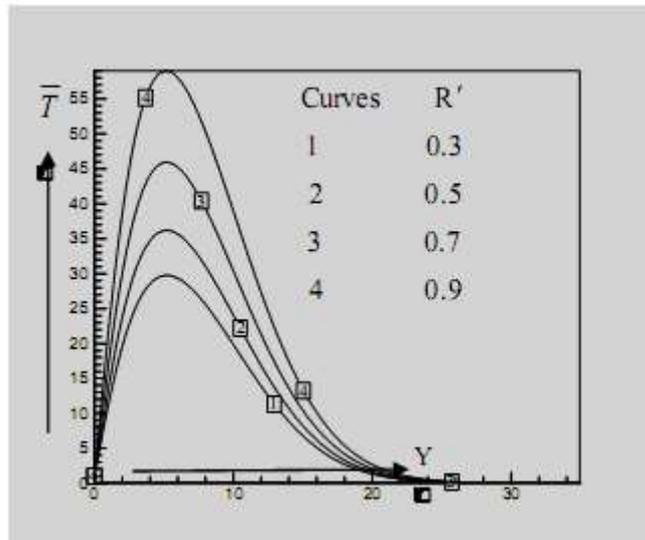
**Fig-7: Temperature velocity profile for effects of different values of Magnetic parameter M with  $G_r = 2.00, G_m = 2.00, \beta = 0.50, K = 1.00, R' = 0.5,$   
 $R = 0.30, P_r = 1.00, S_c = 0.60, S_0 = 0.10$**



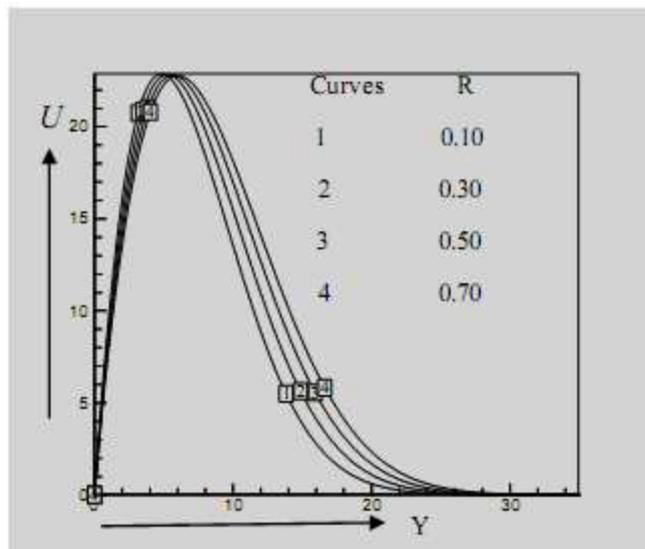
**Fig-8: Secondary velocity profile for effects of different values of Permeability parameter  $K$  with  $G_r = 2.00, G_m = 2.00, \beta = 0.50, M = 1.00, R' = 0.5,$   
 $R = 0.30, P_r = 1.00, S_c = 0.60, S_0 = 0.10$**



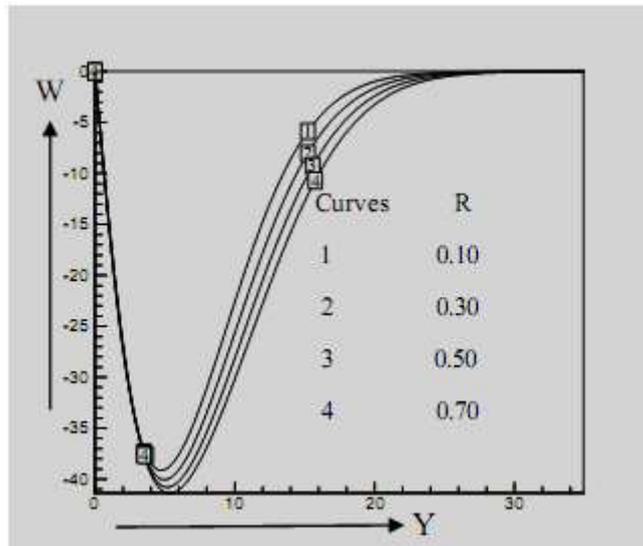
**Fig-9: Secondary velocity profile for effects of different values of Rotational parameter  $R'$  with  $G_r = 2.00, G_m = 2.00, \beta = 0.50, M = 1.00, R' = 0.5,$   
 $R = 0.30, P_r = 1.00, S_c = 0.60, S_0 = 0.10$**



