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A Note on Vorticity of Unsteady MHD Free Convection and Mass Transfer Flow of Visco-elastic fluid through Porous Medium with Constant Suction and Heat flux

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Abstract: *This paper investigate the study of vorticity of unsteady MHD free convection and mass transfer Flow of Visco-elastic fluid through porous medium with constant Suction and Heat flux. The effects of the important flow parameters such as Magnetic Parameter (M), Grashoff number (G_r), Modified Grashoff number (G_m), Prandtle number (P_r) and Schimdt number (S_c) on the vorticity of the flow field are analyzed quantitatively with the help of figures and tables.*
Keywords: *MHD flow, free convection, Porous medium, Suction, Heat flux, Mass transfer, Vorticity.*

NOMENCLATURE

u = Velocity component
M = Magnetic parameter
E_c = Eckert number
t = Time
G_r = Grashof number for heat transfer
G_m = Grashof number for mass transfer
S_c = Schmidt number
P_r = Prandtl number
v_0 = Constant suction
B_0 = Magnetic induction
g = Acceleration due to gravity
k_0 = Porosity parameter
C_p = Specific heat at the constant pressure
D = Concentration diffusivity
T_∞ = Temperature of the fluid in the free stream
q = Constant heat flux per unit area
C_∞ = Concentration at infinite
m = Mass flux per unit area

GREEK SYMBOLS

β = Coefficient of Volume expansion
β^* = Coefficient of Concentration expansion
ρ = Density
ν = Kinematic Viscosity
λ = Thermal Conductivity
σ = Electrical Conductivity

ζ = Vorticity

I. Introduction

The study of free convection MHD flow of a visco-elastic fluid with mass transfer is of general interest in view of its varied applications in the field of Astrophysical and Geophysical Sciences. Such type of problems finds their use in the atmospheric and oceanic circulations as well. Flow through porous media is helpful in the filtration process and also to maintain the temperature of a heated body.

Satyanarayana *et al.* [17] studied current effect on magnetohydro-dynamic free convection flow past a semi-infinite vertical porous plate with mass transfer. Dulal *et al.* [5] studied perturbation analysis of unsteady magnetohydrodynamic convective heat and mass transfer in a boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction. Attia [2] has considered the Hartmann flow with heat transfer of a Visco-elastic fluid considering the Hall Effect. Attia [3] studied the unsteady laminar flow of incompressible viscous fluid and heat transfer two parallel plates in the presence of a uniform suction and injection considering variable properties.

Kesavaiah, D. *et al.* [10] investigate the effect of the chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with heat source and suction. Shakya *et al.* [20] studied a Note on vorticity of unsteady hydromagnetic free convective flow of stratified viscous fluid past a porous vertical plate. Acharya *et al.* [1] have analyzed the magnetic field effects on a free convection and mass transfer flow through porous medium with constant suction and heat flux. Chaudhary and Sahoo [4] studied the unsteady free convective flow and mass transfer of a visco-elastic fluid in a rotating porous medium. Das *et al.* [6] studied the effect of free convection and mass transfer on MHD flow of a rotating elastico-viscous fluid past an infinite vertical porous plate through a porous medium with constant suction and heat flux.

Tak, S. S. and Nain, S. [22] discussed the unsteady free convection through a porous medium of fluctuating permeability bounded by porous vertical plate with constant heat and mass flux. Israel-cookey and Sigalo [7] discussed the unsteady MHD free convection and mass transfer flow past an infinite porous vertical plate with time dependent suction. Singh [18] has studied the MHD free convection flow of a fluid past an accelerated vertical porous plate in a rotating fluid. Raptis and Singh [15] studied the effect of rotation on MHD free convection through a vertical channel in a rotating porous medium. Panda *et al.* [14] have investigated the unsteady free convective flow and mass transfer of a rotating elastico-viscous liquid through a porous media past a vertical infinite porous plate. Kumar and Yadav [9] have studied the unsteady MHD free convection flow through porous medium with heat and mass transfer past a porous vertical moving plate with heat source/sink. Varshney *et al.* [23] discussed the Transpiration effect on unsteady MHD free convection flow through porous medium with heat and mass transfer past a porous vertical moving plate with heat source/sink. Soundalgekar [19] studied the unsteady MHD free convection flow past an infinite vertical flat plate with variable suction. Ram [16] discussed the unsteady MHD free convection flow of a viscous rotating fluid through a porous medium with constant heat flux and heat generation. Johari and Singh [8] discussed the effect of thermal diffusion on unsteady MHD free convection flow and mass transfer through porous medium with radiation and variable permeability in slip flow regime. Kothiyal, A. D. *et al* [11] discussed vorticity of MHD visco-elastic Boundary layer flow through porous medium with free convection past a continuous moving surface.

