MAGNETIC EFFECT OF UNSTEADY FREE CONVECTIVE FLOW OF WATER AT 4^0C

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ABSTRACT: Unsteady free convective, electrically conducting viscous and MHD flow of water at 4^0C past a vertical permeable semi vertical moving plate through porous medium has been studied. The dimensionless governing equations are solved using perturbation technique is taken as Eckert number is very small to solve energy and momentum equation. The temperature and species concentration near the plate are assumed to be fluctuated harmonically from constant mean and series solution method are used to separate the harmonic and non harmonic parts. The influence of the various parameters on the flow field, skin friction, rate of heat transfer, rate of mass transfer and Temperature field are extensively discussed from graphs and tables.

KEY WORDS: MHD, Free convection, Vertical plate, acceleration, Heat Transfer, Mass transfer, Water at 4^0C , Variable suction, Porous medium, viscous and Joulean dissipations.

INTRODUCTION:

Coupled heat and mass transfer by natural convection in a fluid –saturated porous medium has attracted considerable attention in the last few years due to many important engineering and geophysical applications. It occurs not only due to temperature difference, but also due to concentration difference as well as different geophysical situations. Its application in many process industries like extrusion of plastic in the manufacture of Rayon and Nylon, purification of crude oil, pulp, paper industries, Radio propagation through the ionosphere. The phenomenon of mass transfer is a common theory of stellar structure. Free convection flow past an infinite vertical plate is an important application from a technological oint of view .it becomes a more attractive problem when the fluid is water near 4^0C ,electrically conductive ,and flow is subjected to transverse and constant magnetic field. The convection in porous medium saturated with water near 4ºC, point at which the density of water reaches a maximum value ,behaves in a complicated manner. The study of flows through porous media has been motivated by its immense importance and continuing interest in many engineering and technological field.

MHD Power generator is one of its significant applications. Many researchers have confined their study to fluids like water, air or molten metal at normal or high temperatures. The free convection effects on oscillatory flow of water near 4°C past an infinite vertical and porous plate with constant suction was made by Soundalgekar [1]. Pop and Raptis [2] investigated the transient free convection of water near 4°C over a doubly infinite vertical porous plate. The combined convection flow of water near 4°C through a porous medium bounded by a vertical plate was studied by Raptis and Pop [3]. A few of them have studied the effect of mass transfer on MHD free convective flow of water at 4^0C through a porous medium. Takhar and Perdikis [4] have considered the steady free and forced convective flow of water at 4^0C through a porous medium bounded by a semi infinite vertical plate.Gorla and Stratman [5] studied the influence of transverse curvature on laminar free convective boundary layer flow of water at 4^0C over a cone. Mohapatra and Senapati [6] have studied the effect of mass transfer on magneto hydrodynamic free convective flow of water at 4^0C through a porous medium .Jhankal,A.K.[7] have discussed the Unsteady MHD free convection of water at 4^0 C and heat transfer through porous medium bounded by an Isothermal porous vertical plate in presence of variable suction and heat generation absorption.

In this problem, It tries to investigate the Effect of Unsteady free convective, electrically conducting viscous and MHD flow of water at 4^0C past a vertical permeable semi vertical moving plate through porous medium

FORMULATION OF PROBLEM:

Let us consider the unsteady free convectiive, electricaly conducting viscous and MHD flow of water at 4^0C past a vertical permeable semi vertical moving plate through porous medium. The x' axis is taken along the vertical plate in the upward direction and in the direction and in the direction of motion .A uniform magnetic field strength H_0 with magnetic permeability μ_e is applied in the positive direction of y' axis and there is a variable suction $-v_0\left(1+\epsilon e^{i\omega' t'}\right)$ at the plate in the negative direction of y' axis .The plate and fluid are same temperature T_∞ and mass concentration C_∞ in stationary condition, when $t \geq 0$,the temperature and mass concentration at the plate fluctuate harmonically from constant mean. The viscous and Joulean dissipations are taken in the account. It is assumed that the fluid has constant properties, and variation of density $\Delta\rho = \rho\beta(\Delta T')^2 + \rho\beta_c(\Delta C')^2$ is taken in to the account only in body force term. Since the velocity profile is same across any section perpendicular to the plate, all quantities are function of y' and t' only. Then by usual Boussinesq's approximation, the unsteady flow is governed by the following equations:

