ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 2, Issue 4, April 2013

# CHEMICAL REACTION AND OHMIC DISSIPATION EFFECTS ON MHD MEMORY FLOW PAST A MOVING SURFACE THROUGH POROUS MEDIUM

**K. Sreelatha[1], B. Rami Reddy[2] and J. Girish Kumar[3]**

**ABSTRACT: The objectives of the present study are to investigate the unsteady flow and heat transfer of an incompressible electrically conducting, chemically reacting memory fluid via porous medium over a continuous moving horizontal non-conducting surface in the presence of an oscillating free stream and Ohmic dissipation, neglecting induced magnetic field in comparison to the applied magnetic field. The equations of continuity, momentum, energy and diffusion, which govern the flow field, are solved by using the perturbation technique. The effects of material parameters on the velocity, temperature and concentration fields across the boundary layer are investigated.**

**Keywords:** Chemical reaction, MHD, memory flow and porous medium etc

## INTRODUCTION:

Magneto-hydrodynamics (MHD) is the branch of continuum mechanics, which deals with the flow of electrically conducting fluids in electric and magnetic fields. Many natural phenomena and engineering problems are worth being subjected to an MHD analysis. Magneto-hydrodynamic equations are ordinary electromagnetic and hydrodynamic equations modified to take into account the interaction between the motion of the fluid and the electromagnetic field. The formulation of the electromagnetic theory in a mathematics form is known as Maxwell's equation.

The study of magnetic hydrodynamic viscolastic fluids had become of increasing importance in the last few years. This is mainly due to their many applications in petroleum drilling, manufacturing of foods and paper and many other similar activities. Some these fluids, which can be formulated by the model used in the present study, are termed second-grade fluids. It is a well-known fact in the studies of non-Newtonian fluid flows by Hartnett [9]. Thus, if we use a non-Newtonian fluid as the coolant of the cooling system or heat exchangers might greatly reduce the required pumping power. Therefore, a fundamental analysis of the flow field of non-Newtonian fluids in a boundary layer adjacent to a horizontal surface or an extended surface is very important and is also an essential part in the area of the fluid dynamics and heat transfer.

**Karanam Sreelatha**, Dept. of Science and Humanities, Satya Institute of Tech and Management, Vizianagaram, A. P., India.

**B Rami Reddy,** Dept. of Mathematics, Hindu College, Guntur, A. P., India.

**J Girish Kumar**, Dept. of Mathematics, Govt. Degree College, Jammalamadugu, Kadapa, A.P., India.

Mustafa et al. [24] have analyzed the unsteady MHD memory flow with oscillatory suction, variable free stream and heat source. Chowdhury and Islam [16] have discussed the MHD free convection flow of visco-elastic fluid past an infinite vertical porous plate. Ezzat Madgy [3] studied the magnetohydrodynamic unsteady flow of non-Newtonian fluid past an in porous plate. Rita and Kamal [23] have examined the unsteady oscillatory MHD flow of a visco-elastic fluid past a porous vertical plate with periodic suction.

Convection flow driven by temperature and concentration differences has been the objective of extensive research because such processes exists in nature and has engineering applications. The process occurring in nature includes photosynthetic mechanism, calm-day evaporation and vaporization of mist and fog, while the engineering application includes the chemical reaction in a reactor and cooling of electronic equipment.

Flows through porous media are very much prevalent in nature and therefore, the study of flows through porous media has become of principal interest in many scientific and engineering applications. This type of flows has shown their great importance in petroleum engineering to study the movement of natural gas, oil and water through the oil reservoirs; in chemical engineering for filtration and water purification processes. Further, to study the underground water resources, seepage of water in riverbeds also one needs to investigate the flows through porous media. Thus, there are a numerous practical uses of fluid flows through porous media. Books by Nield and Bejan [2], Bejan and Kraus [1] and Ingham et al. [6] excellently describe the extend of the research information in this area. Hemant Poonia and Chaudhary [8] have discussed the effects of heat transfer on MHD free convective flow through porous medium with viscous dissipation. Vinay Kumar et al. [10] have examined the heat transfer in MHD free convection flow over an infinite vertical plate through porous medium with time dependent suction.

The present trend in the field of chemical reaction analysis is to give a mathematical model for the system to predict the reactor performance. A large amount of research work has been reported in this field. In particular, the study of heat and mass transfer with chemical reaction is of considerable importance in chemical and hydrometallurgical industries. Chemical reaction can be codified as either heterogeneous or homogeneous processes. This depends on whether they occur at an interface or as a single phase volume reaction. Muthucumaraswamy and Ganesan [22] have studied effect of the chemical reaction and injection on flow characteristics in an unsteady upward motion of an isothermal plate. Deka et al., [21] have discussed the effect of the first order homogeneous chemical reaction on the process of an unsteady flow past an infinite vertical plate with a constant heat and mass transfer. Sandeep et al. [17] have analyzed the effect of radiation and chemical reaction on transient MHD free convective flow over a vertical plate through porous media. Kishore et al. [19] have tackled the effects of thermal radiation and viscous dissipation on MHD heat and mass diffusion flow past an oscillating vertical plate embedded in a porous medium with variable surface conditions.