Sharma *et al.* [21] studied the unsteady free convection oscillatory coquette flow through a porous medium with periodic wall temperature. Kim *et al.* [12] have studied the unsteady convection flow of micropolar fluids past a vertical porous plate embedded in a porous medium. Ogulu and Makinde [13] studied the unsteady hydromagnetic free convection flow of a dissipative and radiating fluid past a vertical plate with constant heat flux.

The purpose of the present investigation is to the study of vorticity of unsteady MHD free convection mass transfer flow of a viscousincompressible electrically conducting visco-elastic fluid through porous medium with constant suction and heat flux.

II. Mathematical Formulation

We consider unsteady two dimensional motion of visco-elastic fluid through a porous medium occupying semi-infinite region of space bounded by a vertical infinite surface under the action of uniform magnetic field applied normal to the direction of flow .The X-axis is taken along the surface in the upward direction and Y-axis is taken normal to it. The fluid properties are assumed constant except for the influence of density in the body force term. As the bounding surface is infinite in length, all the variables are function of y. Now, under the usual Bossinnesq's approximation, the flow field is governed by the following equations.

Equation of Continuity:

$$\frac{\partial v}{\partial y} = 0 \quad \ldots(1.1)$$

Equation of momentum:

$$\frac{\partial u}{\partial t_0} + v\frac{\partial u}{\partial y} = \left(\nu + \beta\frac{\partial}{\partial t_0}\right)\frac{\partial^2 u}{\partial y^2} + g\beta(T - T_\infty) + g\beta^*(C - C_\infty) - \frac{\sigma B_0^2}{\rho}u - \frac{\nu}{\kappa_0}u \quad \ldots(1.2)$$

Equation of energy:

$$\frac{\partial T}{\partial t_0} + v\frac{\partial T}{\partial y} = \frac{\lambda}{\rho C_p}\left(\nu + \beta\frac{\partial}{\partial t_0}\right)\frac{\partial^2 T}{\partial y^2} \quad \ldots(1.3)$$

Equation of Concentration:

$$\frac{\partial C}{\partial t_0} + v\frac{\partial C}{\partial y} = D\left(\nu + \beta\frac{\partial}{\partial t_0}\right)\frac{\partial^2 C}{\partial y^2} \quad \ldots(1.4)$$

The initial boundary conditions are:

$$\left.\begin{array}{l} t_0 = 0 \;,\; u = 0 \;,\; v = -v_0 = \text{constant} \;,\; \dfrac{\partial T}{\partial y} = \dfrac{-q}{\lambda} \;,\; \dfrac{\partial C}{\partial y} = \dfrac{-m}{D} \quad at \;\; y = 0 \\ t_0 > 0 \;,\; u \to 0 \;,\; T \to T_\infty \;,\; C \to C_\infty \qquad as \quad y \to \infty \end{array}\right\} \quad \ldots(1.5)$$

In view of equations (1.5), equations (1.2), (1.3) and (1.4) can be written as

$$\frac{\partial u}{\partial t_0} - v_0\frac{\partial u}{\partial y} = \left(\nu + \beta\frac{\partial}{\partial t_0}\right)\frac{\partial^2 u}{\partial y^2} + g\beta(T - T_\infty) + g\beta^*(C - C_\infty) - \frac{\sigma B_0^2}{\rho}u - \frac{\nu}{\kappa_0}u \quad \ldots(1.6)$$

$$\frac{\partial T}{\partial t_0} - v_0\frac{\partial T}{\partial y} = \frac{\lambda}{\rho C_p}\left(\nu + \beta\frac{\partial}{\partial t_0}\right)\frac{\partial^2 T}{\partial y^2} \quad \ldots(1.7)$$

$$\frac{\partial C}{\partial t_0} - v_0\frac{\partial C}{\partial y} = D\left(\nu + \beta\frac{\partial}{\partial t_0}\right)\frac{\partial^2 C}{\partial y^2} \quad \ldots(1.8)$$