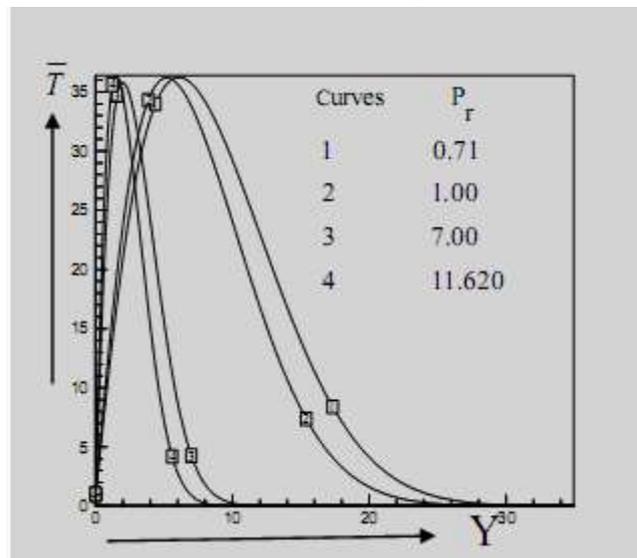
**Fig-10: Temperature velocity profile for effects of different values of Rotational parameter  $R'$  with  $G_r = 2.00, G_m = 2.00, \beta = 0.50, M = 1.00, R' = 0.5,$   
 $R = 0.30, P_r = 1.00, S_c = 0.60, S_0 = 0.10$**



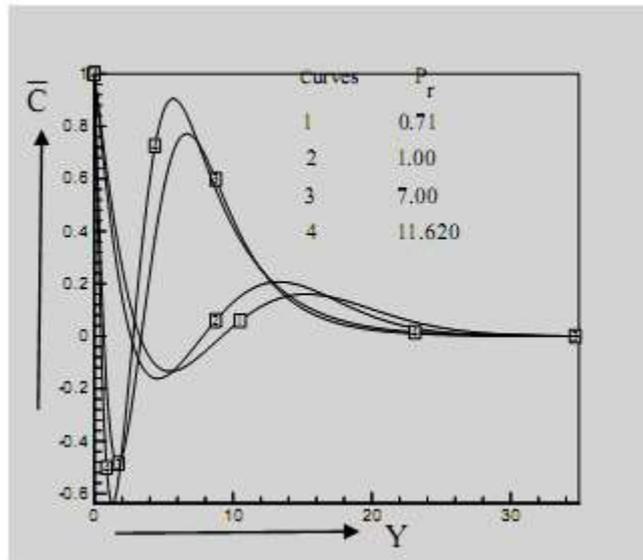
**Fig-11: Primary velocity profile for effects of different values of Radiation parameter  $R$  with  $G_r = 2.00, G_m = 2.00, \beta = 0.50, M = 1.00, K = 1.00,$   
 $R' = 0.50, P_r = 1.00, S_c = 0.60, S_0 = 0.10$**