$$\frac{\partial u'}{\partial t'} - v_0\left(1+\epsilon e^{i\omega' t'}\right)\frac{\partial u'}{\partial y'} = \nu\frac{\partial^2 u'}{\partial y'} - \frac{\sigma B_0^2 u'}{\rho} - \frac{\nu u'}{K'} + g\beta(T-T_\infty)^2 + g\beta_c(C-C_\infty)^2 \qquad (1)$$

$$\frac{\partial T}{\partial t'} - v_0\left(1+\epsilon e^{i\omega' t'}\right)\frac{\partial T}{\partial y'} = \frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y'} + \frac{\nu}{C_p}\left(\frac{\partial u'}{\partial y'}\right)^2 + \frac{\sigma B_0^2}{\rho C_p}u'^2 \qquad (2)$$

$$\frac{\partial C}{\partial t'} - v_0\left(1+\epsilon e^{i\omega' t'}\right)\frac{\partial C}{\partial y'} = D\frac{\partial^2 C}{\partial y'} \qquad (3)$$

With the following boundary conditions

$$\left.\begin{array}{l} t' < 0: u' = 0, T = T_\infty, C = C_\infty \\ t' \geq 0: \left[\begin{array}{c} u' = U_0, T = T_w + (T_w - T_\infty)\epsilon e^{i\omega' t'}, C = C_w + (C_w - C_\infty)T = T_w + (T_w - T_\infty)\epsilon e^{i\omega' t'} \; at\; y' = 0 \\ u' = 0, T = T_\infty, C = C_\infty \;\; as\; y' \to \infty \end{array}\right. \end{array}\right\} \qquad (4)$$

Where ν is the kinematic viscosity, k is the thermal diffusivity, K' is the permeability coefficient, β is the volumetric coefficient of expansion for heat transfer, β_c is the volumetric coefficient of expansion for mass transfer, ρ is the density, σ is the electrical conductivity of the fluid, g is the acceleration due to gravity, ω' is the oscillating frequency and D is the mass diffusion.

Let us introduce the dimensionless quantities

$$u=\frac{u'}{U_0},\ t=\frac{t'v_0^2}{\upsilon},\ y=\frac{y'v_0}{\upsilon},\ \theta=\frac{T-T_\infty}{T_w-T_\infty},\ \varphi=\frac{C-C_\infty}{C_w-C_\infty},\ \omega=\frac{\upsilon\omega'}{v_0^2}$$
$$Gr=\frac{g\beta\upsilon(T_w-T_\infty)^2}{v_0^2U_0},\ Gm=\frac{g\beta_C\upsilon(C_w-C_\infty)^2}{v_0^2U_0},\ Pr=\frac{\mu C_p}{k},\ Sc=\frac{\upsilon}{D},\ M=\frac{\sigma\nu B_0^2}{\rho v_0^2},\ K=\frac{v_0^2K'}{\upsilon^2} \tag{5}$$
$$E=\frac{v_0^2}{C_p(T_w-T_\infty)}$$

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where Gr is Grashof number, Gm is modified Grashof number ,K is permeability of porous medium, M is magnetic parameter ,Sc is Schmidt number, Pr is Prandtl number and E is Eckert number

Substituting equation (5) in the equations (1)- (3) with boundary conditions(4), we have

$$\frac{\partial^2 u}{\partial y^2}+\left(1+\in e^{i\omega t}\right)\frac{\partial u}{\partial y}-\left(M+\frac{1}{K}\right)u=\frac{\partial u}{\partial t}+Gr\theta^2+Gm\varphi^2 \tag{6}$$

$$\frac{\partial^2\theta}{\partial y^2}+Pr\left(1+\in e^{i\omega t}\right)\frac{\partial\theta}{\partial y}=Pr\frac{\partial\theta}{\partial t}-EPr\left(\frac{\partial u}{\partial y}\right)^2-PrEMu^2 \tag{7}$$

$$\frac{\partial^2\varphi}{\partial y^2}+Sc\left(1+\in e^{i\omega t}\right)\frac{\partial\varphi}{\partial y}=Sc\frac{\partial\varphi}{\partial t} \tag{8}$$

with boundary conditions

$$\left.\begin{aligned}&t<0: u=0,\theta=0,\varphi=0\\&t\geq 0:\begin{cases}u=1,\theta=1+\in e^{i\omega t},\varphi=1+\in e^{i\omega t}\ at\, y=0\\ u=0,\theta=0,\varphi=0\ \ as\ y\to\infty\end{cases}\end{aligned}\right\} \tag{9}$$