Introducing the following non-dimensional quantities into (1.6), (1.7), (1.8)

$$u = \frac{u}{v_0},\; y^* = \frac{v_0 y}{\nu},\; \mathrm{S}_c = \frac{\nu}{D}$$

$$\mathrm{M} = \frac{\sigma B_0^2 \nu}{\rho v_0^2} \;,\; \mathrm{G_r} = g\beta\frac{q\nu^2}{v_0^2\lambda} \;,\; \mathrm{G_m} = g\beta^*\frac{m\nu^2}{v_0^4 D}$$

$$\mathrm{P_r} = \frac{\mu C_p}{\lambda}\ ,\ \mathrm{E_c} = \frac{\lambda v_0^3}{\nu q C_p}\ ,\ t^* = \frac{t_0 v_0^2}{\nu}$$

$$\theta = \frac{T - T_\infty}{q\nu} v_0 \lambda\ ,\ \alpha = \frac{v_0^2 \kappa_0}{\nu^2}\ ,\ \phi = \frac{C - C_\infty}{m\nu} v_0 D$$

Equations (1.2), (1.3) and (1.4) after dropping the asterisks (*) can be written as

$$\frac{\partial^2 u}{\partial y^2} + \frac{\partial u}{\partial y} + \beta_0 \frac{\partial^3 u}{\partial t\, \partial y^2} = \frac{\partial u}{\partial t} + u\left(\mathrm{M} + \frac{1}{\alpha}\right) + \mathrm{G_r}\,\theta - \mathrm{G_m}\,\phi \qquad \ldots(2.0)$$

$$\nu \frac{\partial^2 \theta}{\partial y^2} + \mathrm{P_r}\frac{\partial \theta}{\partial y} + \beta_1 \mathrm{P_r} \frac{\partial^3 \theta}{\partial t\, \partial y^2} = \mathrm{P_r}\frac{\partial \theta}{\partial t} \qquad \ldots(2.1)$$

$$\nu \frac{\partial^2 \phi}{\partial y^2} + \mathrm{S_c}\frac{\partial \phi}{\partial y} + \beta_2 \mathrm{S_c} \frac{\partial^3 \phi}{\partial t\, \partial y^2} = \mathrm{S_c}\frac{\partial \phi}{\partial t} \qquad \ldots(2.2)$$

The corresponding initial and boundary conditions in non-dimensional form are:

$$\left.\begin{array}{l} u = 0\ ,\ \theta' = -1\ ,\ \phi' = -1\ \ at\ \ y = 0 \\ u \to 0\ ,\ \theta \to 0\ ,\ \phi \to 0\quad as\ \ y \to \infty \end{array}\right\} \qquad \ldots(2.3)$$

III. Method Of Solution

Let us choose the solutions of equations (2.0), (2.1) and (2.2) respectively as:

$$\left.\begin{array}{lcl} u(y,t) & = & u_0(y)\cdot e^{-nt} \\ \theta(y,t) & = & \theta_0(y)\cdot e^{-nt} \\ \phi(y,t) & = & \phi_0(y)\cdot e^{-nt} \end{array}\right\} \qquad \ldots(2.4)$$

Substituting expressions (2.4) into equations (2.0) to (2.2) , we obtain following equations

$$(1 - n\beta_0)u_0'' + u_0' - \left(\mathrm{M} + \frac{1}{\alpha} - n\right)u_0 = \mathrm{G_r}\theta_0 - \mathrm{G_m}\phi_0 \qquad \ldots(2.5)$$

$$(\nu - \beta_1 \mathrm{P_r})\theta_0'' + \mathrm{P_r}\theta_0' + n\mathrm{P_r}\theta_0 = 0 \qquad \ldots(2.6)$$

$$(\nu - \beta_2 \mathrm{S_c})\phi_0'' + \mathrm{S_c}\phi_0' + n\mathrm{S_c}\phi_0 = 0 \qquad \ldots(2.7)$$