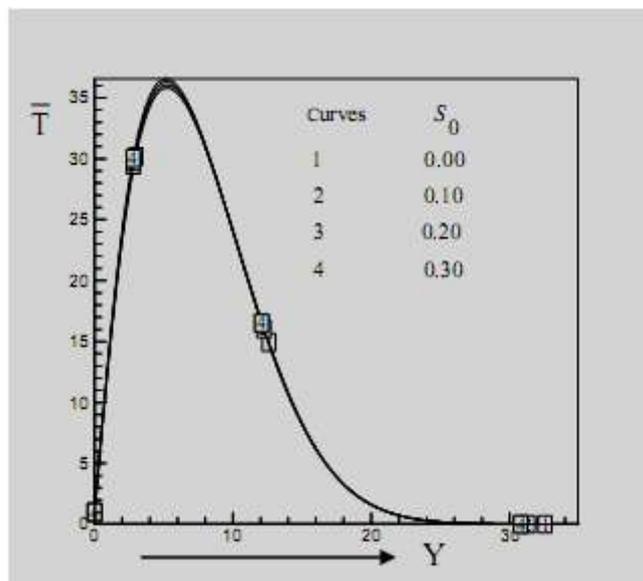
**Fig-12: Secondary velocity profile for effects of different values of Radiation parameter  $R$  with  $G_r = 2.00, G_m = 2.00, \beta = 0.50, M = 1.00, K = 1.00, R' = 0.50, P_r = 1.00, S_c = 0.60, S_0 = 0.10$**



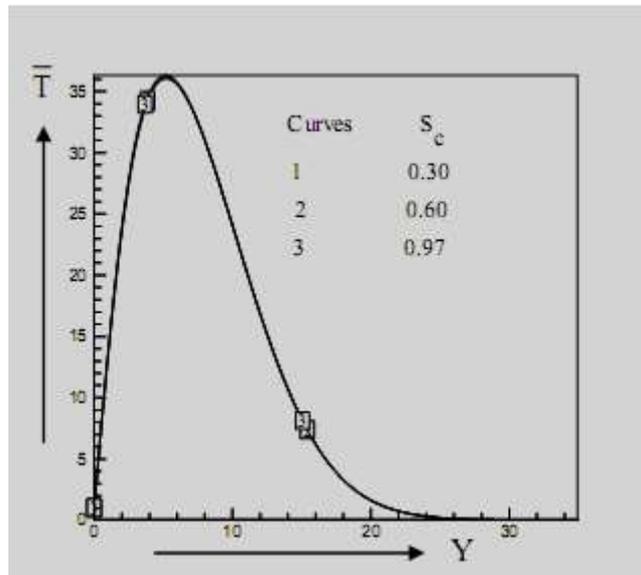
**Fig-13: Temperature velocity profile for effects of different values of Prandtl number  $P_r$  with  $G_r = 2.00, G_m = 2.00, \beta = 0.50, M = 1.00, K = 1.00, R' = 0.50, R = 0.50, S_c = 0.60, S_0 = 0.10$**



**Fig-14: Concentration profile for effects of different values of Prandtl number  $P_r$  with  $G_r = 2.00, G_m = 2.00, \beta = 0.50, M = 1.00, K = 1.00, R' = 0.50, R = 0.50, S_c = 0.60, S_0 = 0.10$**



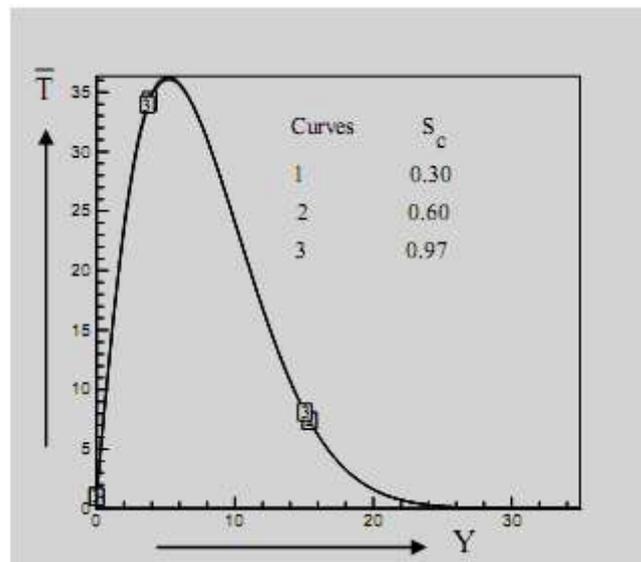
**Fig-15: Temperature profile for effects of different values of Soret number  $S_0$  with  $G_r = 2.00, G_m = 2.00, \beta = 0.50, M = 1.00, K = 1.00, R' = 0.50, P_r = 1.00, S_c = 0.60, P_r = 1.00$**