METHOD OF SOLUTION:

As the equations (6) –(8) are coupled non linear partial differential equations whose solutions in closed form are difficult to obtain. To solve the governing equation by converting into ordinary differential equations, the unsteady flow is superimposed on mean steady flow. So the expressions for velocity, temperature and mass concentration are assumed as

$$u=u_0+u_1\in e^{i\omega t}$$

$$\theta=\theta_0+\theta_1\in e^{i\omega t} \tag{10}$$

$$\varphi = \varphi_0 + \varphi_1 \in e^{i\omega t}$$

By substituting equation (10) in equations (6)-(9) and equating the coefficient of harmonic and non harmonic parts, we get

$$\frac{d^2u_0}{dy^2} + \frac{du_0}{dy} - \left(M + \frac{1}{K}\right)u_0 = Gr\theta_0^2 + Gm\varphi_0^2 \qquad (11)$$

$$\frac{d^2u_1}{dy^2} + \frac{du_1}{dy} - \left(M + \frac{1}{K}\right)u_1 = i\omega u_1 + 2Gr\theta_0.\theta_1 + 2Gm\varphi_0\varphi_1 \qquad (12)$$

$$\frac{d^2\theta_0}{dy^2} + Pr\frac{d\theta_0}{dy} = -EPr\left(\frac{du_0}{dy}\right)^2 - PrEMu_0^2 \qquad (14)$$

$$\frac{d^2\theta_1}{dy^2} + \mathrm{Pr}\left(\frac{d\theta_0}{dy} + \frac{d\theta_1}{dy}\right) = Pri\omega\theta_1 - 2EPr\left(\frac{du_0}{dy}\right)\left(\frac{du_1}{dy}\right) \quad - 2PrEMu_0u_1 \qquad (15)$$

$$\frac{d^2\varphi_0}{dy^2} + Sc\varphi_0 = 0 \qquad (16)$$

$$\frac{d^2\varphi_1}{dy^2} + \mathrm{Sc}\left(\frac{d\varphi_0}{dy} + \frac{d\varphi_1}{dy}\right) = Sci\omega\theta_1 \qquad (17)$$

With boundary conditions

$$\left.\begin{array}{l} u_0 = 1, u_1 = 0, \theta_0 = 1, \theta_1 = 1\ , \varphi_0 = 1\ , \varphi_1 = 1 aty = 0 \\ u_0 = 0, u_1 = 0, \theta_0 = 0, \theta_1 = 0\ , \varphi_0 = 0, \varphi_1 = 0\ \ as\ y \to \infty \end{array}\right\} \qquad (18)$$

By solving equation (16) and (17) using boundary condition (18) ,we get

$$\left.\begin{array}{l} \varphi_0 = e^{-Sc\,y} \\ \varphi_1 = (A_{11}e^{-b_{11}y} + A_{12}e^{-Scy}) \end{array}\right\} \qquad (19)$$

In order to solve equations (11) to (15) using boundary conditions (18) ,perturbation technique is taken as Eckert number is very small. Hence we assumed

$$\left.\begin{array}{l} u_0(y) = u_{00} + Eu_{01} + O(E) \\ u_1(y) = u_{10} + Eu_{11} + O(E) \\ \theta_0(y) = \theta_{00} + E\theta_{01} + O(E) \\ \theta_1(y) = \theta_{10} + E\theta_{11} + O(E) \end{array}\right\} \qquad (20)$$

By equating the co efficient of the power of E, We have

$$\frac{d^2u_{00}}{dy^2} + \frac{du_{00}}{dy} - \left(M + \frac{1}{K}\right)u_{00} = Gr(\theta_{00})^2 + Gme^{-Sc\,y} \qquad (21)$$

$$\frac{d^2u_{01}}{dy^2} + \frac{du_{01}}{dy} - \left(M + \frac{1}{K}\right)u_{01} = 2Gr\ \theta_{00}\theta_{01} \qquad (22)$$

$$\frac{d^2u_{10}}{dy^2} + \frac{du_{10}}{dy} - \left(M + \frac{1}{K} + \omega i\right)u_{10} = 2Gr\theta_{00}\theta_{10} + 2Gm(A_{11}e^{-b_{11}y} + A_{12}e^{-Scy})e^{-Sc\,y} \qquad (23)$$