For the problem of coupled heat and mass transfer in MHD free convection, the effect of both viscous dissipation and Ohmic heating are not studied in the above investigation. However, it is more realistic to include these two effects to explore the impact of the magnetic field on the thermal transport in the boundary layer. With this awareness, Hossian [4] has examined the effect of Ohmic heating on the MHD free convection heat transfer for a Newtonian fluid. Chen [5] tackled the combined heat and mass transfer in MHD free convection from a vertical surface with Ohmic heating and viscous dissipation. Chaudhary et al. [20] have studied the radiation effect with simultaneous thermal and mass diffusion in MHD mixed convection flow from a vertical surface with Ohmic heating. Reddy and Rao [18] have analyzed the numerical solution of thermal diffusion effect on an unsteady MHD free convective mass transfer flow past a vertical porous plate with Ohmic dissipation

The constitutive equation for the theological equation of state for a memory fluid liquid B' model given by Walter's, [11, 12, 13, 14, 15]. The mixture of polymethyl mehacrylate and pyridine at $25^0 C$ containing 30.5g of polymer per litre behaves very nearly as the Walter's liquid B'.

The main objective of the present analysis if to investigate the unsteady flow and heat transfer of an incompressible electrically conducting, chemically reacting memory fluid over a continuous moving horizontal non-conducting surface in the presence of an oscillating free stream and Ohmic dissipation through porous medium. The equations of continuity, momentum, energy and diffusion, which govern the flow field, are solved by using the perturbation technique.

**FORMULATION OF THE ROBLEM:**

Consider unsteady flow and heat transfer of an incompressible electrically conducting, chemically reacting memory fluid over a continuous moving horizontal non-conducting surface in the presence of an oscillating free stream and Ohmic dissipation. The x-axis is taken along surface in flow direction and y-axis is normal to the surface. Transverse magnetic field $B_0$ (constant) is applied and induced magnetic field in comparison to the applied magnetic field is neglected. Initially, the temperature of fluid and plate are assumed to be same. Boussinesq approximation within the boundary layer, the governing equations of continuity, momentum, energy and diffusion are as follows:

Continuity equation

$$\frac{\partial v}{\partial y} = 0 \qquad (1)$$

Momentum equation

$$\rho\left(\frac{\partial u}{\partial t} + v\frac{\partial u}{\partial y}\right) = \rho\frac{\partial U(t)}{\partial t} + \mu\frac{\partial^2 u}{\partial y^2} + \rho g\beta(\theta - \theta_\infty) + \rho g\beta^*(C - C_\infty) - B_1\left(\frac{\partial^3 u}{\partial t\partial y^2} + v\frac{\partial^3 u}{\partial y^3}\right) - \left(\sigma B_0^2 + \rho\frac{v'}{k'}\right)(u - U(t)) \qquad (2)$$

Energy equation

$$\rho C_p\left(\frac{\partial T}{\partial t} + v\frac{\partial T}{\partial y}\right) = \kappa\frac{\partial^2 T}{\partial y^2} + \mu\left(\frac{\partial u}{\partial y}\right)^2 + \sigma B_0^2\big(u - U(t)\big)^2 \qquad (3)$$

Diffusion equation

$$\frac{\partial C}{\partial t} + v\frac{\partial C}{\partial y} = D\frac{\partial^2 C}{\partial y^2} - K_r'(C - C_\infty) \qquad (4)$$

Where u is the fluid velocity component along x-axis, T is the fluid temperature, t is the time, $v_0$ is the cross-flow velocity, $\rho$ is the density, $\mu$ is the coefficient of viscosity, $C_p$ is the specific heat at constant pressure, $\kappa$ is the thermal conductivity, $B_0$ is the applied magnetic field, $B_1$ is the kinematic viscoelasticity, $\sigma$ is the electrical conductivity of the medium and $U(t)$ is the uniform free stream.

From equation (1) we have

$$v = -v_0(1 + \varepsilon e^{i\omega t}) \tag{5}$$

The boundary conditions are:

$$\left.\begin{aligned} y = 0: u = U_w, T = T_w, C = C_\infty + \varepsilon(C_w - C_\infty)e^{i\,w\,t} \\ y \to \infty: \quad u \to U(t), \quad T \to T_\infty, \quad C \to C_\infty \end{aligned}\right\} \tag{6}$$

Where $U_w$ is the surface velocity, is the surface temperature is the surface concentration, is the free stream temperature, is the free stream concentration and is the frequency.

Introducing the following non-dimensional quantities:

$$\left.\begin{aligned} \bar{y} = \frac{yv_0}{v}, \bar{t} = \frac{tv_0^2}{4v}, \bar{u} = \frac{u}{U}, \theta = \frac{(T - T_\infty)}{(T_w - T_\infty)}, \beta = \frac{U_w}{U}, Gr = \frac{vg\beta(T_w - T_\infty)}{v_0^3} \\ \bar{\omega} = \frac{\omega 4v}{v_0^2}, Pr = \frac{\mu C_p}{\kappa}, \quad R_m = \frac{B_1 v_0^2}{\rho v^2}, M = \frac{\sigma B_0^2 v}{\rho v_0^2}, Gc = \frac{vg\beta^*(C_w - C_\infty)}{v_0^3}, k = \frac{k' v^2}{v_0^2} \\ \bar{U}(t) = \frac{U(t)}{U}, Ec = \frac{U^2}{C_p(T_w - T_\infty)} C^* = \frac{(C - C_\infty)}{(C_w - C_\infty)}, Kr = \frac{K_r' v}{v_0^2}, Sc = \frac{v}{D} \end{aligned}\right\} \tag{7}$$

From (5) and (7) the equations (2), (3) and (4) become:

$$\frac{1}{4}\frac{\partial u}{\partial t} - (1 + \varepsilon e^{i\omega t})\frac{\partial u}{\partial y} = \frac{1}{4}\frac{\partial U}{\partial t} + \frac{\partial^2 u}{\partial y^2} + Gr\theta + GcC - R_m\left[\frac{1}{4}\frac{\partial^3 u}{\partial t \partial y^2} - (1 + \varepsilon e^{i\omega t})\frac{\partial^3 u}{\partial y^3}\right] - \left(M + \frac{1}{k}\right)(u - U(t)) \tag{8}$$

$$\frac{1}{4}\frac{\partial \theta}{\partial t} - (1 + \varepsilon e^{i\omega t})\frac{\partial \theta}{\partial y} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial y^2} + Ec\left(\frac{\partial u}{\partial y}\right)^2 + MEc\left(u - U(t)\right)^2 \tag{9}$$

$$\frac{1}{4}\frac{\partial C}{\partial t} - (1 + \varepsilon e^{i\omega t})\frac{\partial C}{\partial y} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} - Kr \tag{10}$$

Where M is the Hartmann Number, k is the permeability parameter, Pr is the Prandtl number, Ec is the Eckert number and $R_m$ is the Magnetic Reynolds number.