**Fig-16: Temperature profile for effects of different values of Schmidt number  $S_c$  with**

$G_r = 2.00, G_m = 2.00, \beta = 0.50, M = 1.00, K = 1.00,$

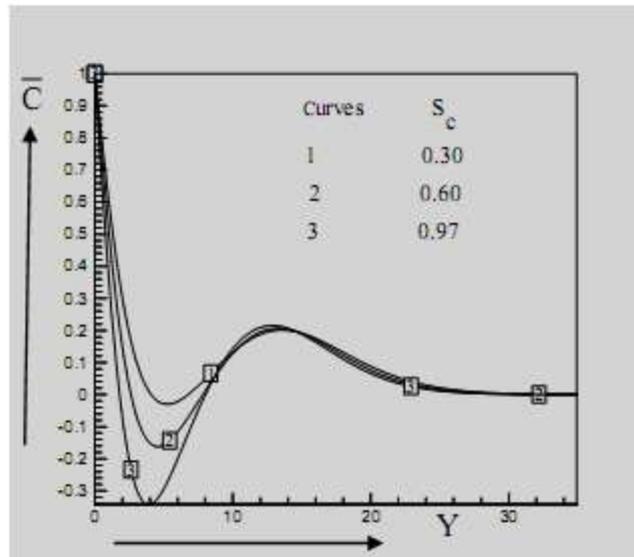
$R' = 0.50, P_r = 1.00, S_0 = 0.10, P_r = 1.00$



**Fig-17: Temperature profile for effects of different values of Schmidt number  $S_c$  with**

$G_r = 2.00, G_m = 2.00, \beta = 0.50, M = 1.00, K = 1.00,$

$R' = 0.50, P_r = 1.00, S_0 = 0.10, P_r = 1.00$



**Fig-18: Concentration profile for effects of different values of Schmidt number  $S_c$  with**

$$G_r = 2.00, G_m = 2.00, \beta = 0.50, M = 1.00, K = 1.00,$$

$$R' = 0.50, P_r = 1.00, S_0 = 0.10, P_r = 1.00$$

We have presented the physical simulation of the problem in Figure 3-17. The primary velocity, secondary velocity and temperature profiles have been presented for numerous values of Heat generation parameter ( $\beta$ ) in Figure 3-5 respectively. We found that the primary velocity and temperature increases with the increases of Heat generation parameter and the secondary velocity decreases with increases of Heat generation parameter.

The secondary velocity and temperature profiles have displayed for various values of Magnetic parameter ( $M$ ) in Figure 6-7 respectively. It is showed that the Magnetic parameter has a decreases effect on the secondary velocity and increases effect on the temperature profile. The secondary velocity profiles showed the effects of Permeability parameter ( $K$ ) in Figure 8, and result shows that the secondary velocity decrease with the increase of Permeability parameter ( $K$ ).

The secondary velocity and temperature profiles have been displayed for various values of rational parameter ( $R'$ ) in Figure 9-10 respectively. It is noted that the rational parameter has a decreases effect on the secondary velocity while it has a large increases effect on the temperature profiles.

The primary velocity and secondary velocity have been displayed for several values of Radiation parameter ( $R$ ) in Figure 11-12 respectively. It is found that the primary velocity increases and secondary velocity decreases with the increases Radiation parameter. The temperature distributions and fluid concentration have been presented for different values of Prandtl number ( $P_r$ ) in Figs. 13-14. The given results shows that both of temperature distributions and fluid concentration decreases with the increases of Prandtl number.