$$\frac{d^2u_{11}}{dy^2}+\frac{du_{11}}{dy}-\left(M+\frac{1}{K}+\omega i\right)u_{11}=2Gr(\theta_{00}\theta_{11}+\theta_{01}\theta_{10}) \tag{24}$$

$$\frac{d^2\theta_{00}}{dy^2}+Pr\frac{d\theta_{00}}{dy}=0 \tag{25}$$

$$\frac{d^2\theta_{01}}{dy^2}+Pr\frac{d\theta_{01}}{dy}=-Pr\left(\frac{du_{00}}{dy}\right)^2-PrMu_{00}^2 \tag{26}$$

$$\frac{d^2\theta_{10}}{dy^2}+Pr\frac{d\theta_{10}}{dy}-Pr\omega i\theta_{10}=-Pr\frac{d\theta_{00}}{dy} \tag{27}$$

$$\frac{d^2\theta_{11}}{dy^2}+Pr\frac{d\theta_{11}}{dy}-Pr\omega i\theta_{11}=-Pr\frac{d\theta_{01}}{dy}-2Pr\frac{du_{00}}{dy}\frac{du_{10}}{dy}-2PrMu_{00}u_{10} \tag{28}$$

By solving the above equations, we get

$$\left.\begin{aligned}
&\theta_{00}=e^{-\mathrm{Pr}\,y}\\
&\theta_{10}=A_{13}e^{-b_{12}y}+A_{14}e^{-Pry}\\
&u_{00}=A_{17}e^{-b_{13}y}+A_{15}e^{-2Pry}+A_{16}e^{-Scy}\\
&\theta_{01}=A_{24}e^{-\mathrm{Pr}\,y}+A_{18}e^{-2b_{13}y}+A_{19}e^{-4\,\mathrm{Pr}\,y}+A_{20}e^{-2Sc\,y}+A_{21}e^{-(b_{13}+2Pr)y}+\\
&A_{22}e^{-(2Pr+Sc)y}+A_{23}e^{-(b_{13}+Sc)}\\
&u_{01}=A_{32}e^{-b_{13}y}+A_{25}e^{-2\,\mathrm{Pr}\,y}+A_{26}e^{-(2b_{13}+Pr)}+A_{27}e^{-5Pry}+A_{28}e^{-(2Sc+Pr)y}+\\
&A_{29}e^{-(b_{13}+3Pr)y}+A_{30}\quad e^{-(3Pr+Sc)y}+A_{31}e^{-(b_{13}+Sc+Pr)y}\\
&u_{10}=A_{37}e^{-b_{14}y}+A_{33}e^{-(b_{12}+Pr)y}+A_{34}e^{-2Pry}+A_{35}e^{-(b_{11}+Sc)y}+A_{36}e^{-2Scy}\\
&\theta_{11}=A_{58}e^{-b_{12}y}+A_{38}e^{-\mathrm{Pr}\,y}+A_{39}e^{-2b_{13}y}+A_{40}e^{-4Pry}+A_{41}e^{-2Scy}+A_{42}e^{-(2Pr+b_{11})y}+\\
&A_{43}e^{-(2Pr+Sc)y}+A_{44}e^{-(Sc+b_{13})y}+A_{45}e^{-(b_{13}+b_{14})y}+A_{46}e^{-(b_{13}+b_{14}+Pr)y}+A_{47}e^{-(2Pr+b_{13})y}+\\
&A_{48}e^{-(b_{13}+b_{11}+Sc)y}+A_{49}e^{-(b_{13}+2Sc)y}+A_{50}e^{-(2\,\mathrm{Pr}\,+b_{14})y}+A_{51}e^{-(3Pr+b_{12})y}+\\
&A_{52}e^{-(b_{12}+Pr+Sc)y}+A_{53}e^{-(2Pr+2Sc)y}+A_{54}e^{-(Sc+b_{14})y}+A_{55}e^{-3Scy}+A_{56}e^{-(2Sc+b_{11})y}+\\
&A_{57}e^{-(b_{11}+Sc+2Pr)y}\\
&u_{11}=A_{81}e^{-b_{14}y}+A_{59}e^{-(b_{11}+Pr)y}+A_{60}e^{-2\,\mathrm{Pr}\,y}+A_{61}e^{-(Pr+2b_{13})y}+A_{62}e^{-5\,\mathrm{Pr}\,y}+\\
&A_{63}e^{-(Pr+2Sc)y}+A_{64}e^{-(Sc+3Pr)y}+A_{65}e^{-(b_{13}+Sc+Pr)y}+A_{66}e^{-(b_{13}+3Pr)y}+A_{67}e^{-(b_{12}+4Pr)y}+\\
&A_{68}e^{-(b_{11}+3Pr)y}+A_{69}e^{-(b_{13}+b_{14}+Pr)y}+A_{70}e^{-(b_{13}+b_{14}+2Pr)y}+A_{71}e^{-(b_{13}+b_{11}+Pr+Sc)y}+\\
&A_{72}e^{-(b_{13}+2Sc+Pr)y}+A_{73}e^{-(b_{14}+3Pr)y}+A_{74}\,e^{-(b_{12}+Sc+2Pr)y}+A_{75}e^{-(3Pr+2Sc)y}+\\
&A_{76}e^{-(Sc+Pr+2)y}+A_{77}e^{-(Pr+3Sc)y}+A_{78}e^{-(Pr+2Sc+b_{11})y}+A_{79}e^{-(3Pr+Sc+b_{11})y}+\\
&A_{80}e^{-(2b_{13}+b_{12})y}+A_{81}e^{-(2Sc+b_{12})y}
\end{aligned}\right\} \tag{29}$$