The corresponding boundary conditions can be written as

$$\left.\begin{array}{llll} u_0 = 0 & at & y = 0 \\ u_0 \to 0 & as & y \to \infty \end{array}\right\} \qquad \ldots(2.8)$$

Solving equation (2.5) under the boundary conditions (2.8), we obtain the velocity distribution in the boundary layer as

$$u(y,t) \;=\; \left[K_1 \mathrm{G_r} e^{-K_2 y} + K_2 \mathrm{G_m} e^{-K_3 y} - K_1 \mathrm{G_r} e^{-K_4 y} - K_2 \mathrm{G_m} e^{-K_5 y}\right]\cdot e^{-nt} \qquad \ldots(2.9)$$

The vorticity of the equation (2.9) will be

$$\zeta = \left[K_1 K_4 e^{-K_4 y} + K_2 K_5 e^{-K_5 y} - K_2 (K_1 G_r e^{-K_2 y} + K_3 G_m e^{-K_3 y})\right] e^{-nt}$$

Where,

$$K_1 = \frac{1}{K_4\left[(1-n\beta_0)K_4^2 + K_4 - \left(\mathrm{M} + \frac{1}{\alpha} - n\right)\right]}, \; K_2 = \frac{1}{K_5\left[(1-n\beta_0)K_5^2 + K_5 - \left(\mathrm{M} + \frac{1}{\alpha} - n\right)\right]}$$

$$K_3 = \frac{1 + \sqrt{1 + 4(1-n\beta_0)\left(\mathrm{M} + \frac{1}{\alpha} - n\right)}}{2(1-n\beta_0)}, \; K_4 = \frac{\mathrm{P_r} + \sqrt{\mathrm{P_r^2} - 4n(\nu - \beta_1 \mathrm{P_r})\mathrm{P_r}}}{2(\nu - \beta_1 \mathrm{P_r})}$$

$$K_5 = \frac{\mathrm{S_c} + \sqrt{\mathrm{S_c^2} - 4n(\nu - \beta_2 \mathrm{S_c})\mathrm{S_c}}}{2(\nu - \beta_2 \mathrm{S_c})}$$

IV. Numericals Results And Discussion

Table-1 $P_r = 0.71, G_r = 2, G_m = 2, S_c = 0.6, R_e = 1$

Y	0	1	2	3	4	5
M = 1	0.4736	0.2516	0.1920	0.1434	0.0997	0.0655
M = 2	0.1041	0.1063	0.1020	0.0800	0.0561	0.0368
M = 3	-0.3268	0.0328	0.0671	0.0550	0.0391	0.0256
M = 4	-0.7103	-0.0041	0.0501	0.0426	0.0300	0.0196

Table-2 $P_r = 0.71, M = 2, G_m = 2, S_c = 0.6, R_e = 1$

Y	0	1	2	3	4	5
$G_r = 2$	0.1041	0.1063	0.1020	0.0800	0.0561	0.0368
$G_r = 4$	-3.4673	1.8381	1.5520	0.9431	0.5391	0.3031
$G_r = 6$	-9.4197	4.7242	3.9686	2.3824	1.3441	0.7470
$G_r = 8$	-17.7530	8.7649	7.3520	4.3970	2.4711	1.3684

Table-3 $M = 2, G_r = 2, G_m = 2, S_c = 0.6, R_e = 1$

Y	0	1	2	3	4	5
$P_r = 0.71$	0.1041	0.1063	0.1020	0.0800	0.0561	0.0368
$P_r = 1.42$	-2.0265	0.1609	0.3537	0.2525	0.1519	0.0865
$P_r = 2.13$	-2.5905	0.2256	0.4165	0.2765	0.1592	0.0885
$P_r = 2.84$	-2.8237	0.2608	0.4349	0.2809	0.1600	0.0886

Table-4 $M=2, G_r=2, G_m=2, P_r=0.71, R_e=1$

Y	0	1	2	3	4	5
$S_c=0.6$	0.1041	0.1063	0.1020	0.0800	0.0561	0.0368
$S_c=1.0$	1.2946	-0.0058	-0.1473	-0.1132	-0.0689	-0.0368
$S_c=1.4$	2.0883	-0.0544	-0.2488	-0.1710	-0.0953	-0.0495
$S_c=1.8$	4.4692	-0.1728	-0.2589	-0.1854	-0.1009	-0.0512