The boundary conditions are:

$$\left.\begin{aligned} y = 0: u = \beta, \theta = 1, C = 1 + \varepsilon e^{i\,\omega\,t} \\ y \to \infty: \quad u \to U(t), \quad \theta \to 0, \quad C \to 0 \end{aligned}\right\} \tag{11}$$

## 5.3 SOLUTION OF THE PROBLEM:

Equations (8) – (10) are coupled, non-linear partial differential equations and these cannot be solved in closed form. However, these equations can be reduced to a set of ordinary differential equations, which can be solved analytically. This can be done by representing the velocity, temperature and concentration of the fluid in the neighbourhood of the plate as:

$$\left.\begin{aligned} u(y,t) = u_0(y) + \varepsilon e^{i\omega t} u_1(y) \\ \theta(y,t) = \theta_0(y) + \varepsilon e^{i\omega t} \theta_1(y) \\ C(y,t) = C_0(y) + \varepsilon e^{i\omega t} C_1(y) \end{aligned}\right\} \tag{12}$$

And for free stream velocity

$$U(t) = 1 + \varepsilon e^{i\omega t} \tag{13}$$

Where u, $\theta$ and C are velocity, temperature and concentration and we assume $\omega$ to be very small. Substituting (12) and (13) in equations (8), (9) and (10), equating harmonic and non-harmonic terms for velocity, temperature and concentration, after neglecting coefficient of $\varepsilon^2$, we get

Zero-Order Equations of $\varepsilon e^{i\omega t}$

$$R_m u_0''' + u_0'' + u_0' - \left(M + \frac{1}{k}\right)u_0 = -\left[Gr\theta_0 + GcC_0 + \left(M + \frac{1}{k}\right)\right] \tag{14}$$

$$\theta_0''' + Pr\theta_0'' = -PrEc(u_0')^2 - PrMEc(u_0 - 1)^2 \tag{15}$$

$$C_0'' + ScC_0' - KrScC_0 = 0 \tag{16}$$

First- Order Equations of $\varepsilon e^{i\omega t}$

$$R_m u_1''' - \left(R_m \frac{i\omega}{4} - 1\right)u_1'' + u_1' - \left(\frac{i\omega}{4} + M + \frac{1}{k}\right)u_1 = -R_m u_0''' - u_0' - Gr\theta_1 - GcC_1 - \left(\frac{i\omega}{4} + M + \frac{1}{k}\right) \tag{17}$$

$$\theta_1''' + Pr\theta_1' - \frac{i\omega}{4}Pr\theta_1 = -Pr\theta_0' - 2PrEcu_0'u_1' - 2PrMEc(u_0 - 1)(u_1 - 1) \tag{18}$$

$$C_1'' + ScC_1' - \left(Kr - \frac{i\,\omega}{4}\right)ScC_1 = 0 \tag{19}$$

Here, the prime denotes differentiation with respect to 'y'

The corresponding boundary conditions are reduced to

$$\left.\begin{aligned} y = 0: \; u_0 = \beta, u_1 = 0, \theta_0 = 1, \theta_1 = 0, C_0 = 1, C_1 = 0 \\ y \to \infty: u_0 \to 1, u_1 \to 1, \theta_0 \to 0, \theta_1 \to 0, C_0 \to 0, C_1 \to 0 \end{aligned}\right\} \tag{20}$$

The zero order and first order equations correspond to steady flow and unsteady flow, respectively. Since (14), (15), (17) and (18) are coupled nonlinear third order differentiation equation due to presence of elasticity of the fluids.

ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 2, Issue 4, April 2013

Therefore $u_0$ and $u_1$ are expanded using (Beard and Walters rule, 1964).

$$u_0 = u_{00} + R_m u_{01} \qquad (21)$$
$$u_1 = u_{10} + R_m u_{11} \qquad (22)$$

Zero-Order of $R_m$

$$u''_{00} + u'_{00} - \left(M + \frac{1}{k}\right) u_{00} = -\left[Gr\theta_0 + GcC_0 + \left(M + \frac{1}{k}\right)\right] \qquad (23)$$

$$u''_{10} + u'_{10} - \left(\frac{i\omega}{4} + M + \frac{1}{k}\right) u_{10} = -u'_{00} - \left[Gr\theta_1 + GcC_1 + \left(\frac{i\omega}{4} + M + \frac{1}{k}\right)\right] \qquad (24)$$

First-Order of $R_m$

$$u''_{01} + u'_{01} - \left(M + \frac{1}{k}\right) u_{01} = -u'''_{00} \qquad (25)$$

$$u''_{11} + u'_{11} - \left(\frac{i\omega}{4} + M + \frac{1}{k}\right) u_{11} = -u'''_{00} - u'_{01} - u'''_{10} + \frac{i\omega}{4} u''_{10} \qquad (26)$$