The temperature profiles have been displayed for several values of Soret number ( $S_0$ ) in Figure 15. It is observed that the temperature profile has minor increasing with the increases Soret number. The fluid concentration profiles have initially decreases but after a few time the fluid concentration increases with the increases Soret number. The temperature profiles and fluid concentration in the presence of different species with various Schimdt number ( $S_c$ ), namely, helium ( $Sc = 0.30$ ), oxygen ( $Sc = 0.60$ ), and methanol ( $Sc = 0.97$ ), at  $25^0C$  temperature and 1 atmosphere pressure, are shown in Figure 17-18. It is noted that the temperature profiles are minor decreases as well as fluid concentrations are also decreases if  $Sc$  increases.

**Table 1: A qualitative comparison of the present steady-state results with the published results<sup>13</sup> are good agreement in case of all the flow parameter**

Increased Parameter	Previous results given by Sivaiah[13]			Present result			
	Velocity ( $q$ )	Temperature ( $\theta$ )	Concentration ( $C$ )	Primary velocity ( $U$ )	Secondary velocity ( $W$ )	Temperature ( $\bar{T}$ )	Concentration ( $\bar{C}$ )
$R$	Inc.	Inc.		Inc.	Dec.		
$Pr$	Dec.	Dec.				Dec.	Dec.
$Sc$	Dec.		Dec.			Dec.	Dec.
$R'$	Inc.				Dec.	Inc.	
$\beta$				Inc.	Dec.	Inc.	
$So$				Inc.		Inc.	Inc.
$K$					Dec.		
$M$					Dec.	Inc.	

**CONCLUSIONS**

The combined effects of radiation and heat transfer of a heat generation on the magnetohydrodynamic (MHD) free convection flow of an electrically conducting viscous fluid over a vertical porous flat plate in a rotating system is investigated in present study. The physical properties of fluid mechanics and important findings of this investigation are given below;

1. The primary velocity profiles are increase with the increase of  $\beta$ ,  $R$ ,  $S_0$
2. The secondary velocity profiles are decreases with the increase of  $\beta$ ,  $K$ ,  $R$  and  $R'$
3. The temperature distributions are increase with the increase of  $\beta$ ,  $M$ ,  $S_0$ ,  $R'$  and decreases with increases in  $P_r$  and  $S_c$ .
4. The concentration profiles are increase with the increase of  $S_0$  and reverse effects with the increase  $P_r$  and  $S_c$ .

**REFERENCE**

1. Sakiadis BC; Boundary-layer behavior on continuous solid surfaces, 1961; I: 26-28.
2. Agrawal HL, Ram PC, Singh V; Effects of hall current on the hydromagnetic free convection with mass transfer in a rotating fluid. Astrophysics and space science, 1984; 100(1-2): 279-286.
3. Takhar HS, Ram PC; Effects of Hall current on hydromagnetic free-convective flow through a porous medium. Astrophysics and space science, 1992; 192(1): 45-51.
4. Devi SA, Devi RU; Effects of Thermal Radiation on Hydromagnetic Flow due to a Porous Rotating Disk with Hall Effect. Journal of Applied Fluid Mechanics, 2012; 5(2): 1-7.
5. Bestman AR, Adjepong SK; Unsteady hydromagnetic free-convection flow with radiative

heat transfer in a rotating fluid. Astrophysics and space science, 1988; 143(1): 73-80.