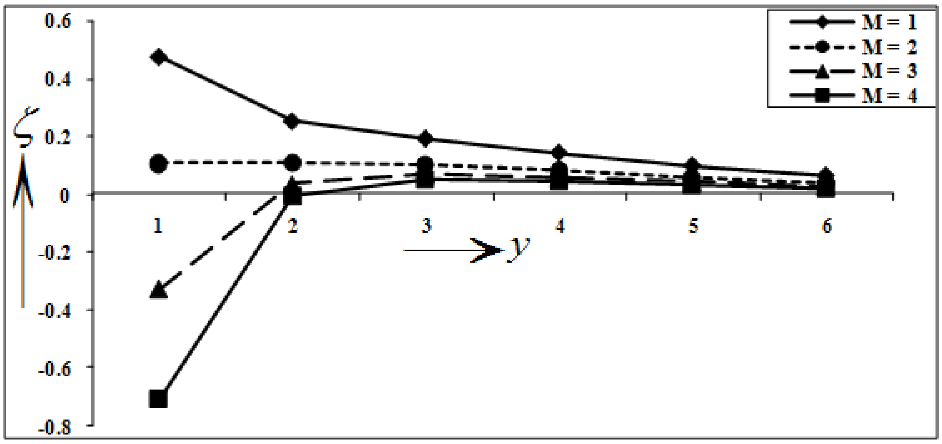

Figure 1. Vorticity profiles against *y* for different values of *M* with $P_r=0.71,\ G_r=2$
$G_m=2, S_c=0.6$ and $R_e=1$

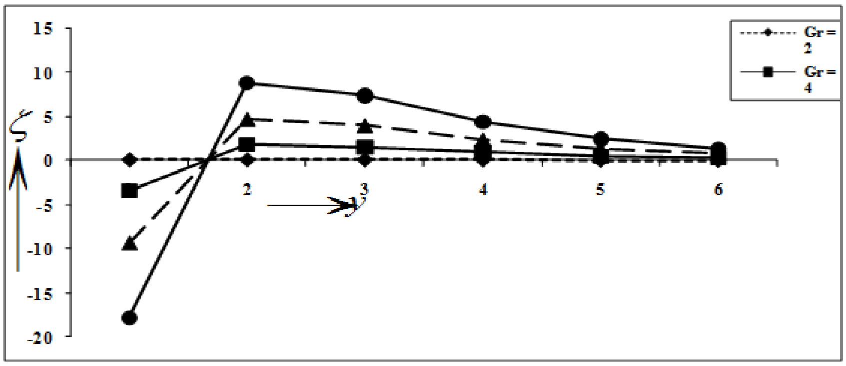

Figure 2. Vorticity profiles against *y* for different values of G_r with $M=2$, $P_r=0.71$
$G_m=2, S_c=0.6$ and $R_e=1$

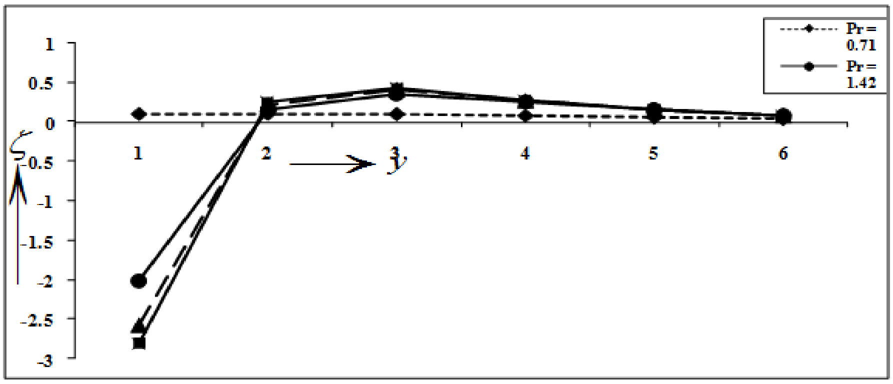

Figure 3. Vorticity profiles against *y* for different values of P_r with $M=2$, $G_r=2$
$G_m=2, S_c=0.6$ and $R_e=1$