Using the multi parameter perturbation technique and assuming $Ec \ll 1$, we write

$$\left.\begin{aligned} u_{00} &= u_{000} + Ec u_{001} \\ u_{01} &= u_{011} + Ec u_{012} \\ u_{10} &= u_{100} + Ec u_{101} \\ u_{11} &= u_{111} + Ec u_{112} \end{aligned}\right\} \qquad (27)$$

And

$$\left.\begin{aligned} \theta_0 &= \theta_{00} + Ec\theta_{01} \\ \theta_1 &= \theta_{10} + Ec\theta_{11} \end{aligned}\right\} \qquad (28)$$

Using equations (27) and (28) in the equations (23), (24), (25), (26), (15) and (18) and also equating the coefficient of $Ec^0$ and $Ec^1$, we get the following set of differential equations:

Zero order of Ec

$$u''_{000} + u'_{000} - \left(M + \frac{1}{k}\right) u_{000} = -Gr\theta_{00} - GcC_{00} - \left(M + \frac{1}{k}\right) \qquad (29)$$

$$u''_{011} + u'_{011} - \left(M + \frac{1}{k}\right) u_{011} = -u'''_{000} \qquad (30)$$

$$u''_{100} + u'_{100} - \left(\frac{i\omega}{4} + M + \frac{1}{k}\right) u_{100} = -u'_{000} - Gr\theta_{10} - GcC_{10} - \left(\frac{i\omega}{4} + M + \frac{1}{k}\right) \qquad (31)$$

$$u''_{111} + u'_{111} - \left(\frac{i\omega}{4} + M + \frac{1}{k}\right) u_{111} = -u'''_{000} - u'_{011} - u'''_{100} + \frac{i\omega}{4} u''_{100} \qquad (32)$$

$$\theta''_{00} + Pr\theta'_{00} = 0 \qquad (33)$$

$$\theta''_{10} + Pr\theta'_{10} - \frac{i\omega}{4} Pr\theta_{10} = -Pr\theta_{00} \qquad (34)$$

First order of Ec

$$u''_{001} + u'_{001} - \left(M + \frac{1}{k}\right) u_{001} = -Gr\theta_{01} - GcC_{01} \qquad (35)$$

$$u''_{012} + u'_{012} - \left(M + \frac{1}{k}\right) u_{012} = -u'''_{001} \qquad (38)$$

$$u''_{101} + u'_{101} - \left(\frac{i\omega}{4} + M + \frac{1}{k}\right) u_{101} = -u'_{001} - Gr\theta_{11} - GcC_{11} \qquad (39)$$

$$u''_{112} + u'_{112} - \left(\frac{i\omega}{4} + M + \frac{1}{k}\right) u_{112} = -u'''_{001} - u'_{012} - u'''_{101} + \frac{i\omega}{4} u''_{101} \qquad (40)$$

$$\theta''_{01} + Pr\theta'_{01} = -PrEc(u'_{000})^2 - PrMEc(u_{000} - 1)^2 \qquad (41)$$

$$\theta''_{11} + Pr\theta'_{11} - \frac{i\omega}{4} Pr\theta_{11} = -Pr\theta_{01} - 2Pr(u'_{000})(u'_{111}) - 2PrM(u_{000} - 1)(u_{111} - 1) \qquad (42)$$

The corresponding boundary conditions are:

$$\left.\begin{aligned} &y = 0: u_{000} = u_{001} = u_{100} = u_{101} = \beta, u_{011} = u_{012} = u_{111} = u_{112} = 0 \\ &\qquad \theta_{00} = 1, \theta_{01} = 0, \theta_{10} = 1, \theta_{11} = 0 \\ &y \to \infty: u_{000} \to u_{001} \to u_{011} \to u_{012} \to u_{100} \to u_{111} \to u_{101} \to u_{112} \to 0 \\ &\qquad \theta_{00} \to 0, \theta_{01} \to 0, \theta_{10} \to 0, \theta_{11} \to 0 \end{aligned}\right\} \qquad (43)$$

Solving the differential equations (16), (19), and from (29) – (42), using the boundary conditions (43), and then making use of equations (27) & (28), finally with the help of equations (12) we obtain the velocity, temperature and concentration profiles as follows:

$$u(y,t) = \Big[\Big\{\big(\alpha_5 e^{\alpha_2 y} + \alpha_3 e^{\beta_2 y} + \alpha_4 e^{\gamma_2 y} + 1\big) + (Ec)\big(\alpha_{13} e^{\alpha_2 y} + \alpha_6 e^{\beta_2 y} + \alpha_7 e^{2\alpha_2 y} + \alpha_8 e^{2\beta_2 y} + \alpha_9 e^{2\gamma_2 y} + \alpha_{10} e^{(\alpha_2+\beta_2)y} + \alpha_{11} e^{(\beta_2+\gamma_2)y} + \alpha_{12} e^{(\alpha_2+\gamma_2)y}\big)\Big\} + R_m \Big\{\big(\alpha_{17} e^{\alpha_2 y} + \alpha_{14} e^{\alpha_2 y} + \alpha_{15} e^{\beta_2 y} + \alpha_{16} e^{\gamma_2 y}\big) + (Ec)\Big(\big(\alpha_{26} + \alpha_{18}\big) e^{\alpha_2 y} + \alpha_{19} e^{\beta_2 y} + \alpha_{20} e^{2\alpha_2 y} + \alpha_{21} e^{2\beta_2 y} + \alpha_{22} e^{2\gamma_2 y} + \alpha_{23} e^{(\alpha_2+\beta_2)y} + \alpha_{24} e^{(\beta_2+\gamma_2)y} + \alpha_{25} e^{(\gamma_2+\alpha_2)y}\Big)\Big\}\Big] + \varepsilon e^{i\omega t}\Big[\Big\{\big(\alpha_{35} e^{\alpha_{28} y} + \alpha_{29} e^{\alpha_2 y} + \alpha_{30} e^{\beta_2 y} + \alpha_{31} e^{\gamma_2 y} + \alpha_{32} e^{\beta_4 y} + \alpha_{33} e^{\beta_2 y} + \alpha_{34} e^{\gamma_4 y} + 1\big) + (Ec)\big(\alpha_{110} e^{\alpha_{28} y} + \alpha_{93} e^{\alpha_2 y} + \alpha_{94} e^{\beta_2 y} + \alpha_{95} e^{2\alpha_2 y} + \alpha_{96} e^{2\beta_2 y} + \alpha_{97} e^{2\gamma_2 y} + \alpha_{98} e^{(\alpha_2+\beta_2)y} + \alpha_{99} e^{(\beta_2+\gamma_2)y} + \alpha_{100} e^{(\alpha_2+\gamma_2)y} + \alpha_{101} e^{(\alpha_2+\alpha_{28} y)} + \alpha_{102} e^{(\beta_2+\alpha_{28})y} + \alpha_{103} e^{(\gamma_2+\alpha_{28})y} + \alpha_{104} e^{(\alpha_2+\beta_4)y} + \alpha_{105} e^{(\beta_2+\beta_4)y} + \alpha_{106} e^{(\beta_2+\gamma_4)y} + \alpha_{107} e^{(\gamma_2+\beta_4)y} + \alpha_{108} e^{(\gamma_2+\gamma_4)y} + \alpha_{109} e^{(\alpha_2+\gamma_4)y}\big)\Big\} + R_m\Big\{\big(\alpha_{49} e^{\alpha_{28} y} + \alpha_{42} e^{\alpha_2 y} + \alpha_{43} e^{\beta_2 y} + \alpha_{44} e^{\gamma_2 y} + \alpha_{45} e^{\beta_4 y} + \alpha_{47} e^{\gamma_4 y}\big) + (Ec)\big(\alpha_{147} e^{\alpha_{28} y} + \alpha_{129} e^{\alpha_2 y} + \alpha_{130} e^{\beta_2 y} + \alpha_{131} e^{2\alpha_2 y} + \alpha_{132} e^{2\beta_2 y} + \alpha_{133} e^{2\gamma_2 y} + \alpha_{134} e^{(\alpha_2+\beta_2)y} + \alpha_{135} e^{(\beta_2+\gamma_2)y} + \alpha_{136} e^{(\alpha_2+\gamma_2)y} + \alpha_{137} e^{\alpha_{28} y} + \alpha_{138} e^{(\alpha_2+\alpha_{28} y)} + \alpha_{139} e^{(\beta_2+\alpha_{28})y} + \alpha_{140} e^{(\gamma_2+\alpha_{28})y} + \alpha_{141} e^{(\alpha_2+\beta_4)y} + \alpha_{142} e^{(\beta_2+\beta_4)y} + \alpha_{143} e^{(\beta_2+\gamma_4)y} + \alpha_{144} e^{(\gamma_2+\beta_4)y} + \alpha_{145} e^{(\gamma_2+\gamma_4)y} + \alpha_{146} e^{(\alpha_2+\gamma_4)y}\big)\Big\}\Big]$$

$$\theta(y,t) = \big[\beta_{18} e^{\beta_2 y} + (\beta_6 + \beta_{12}) e^{2\alpha_2 y} + (\beta_7 + \beta_{13}) e^{2\beta_2 y} + (\beta_8 + \beta_{14}) e^{2\gamma_2 y} + (\beta_9 + \beta_{15}) e^{(\alpha_2+\beta_2)y} + (\beta_{10} + \beta_{16}) e^{(\beta_2+\gamma_2)y} + (\beta_{11} + \beta_{17}) e^{(\alpha_2+\gamma_2)y}\big] + \varepsilon e^{i\omega t}\Big[\big(\beta_{18} e^{\beta_2 y} + (\beta_6 + \beta_{12}) e^{2\alpha_2 y} + (\beta_7 + \beta_{13}) e^{2\beta_2 y} + (\beta_8 + \beta_{14}) e^{2\gamma_2 y} + (\beta_9 + \beta_{15}) e^{(\alpha_2+\beta_2)y} + (\beta_{10} + \beta_{16}) e^{(\beta_2+\gamma_2)y} + (\beta_{11} + \beta_{17}) e^{(\alpha_2+\gamma_2)y}\big) + (Ec)\big(\beta_{51} e^{\beta_4 y} + \beta_{35} e^{\beta_2 y} + \beta_{36} e^{2\alpha_2 y} + \beta_{37} e^{2\beta_2 y} + \beta_{38} e^{2\gamma_2 y} + \beta_{39} e^{(\alpha_2+\beta_2)y} + \beta_{40} e^{(\beta_2+\gamma_2)y} + \beta_{41} e^{(\alpha_2+\gamma_2)y} + \beta_{42} e^{(\alpha_2+\alpha_{28})y} + \beta_{43} e^{(\beta_2+\alpha_{28})y} + \beta_{44} e^{(\gamma_2+\alpha_{28})y} + \beta_{45} e^{(\alpha_2+\beta_4)y} + \beta_{46} e^{(\beta_2+\beta_4)y} + \beta_{47} e^{(\gamma_2+\beta_4)y} + \beta_{48} e^{(\gamma_2+\beta_4)y} + \beta_{49} e^{(\gamma_2+\gamma_4)y} + \beta_{50} e^{(\alpha_2+\gamma_4)y}\big)\Big]$$

$$C(y,t) = [e^{\gamma_2 y}] + \varepsilon e^{i\omega t} [e^{\gamma_4 y}]$$

## RESULTS AND DISCUSSIONS:

The problem of unsteady flow and heat transfer of an incompressible electrically conducting, chemically reacting memory fluid over a continuous moving horizontal non-conducting surface in the presence of an oscillating free stream, Ohmic dissipation has been formulated, analyzed and solved by using multi-parameter perturbation technique. Approximate solutions have been derived for the velocity, temperature and concentration. The effects of the flow parameters such as magnetic parameter (M = 0.4), Grashof number for heat and mass transfer (Gr = Gc = 5), Schmidt number (Sc = 0.6), Chemical reaction parameter (Kr = 0.2), Prandtl number (Pr = 0.7) and Eckert number (Ec = 0.01), porous parameter (k = 10) on the velocity, temperature and concentration fields have been discussed with the help of graphs.