Now using equations(10),(19),(20) and (29) ,we get

$$\begin{aligned}
&u=\big[(A_{17}e^{-b_{13}y}+A_{15}e^{-2Pry}+A_{16}e^{-Scy})+E\big(A_{32}e^{-b_{13}y}+A_{25}e^{-2\,\mathrm{Pr}\,y}+A_{26}e^{-(2b_{13}+Pr)y}+\\
&A_{27}e^{-5Pry}+A_{28}e^{-(2Sc+Pr)y}+A_{29}e^{-(b_{13}+3Pr)y}+A_{30}\quad e^{-(3Pr+Sc)y}+A_{31}e^{-(b_{13}+Sc+Pr)y}\big)\big]+\in\\
&e^{i\omega t}\big[\big(A_{37}e^{-b_{14}y}+A_{33}e^{-(b_{12}+Pr)y}+A_{34}e^{-2Pry}+A_{35}e^{-(b_{11}+Sc)y}+A_{36}e^{-2Scy}\big)+\\
&E\big(A_{83}e^{-b_{14}y}+A_{59}e^{-(b_{11}+Pr)y}+A_{60}e^{-2\,\mathrm{Pr}\,y}+A_{61}e^{-(Pr+2b_{13})y}+A_{62}e^{-5\,\mathrm{Pr}\,y}+
\end{aligned}$$

$$A_{63}e^{-(Pr+2Sc)y} + A_{64}e^{-(Sc+3Pr)y} + A_{65}e^{-(b_{13}+Sc+Pr)y} + A_{66}e^{-(b_{13}+3Pr)y} + A_{67}e^{-(b_{12}+4Pr)y} + A_{68}e^{-(b_{11}+3Pr)y} + A_{69}e^{-(b_{13}+b_{14}+Pr)y} + A_{70}e^{-(b_{13}+b_{14}+2Pr)y} + A_{71}e^{-(b_{13}+b_{11}+Pr+Sc)y} + A_{72}e^{-(b_{13}+2Sc+Pr)y} + A_{73}e^{-(b_{14}+3Pr)y} + A_{74}\, e^{-(b_{12}+Sc+2Pr)y} + A_{75}e^{-(3Pr+2Sc)y} + A_{76}e^{-(Sc+Pr+B_{14})y} + A_{77}e^{-(Pr+3Sc)y} + A_{78}e^{-(Pr+2Sc+b_{11})y} + A_{79}e^{-(3Pr+Sc+b_{11})y} + A_{80}e^{-(2b_{13}+b_{12})y} + A_{81}e^{-(2Sc+b_{12})y}\Big) + A_{82}e^{-(b_{12}+b_{13}+2Pr)y}\Big] \quad (30)$$