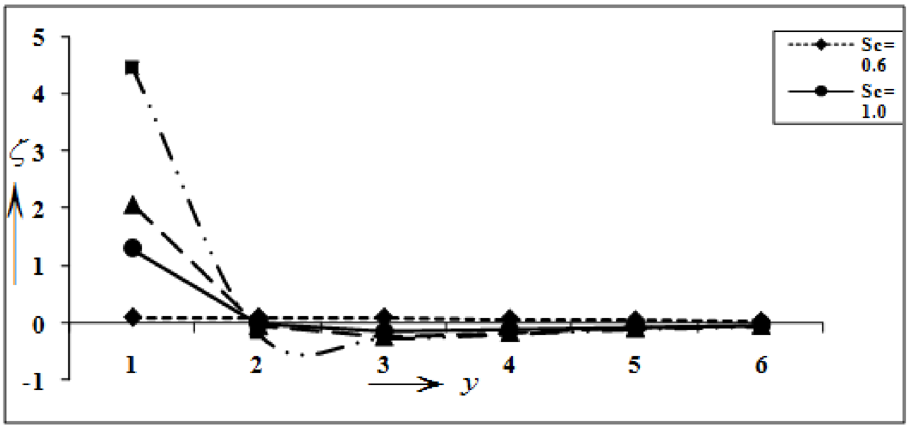

Figure 4. Vorticity profiles against *y* for different values of S_c with $M = 2$, $G_r = 2$ $G_m = 2, P_r = 0.71$ and $R_e = 1$

The vorticity distribution for different values of magnetic parameter M (M =1, 2, 3, 4) with $P_r = 0.71, G_r = 2, G_m = 2, S_c = 0.6, R_e = 1$ are shown in table (1) and Figure (1). Separately it is found that the vorticity increases sharply till y = 0, after its vorticity decreases continuously with increases in y. it is observed that vorticity distribution decreases due to increasing the value of Magnetic parameter M at y = 0.

The vorticity distribution for different values of Grashoff number G_r (G_r = 2, 4, 6, 8) with $P_r = 0.71, M = 2, G_m = 2, S_c = 0.6, R_e = 1$ are shown in table (2) and figure (2). Separately it is found that the vorticity increases sharply y = 0 to y = 2, after its vorticity decreases continuously with increases in y. it is observed that vorticity distribution decreases due to increases the value of Graashoff number G_r at y = 0.

The vorticity distribution for different values of P_r (P_r = 0.71, 1.42, 2.13, 2.83) with $M = 2, G_r = 2, G_m = 2, S_c = 0.6, R_e = 1$ are shown in table (3) and figure (3), Separately it is found that the vorticity vorticity decreases continuously with increases in y. It is observed that vorticity decreases with increasing Prandtl number P_r.

The vorticity distribution for different values of S_c (S_c =0.6, 1.0, 1.4, 1.8) with $M = 2, G_r = 2, G_m = 2, P_r = 0.71, R_e = 1$ are shown in table (4) and figure (4), separately it is found that the vortocity decrease with increases in y. It is observed that vorticity increases with increasing Schimdt number S_c at y = 0.

References

[1]. Acharya, M., Dash, G. C. and Singh, L. P., Magnetic field effects on the free convection and mass transfer flow through porous medium with constant suction and constant heat flux. Int. J. Pure Appl. Math. 31, Pp. 1-18, (2000).

[2]. Attia, H.A., Unsteady Hartmann flow with heat transfer of a viscoelastic fluid considering the Hall Effect. Can. J. Phys. Rev. 82, Pp. 127-139 (2004).

[3]. Attia, H. A., The effect of suction and injection on the unsteady flow between two parallel porous plates with variables properties. Tamkang J. Sci. Engg., 8, Pp. 17-22 (2005).

[4]. Chaudhary, N. K. and Sahoo, R.C., Unsteady free convective flow and mass transfer of visco-elastic fluid in a rotating porous medium. J. Energy, Heat and Mass transfer. 17, Pp. 129-133(1995).

[5]. Dulal, P. and Talukdar, B., Perturbation analysis of unsteady Magneto hydrodynamic free convection flow past a semi-infinite vertical porous plate with mass transfer. Communications in Non-linear Science and Numerical Simulation Pp. 1813-1830, (2010).