Figs. 1(a) display the influence of chemical reaction parameter (Kr) on the velocity (u) in case of cooling surface. It is clear that increasing the chemical reaction parameter tends to decrease the velocity for the case of cooling surface (Gr > 0). Fig. 1(b) illustrates the chemical reaction effects on concentration($C$). It is noticed that an increase in Kr leads to decrease the concentration field. This means that in the case of suction, the chemical reaction decelerates the fluid motion. In turn, this causes the concentration buoyancy effects to decrease as Kr increases. Consequently, less flow is induced along the surface resulting in decrease in the fluid velocity in the boundary layer.

Fig. 2(a) illustrates the influences of M in cases of cooling surface (Gr > 0). It is found that the velocity increases with decrease of magnetic parameter M for the cooling surface. It is also found that the velocity is maximum near the surface and decreases away from the surface. Fig. 2(b) depicts dimensionless temperature profile $\theta$. The dimensionless temperature profiles $\theta$ are satisfied the boundary conditions and varies by a smooth curve for different M values. When M is larger and the $\theta$ curve is lower, so, that the heat convective effect is higher for a larger M. On the physical aspect, when the M increases, then the flow will slow down and the temperature will be lower too. On the mathematical aspect, it has used a negative sign to this item on the momentum and energy equation.

Figs. 3(a) and 3(b) display the effects of Prandtl number (Pr) on the velocity and temperature fields for the case of cooling surface (Gr > 0). The velocity decreases with increasing Prandtl number. Physically, it is possible because fluids with high Prandtl number have high viscosity and hence move slowly.

Figs. 4(a) and 4(b) reveal that the velocity variations with Gr and Gc in case of cooling surface. It is observed that greater cooling (Gr > 0) of surface an increase in Gr results in an increase in the velocity the same results happen when Gc. It is due to the face increase in the values of thermal Grashof number and mass Grashof number has the tendency to increase the thermal and mass buoyancy effect. This gives rise to an increase in the induced flow.

Figs. 5(a) and 5(b) display velocity and concentration profiles with Sc in case of cooling surface(Gr > 0). The velocity is observed to increase with decreasing Schmidt number (Sc). It is also observed that the velocity is maximum near that surface and decreases away from the surface.

The effects of viscous dissipative heat (Ec) on the velocity (u) as well as temperature ($\theta$) have been plotted in Figs. 6(a) and 6(b). It is noticed that an increase in viscous dissipative heat leads to increase in both the transient velocity as well as the temperature.

Fig. 7 illustrates the influences of k in cases of cooling surface. It is found that the velocity increases with increase of permeability parameter k for the cooling surface.

**REFERENCES:**


1. A. Bejan, and A D Kraus, *Heat Transfer Handbook*, Wiley, New York, 2003.
2. A. D. Nield, and A. Bejan, *Convection in Porous Media*, 2nd edn., Springer, New York, 1999.
3. A. Ezzat Magdy, "Magnetohydrodynamic unsteady flow of non-Newtonian fluid past an infinite porous plate", Indian J. Pure Appl. Math. vol.25 (6), pp.655-664, 1994.
4. A. M. Hossain, "Viscous and Joule heating effects on MHD free convection flow with variable plate temperature", Int. J. Heat and Mass transfer, vol. 35, pp.3485, 1992.
5. Chien-Hsin-Chen, "Combined heat and mass transfer in MHD free convection from a vertical surface with Ohmic heating and viscous dissipation", Int. J. Engineering Science, 42, pp.699, 2004.
6. D. B. Ingham, A. Bejan, E. Mamut, and L. Pop, "Emerging Technologies and Techniques in Porous Media", Kluwer, Dordrecht 3, 2004.
7. D. W. Beard, and K. Walters, "Elastico-viscous boundary-layer flows. I. Two-dimensional flow near a stagnation point", Proc. Camb. Phil. Soc., vol. 60, pp. 667-674, 1964.
8. Hemant Poonia and R. C. Chaudhary, "Effects of heat transfer on MHD free convective flow through porous medium with viscous dissipation", Journal of Energy, Heat and Mass Transfer, vol. 34, 2012, pp.103-120, 2012.
9. J. P. Hartnett, "Viscoelastic Fluids: A new challenge in heat transfer", Transactions of ASME, pp.296-303, 1992.
10. Jadon Vinay Kumar, Jha Rajeev and S. S. Yadav, "Heat transfer in MHD free convection flow over an infinite vertical plate through porous medium with time dependent suction", The Aligarh Bull. of Maths., 26, pp.29-35, 2007.
11. K. Walter, "Non-Newtonian effects in some elastico-viscous liquids whose behaviour at small rates of shear is characterized by a general linear equation of state", Quarterly Journal of Mechanics and Applied Mathematics, vol. 15(1), pp. 63-76, 1962.
12. K. Walter, "The motion of an elastic-viscous liquid contained between concentric spheres", Quart. J. Math. Appl. Mech. vol. 13 (3), pp. 325-333, 1960.
13. K. Walter, "The motion of an elastic-viscous liquid contained between coaxial cylinders (II)", Quart. J. Math. Appl. Mech., vol. 13 (4), pp.444-461, 1960.
14. K. Walters, "The motion of an elastic-viscous liquid contained between co-axial cylinders", Quart. J. Mech. Appl. Math., vol. 13, pp.441-461, 1960.
15. K. Walters, "The solutions of flow problems in the case of materials with memories", J. Mecanique., vol. 1, pp.473-478, 1962.
16. M. K. Chowdhury, and M. N. Islam, "MHD free convection flow of visco-elastic fluid past an infinite vertical porous plate", Heat and Mass Transfer, 36, pp.439-447, 2000.
17. N. Sandeep, A. Vijaya Bhaskar Reddy, and V. Sugunamma, "Effect of radiation and chemical

ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 2, Issue 4, April 2013

reaction on Transient MHD free convective flow over a vertical plate through porous media", Chemical and Process Engineering Research, vol. 2, pp. 1-9, 2012
18. P. B. Reddy, and J. A. Rao, "Numerical solution of thermal diffusion effect on an unsteady MHD free convective mass transfer flow past a vertical porous plate with Ohmic dissipation", Int. J. of Appl. Math and Mech.7(8), pp.78-97, 2011.
19. P. M. Kishore, V. Rajesh, and S. Vijayakumar Verma, "The effects of thermal radiation and viscous dissipation on MHD heat and mass diffusion flow past an oscillating vertical plate embedded in a porous medium with variable surface conditions", Thoeret. Appl. Mech. vol. 39, No. 2, pp.99-125, 2012.
20. R. C. Chaudhary, Bhupendra Kumar Sharma, and Abhay Kumar Jha, "Radiation effect with simultaneous thermal and mass diffusion in MHD mixed convection flow from a vertical surface with Ohmic heating", Rim. Journ. Phys. vol. 51, Nos.7-8, pp.715-727, 2006.
21. R. Deka, U. N. Das, V. M. Soundalgekar, "Effects of mass transfer on flow past an impulsively started infinite vertical plate with constant heat flux and chemical reaction", Forschung im Ingenieurwesen, vol. 60, pp.284-287, 1994.
22. R. Muthucumaraswamy, and P. Ganesan, "Effect of the chemical reaction and injection on flow characteristics in an unsteady upward motion of an isothermal plate", J. Appl. Mech. Tech Phys; vol. 42, pp. 665-71, 2001.
23. Rita Choudhury and Kamal Debnath, "Unsteady oscillatory MHD flow of a visco-elastic fluid past a porous vertical plate with periodic suction", International Journal of Mathematical Archive, 3(5), pp.1764-1771, 2012.
24. S. Mustafa, Rafiuddin and M. V. Ramana Murthy, "Unsteady MHD memory flow with oscillatory suction, variable free stream and heat source", ARPN Journal of Engineering and Applied Sciences, vol.3. No.3, pp.17-24, June 2008,

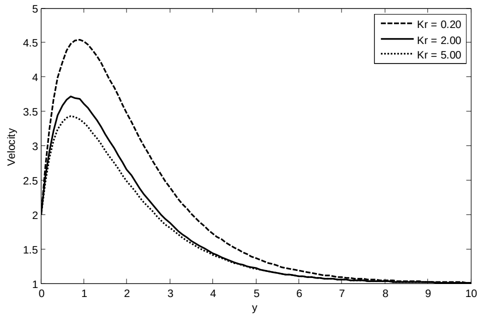

Figure - 1(a)

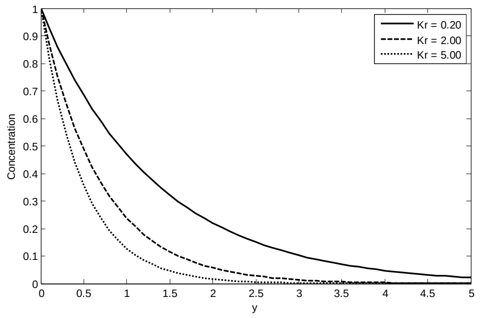

Figure - 1(b)

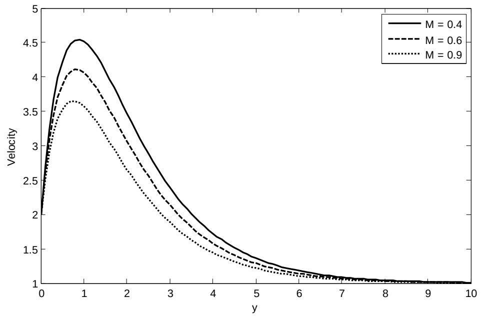

Figure - 2(a)

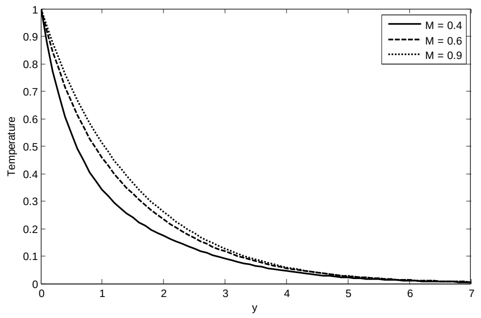

Figure - 2(b)

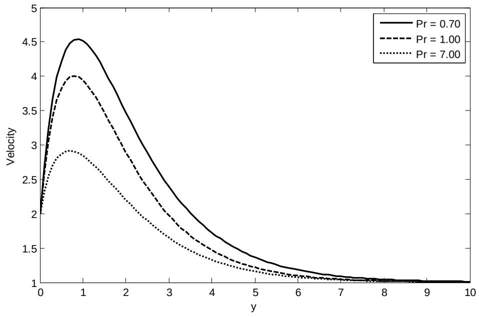


Figure - 3(a)