$$\theta = \left[(e^{-\mathrm{Pr}\, y}) + E\Big(A_{24}e^{-\mathrm{Pr}\, y} + A_{18}e^{-2b_{13}y} + A_{19}e^{-4\,\mathrm{Pr}\, y} + A_{20}e^{-2Sc\, y} + A_{21}e^{-(b_{13}+2Pr)y} + A_{22}e^{-(2Pr+Sc)y} + A_{23}e^{-(b_{13}+Sc)}\Big)\right] + \in e^{i\omega t}\Big[(A_{13}e^{-b_{12}y} + A_{14}e^{-Pry}) + E\Big(A_{58}e^{-b_{12}y} + A_{38}e^{-\mathrm{Pr}\, y} + A_{39}e^{-2b_{13}y} + A_{40}e^{-4Pry} + A_{41}e^{-2Scy} + A_{42}e^{-(2Pr+b_{11})y} + A_{43}e^{-(2Pr+Sc)y} + A_{44}e^{-(Sc+b_{13})y} + A_{45}e^{-(b_{13}+b_{14})y} + A_{46}e^{-(b_{13}+b_{14}+Pr)y} + A_{47}e^{-(2Pr+b_{13})y} + A_{48}e^{-(b_{13}+b_{11}+Sc)y} + A_{49}e^{-(b_{13}+2Sc)y} + A_{50}e^{-(2\,\mathrm{Pr}\,+b_{14})y} + A_{51}e^{-(3Pr+b_{12})y} + A_{52}e^{-(b_{12}+Pr+Sc)y} + A_{53}e^{-(2Pr+2Sc)y} + A_{54}e^{-(Sc+b_{14})y} + A_{55}e^{-3Scy} + A_{56}e^{-(2Sc+b_{11})y} + A_{57}e^{-(b_{11}+Sc+2Pr)y}\Big)\Big] \quad (31)$$

$$\varphi = [e^{-Sc\, y}] + \in e^{i\omega t}[A_{11}e^{-b_{11}y} + A_{12}e^{-Scy}] \quad (32)$$

The dimensional rate of heat transfer or Nusselt number is

$$\mathrm{Nu} = -\left(\frac{\partial\theta}{\partial y}\right)_{y=0} = [Pr + E(PrA_{24} + 2b_{13}A_{18} + 4PrA_{19} + 2ScA_{20} + (b_{13} + 2Pr)A_{21} + (2Pr + Sc)A_{22} + (b_{13} + Sc)A_{23})] + \in e^{i\omega t}[(b_{12}A_{13} + PrA_{14}) + E(b_{12}A_{58} + PrA_{38} + 2b_{13}A_{39} + 4PrA_{40} + 2ScA_{41} + (2Pr + b_{11})A_{42} + (2Pr + Sc)A_{43} + (Sc + b_{13})A_{44} + (b_{13} + b_{14})A_{45} + (b_{13} + b_{14} + Pr)A_{46} + (2Pr + b_{13})A_{47} + (b_{13} + b_{11} + Sc)A_{48} + (b_{13} + 2Sc)A_{49} + (2\,\mathrm{Pr}\, + b_{14})A_{50} + (3Pr + b_{12})A_{51} + (b_{12} + Pr + Sc)A_{52} + (2Pr + 2Sc)A_{53} + (Sc + b_{14})A_{54} + 3ScA_{55} + (2Sc + b_{11})A_{56} + (b_{11} + Sc + 2Pr)A_{57})] \quad (33)$$

The dimensionless rate of mass transfer or Sherwood number is

$$Sh = -\left(\frac{\partial\varphi}{\partial y}\right)_{y=0} = Sc + \in e^{i\omega t}(A_{11}b_{11} + ScA_{12}) \,, \quad (34)$$

The non-dimensional Skin friction at the Plate from the equations (30) is given by