6. Sharma BK, Jha AK, Chaudhary RC; Hall effect on MHD mixed convective flow of a viscous incompressible fluid past a vertical porous plate immersed in porous medium with heat source/sink. Rom. Journal Phys., 2007; 52(5): 487-503.
7. Sarkar BC, Das S, Jana RN; Effects of hall currents radiation on MHD free convective flow past a oscillating vertical plate with oscillatory plate temperature in a porous medium. Bulletin of Society for Mathematical Services and Standards, 2012; 1(3):06-32.
8. Islam N, Alam MM; Dufour and Soret effects on steady MHD free convection and mass transfer fluid flow through a porous medium in a rotating system. Journal of Naval Architecture and Marine Engineering, 2007; 4(1): 43-55.
9. Lavanya B, Ratnam AL; Dufour and soret effects on steady MHD free convective flow past a vertical porous plate embedded in a porous medium with chemical reaction, radiation heat generation and viscous dissipation, Advances in Applied Science Research, 2014; 5(1): 127-142.
10. Aiyesimi YM, Abah SO, Okedayo GT; The analysis of hydromagnetic free convection heat and mass transfer flow over a stretching vertical plate with suction. American Journal of Computational and Applied Mathematics, 2011; 1(1): 20-26.
11. Kalita B, Lahkar J; Magnetic Field Effects on Unsteady Free Convection MHD Flow between Two Heated Vertical Plates (One Adiabatic). Advanced Studies in Theoretical Physics, 2012; 6: 765-775.
12. Chauhan DS, Rastogi P; Heat transfer effects on rotating MHD Couette flow in a channel partially filled by a porous medium with Hall current. Journal of Applied Science and Eng., 2012; 15(3): 281-290.

13. Rahman MM, Hye MA, Rahman MM, Rahaman MM; Numerical Simulation on MHD Free Convection Mass and Heat Transfer Fluid Flow over a Vertical Porous Plate in a Rotating System with Induced Magnetic Field. *Annals of Pure and Applied Mathematics*, 2014; 7(2): 35-44.
14. Ahmed S, Kalita K; Analytical and Numerical Study for MHD Radiating Flow over an Infinite Vertical Surface Bounded by a Porous Medium in Presence of Chemical Reaction. *Journal of Applied Fluid Mechanics*, 2013; 6(4).
15. Garg BP; Combined effects of thermal radiations and hall current on moving vertical porous plate in a rotating system with variable temperature. *International Journal of Pure and Applied Mathematics*, 2012; 81(2): 335-345.
16. Sivaiah S; MHD Flow of a Rotating Fluid Past a Vertical Porous Flat Plate in the Presence of Chemical Reaction and Radiation. *Journal of Engineering Physics and Thermophysics*, 2013; 86(6): 1328-1336.
17. Hye MA, Rahman MM, Ali LN, Afrin S; Steady and Unsteady Solutions of Non-Isothermal Turbulent Flow through a Curved Duct with Square Cross Section. *Int. J. Pure Appl. Sci. Technol.*, 2013; 15(1): 67-78.
18. Guchhait SK, Das S, Jana RN; Combined Effects of Hall Currents and Rotation on MHD Mixed Convection Oscillating Flow in a Rotating Vertical Channel. *International Journal of Computer Applications*, 2012; 49(13):0975– 8887.
19. Postelnicu A; Influence of chemical reaction on heat and mass transfer by natural convection from vertical surfaces in porous media considering Soret and Dufour effects. *Heat and Mass transfer*, 2007; 43(6): 595-602.
20. Uwanta IJ, Hussaini A; Effect of mass transfer of hydro-magnetic free convective Rivlin-Ericksen flow through a porous medium with time dependent suction. *International Journal of Engineering and Science*, 2012; 1: 21-30.
21. Afify AA; Similarity solution in MHD: effects of thermal diffusion and diffusion thermo on free convective heat and mass transfer over a stretching surface considering suction or injection. *Communications in Nonlinear Science and Numerical Simulation*, 2009; 14(5):2202-2214.
22. Sandeep N, Sugunamma V; Radiation and Inclined Magnetic Field Effects on Unsteady Hydromagnetic Free Convection Flow past an Impulsively Moving Vertical Plate in a Porous Medium. *Journal of Applied Fluid Mechanics*, 2014; 7(2).
23. Brewster MQ; Thermal radiative transfer and properties. John Wiley & Sons, 1992.