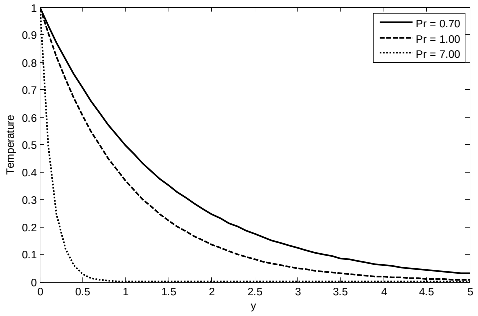


Figure - 3(b)

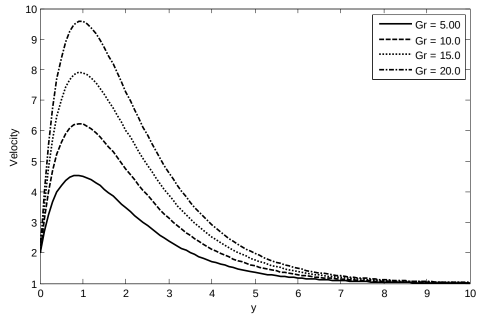


Figure - 4(a)

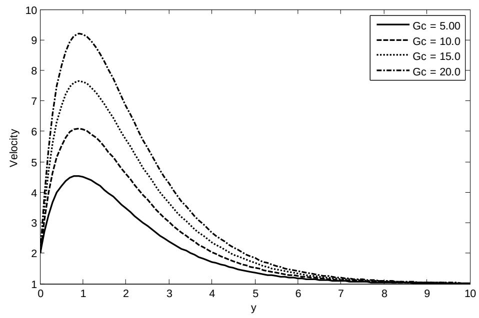


Figure - 4(b)

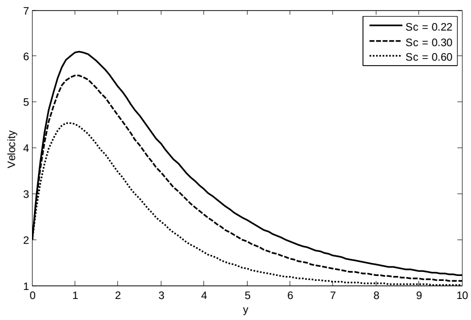


Figure - 5(a)

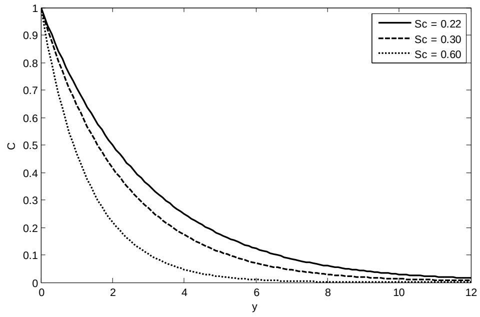


Figure - 5(b)

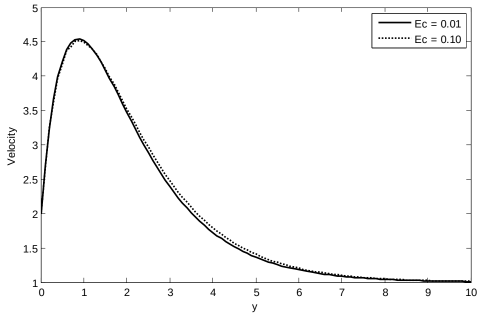


Figure - 6(a)

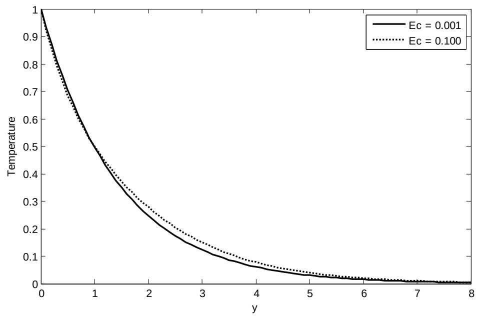


Figure - 6(b)

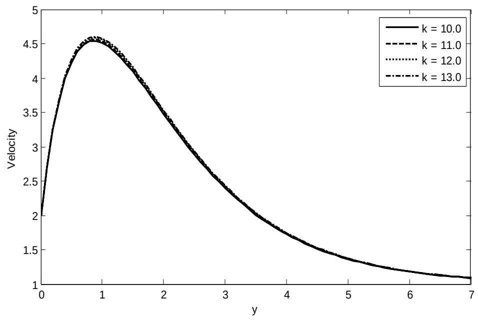


Figure - 7

**Karanam Sreelatha**: Obtained M. Sc. and M. Phil. from Andhra University, Visakhapatnam, A.P., India. Present working as an Assistant Professor of Mathematics in Satya Institute of Technology and Management, Vizianagaram, A.P., India.

**B Rami Reddy:** Obtained M. Sc. from University of Hyderabad, Hyderabad, M. Phil. and Ph. D., from Achary Nagarjuna University, Guntur, A.P., India. Present working as a Associative Professor of Mathematics, Department of Mathematics, Hindu College, Guntur, A.P., India.

**J Girish Kumar:** Obtained M. Sc. from Sri Venkateswara University, Tirupati, Ph. D. from Sri Venkateswara University, Tirupati, Andhra Pradesh, India. Present working as a Lecturer in Mathematics, Department of Mathematics, Government Degree College, Jammalamadugu, Kadapa, A.P. India.