[6]. Das, S. S., Panda, J. P. and Patnaik, A. B., Effect of free convection and mass transfer on MHD flow of a rotating elastico-viscous fluid past an infinite vertical porous plate through a porous medium with constant suction and heat flux. Indian journal of Science and technology, 2(9).Pp. 32-37 (2009).

[7]. Israel-cookey, C. and Sigalo, F. B., Unsteady MHD free convection and mass transfer flow past an infinite heated porous vertical plate with time dependent suction. AMSE J. Mod., Meas.Cont.B.72, Pp. 25-38(2003).

[8]. Johari, R. and Singh, D., Effect of thermal diffusion on unsteady MHD free convective flow and mass transfer through porous medium with radiation and variable permeability slip flow regime. Acta Ciencia Indica. 36 M, 1, Pp. 165-176 (2010).

[9]. Kumar, V. and Yadav, S. S., Unsteady MHD free convection flow through porous medium with heat and mass transfer past a porous vertical moving plate with heat source/sink. Acta Ciencia Indica, 33M , 4, Pp. 22-37(2007).

[10]. Kesavaiah, D., Satyanarayana, P. V. and Venkataramana, S., Effect of the chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with heat source and suction. Int. J. of Appl. Math and Mech.7 (1), Pp.52-69(2011).

[11]. Kothiyal' A. D., Ansari, S. R. and Sangeeta. A Study of Vorticity of MHD Visco-elastic Boundary layer flow through porous medium with free convection past a continuous moving surface. International Journal of Scientific & Engineering Research, Volume 4, No. 6, , Pp. 3091-3101(2013).

[12]. Kim, J. Y., Unsteady convection flow of micropolar fluids past a vertical porous plate embedded in a porous medium. Acta Mechanica 148, Pp. 105-116 (2001).

[13]. Ogulu, A. and Makinde, O. D., Unsteady hydromagnetic free convection flow of a dissipative and radiating fluid past a vertical plate with constant heat flux. Chem. Eng. Comm. 196, Pp. 454-462(2009).

[14]. Panda, J. P., Dash, G.C. and Das, S. S., Unsteady free convective flow and mass transfer of a rotating elastico-viscous liquid through porous media past a vertical porous plate .AMSE J.Mod.Meas.Cont.B.72,Pp. 47-59(2003).

[15]. Raptis, A. and Singh, A. K., Rotation effect on MHD free convection flow past an accelerated vertical plate. Mech. Res. Comm.12, Pp. 31-41(1985).

[16]. Ram, P. C., Unsteady MHD free convection flow of a viscous rotating fluid through a porous medium with constant heat flux and heat generation. J. of Astrophysics and Space Science, 161, Pp. 167-170 (1989).

[17]. Satyanarayana, P.V. and Venkataramana, S., Hall current effect on Magneto hydrodynamic free convection flows past a semi-infinite vertical porous plate with mass transfer. S.V. University, Ph.D. Thesis. (2007).

[18]. Singh, A.K., MHD free convection flow past an accelerated vertical porous plate in a rotating fluid. Astrophys. Space Sci. 103, Pp. 155-163(1984).

[19]. Soundalgekar, V. M., Unsteady MHD free convection flow past an infinite vertical flat plate with variable suction. Int. J. of Appl. Math 3(3), Pp. 26-36 (1970).

[20]. Shakya S. K., Shriprakash and Singh, M. P., A note on vorticity of unsteady hydromagnetic free convective flow of stratified viscous fluid past a porous vertical plate. Acta Ciencia Indica, 38 M, 4, Pp. 661-674 (2012).

[21]. Sharma, P. K., Sharma, B. K., and Chaudhary, R. C., Unsteady free convection oscillatory couette flow through a porous medium with periodic wall temperature. TAMKANG journal of mathematics, 38(1), Pp. 93-102 (2007).

[22]. Tak, S. S. and Nain, S.; Unsteady free convection through a porous medium of fluctuating permeability bounded by porous vertical plate with constant heat and mass flux. Acta Ciencia Indica, 30M, 1, Pp.63-70(2004).

[23]. Varshney, N.K. and Gupta, R.K., Transpiration effect on unsteady MHD free convection flow through porous medium with heat and mass transfer past a porous vertical moving plate with heat source/sink. Acta Ciencia Indica, 35M, 1, Pp. 113-120 (2009).