$$\tau = -\left(\frac{\partial\theta}{\partial y}\right)_{y=0} = \Big[(b_{13}A_{17} + 2PrA_{15} + ScA_{16}) + E\Big(b_{13}A_{32} + 2PrA_{25} + (2b_{13} + Pr)A_{26} + 5PrA_{27} + (2Sc + Pr)A_{28} + (b_{13} + 3Pr)A_{29} + (3Pr + Sc)A_{30} + (b_{13} + Sc + Pr)A_{31}\Big)\Big] + \in e^{i\omega t}[(b_{14}A_{37} + (b_{12} + Pr)A_{33} + 2PrA_{34} + (b_{11} + Sc)A_{35} + 2ScA_{36}) + E(b_{14}A_{83} + (b_{11} + Pr)A_{59} + 2PrA_{60} + (Pr + 2b_{13})A_{61} + 5PrA_{62}e^{-5\,\mathrm{Pr}\, y} + (Pr + 2Sc)A_{63} + (Sc + 3Pr)A_{64} + (b_{13} + Sc + Pr)A_{65} + (b_{13} + 3Pr)A_{66} + (b_{12} + 4Pr)A_{67} + (b_{11} + 3Pr)A_{68} + (b_{13} + b_{14} + Pr)A_{69} + (b_{13} + b_{14} + 2Pr)A_{70} + (b_{13} + b_{11} + Pr + Sc)A_{71} + (b_{13} + 2Sc + Pr)A_{72} + (b_{14} + 3Pr)A_{73} + (b_{12} + Sc + 2Pr)A_{74} + (3Pr + 2Sc)A_{75} + (Sc + Pr + 2)A_{76} + (Pr + 3Sc)A_{77} + (Pr + 2Sc + b_{11})A_{78} + (3Pr + Sc + b_{11})A_{79} + (2b_{13} + b_{12})A_{80} + (2Sc + b_{12})A_{81} + (b_{12} + b_{13} + 2Pr)A_{82})] \quad (35)$$

Where $b_{11}=\frac{Sc+\sqrt{Sc^2+4Sc\omega i}}{2}$,$b_{12}=\frac{Pr+\sqrt{Pr^2+4Pr\omega i}}{2}$, $b_{13}=\frac{1+\sqrt{1+4\left(M+\frac{1}{K}\right)}}{2}$, $b_{14}=\frac{1+\sqrt{1+4\left(M+\frac{1}{K}+\omega i\right)}}{2}$

$$A_{11}=1-\frac{Sc^2}{2Sc^2-2Sc\omega i},A_{12}=\frac{Sc^2}{2Sc^2-2Sc\omega i}A_{13}=1+\frac{1}{\omega i},A_{14}=\frac{-1}{\omega i}$$

$$A_{15}=\frac{Gr}{4Pr^2-2Pr-\left(M+\frac{1}{K}\right)},A_{16}=\frac{Gm}{4Sc^2-Sc-\left(M+\frac{1}{K}\right)},A_{17}=1-A_{15}-A_{16}$$

$$A_{18}=\frac{-\left(PrA_{17}^2+PrM(b_{13}A_{17})^2\right)}{4b_{13}^2-2b_{13}Pr},A_{19}=\frac{-\left(A_{15}^2+4(PrA_{15})^2\right)}{12Pr},A_{20}=\frac{-\left(PrA_{16}^2+PrM(ScA_{16})^2\right)}{4Sc^2-2ScPr}$$

$$,A_{21}=\frac{-(2PrA_{17}A_{15}+4PrMb_{13}A_{17}A_{15})}{(b_{13}+2Pr)^2-Pr(b_{13}+2Pr)},$$

$$A_{22}=\frac{-\left(2PrA_{16}A_{15}+4MScPr^2A_{15}A_{16}\right)}{(2Pr+Sc)^2-Pr(2Pr+Sc)},A_{23}=\frac{-(2PrA_{17}A_{15}+2PrScMb_{13}A_{17}A_{16})}{(b_{13}+Sc)^2-Pr(b_{13}+Sc)}$$

$$A_{24}=-(A_{18}+A_{19}+A_{20}+A_{21}+A_{22}+A_{23})$$

$$A_{25}=\frac{2GrA_{24}}{4Pr^2-2Pr-\left(M+\frac{1}{K}\right)},A_{26}=\frac{2GrA_{18}}{4(2b_{13}+Pr)^2-2\,(2b_{13}+Pr)-\left(M+\frac{1}{K}\right)}$$

$$A_{27}=\frac{2GrA_{19}}{25(Pr)^2-5\,(Pr)-\left(M+\frac{1}{K}\right)},A_{28}=\frac{2GrA_{20}}{(2Sc+Pr)^2-\,(2Sc+Pr)-\left(M+\frac{1}{K}\right)}$$

$$A_{29}=\frac{2GrA_{21}}{(b_{13}+3Pr)^2-\,(b_{13}+3Pr)-\left(M+\frac{1}{K}\right)},A_{30}=\frac{2GrA_{22}}{(Sc+3Pr)^2-\,Sc-\left(M+\frac{1}{K}\right)}$$

$$A_{32}=1-(A_{25}+A_{26}+A_{27}+A_{28}+A_{29}+A_{30}+A_{31})$$

$$A_{33}=\frac{2GrA_{13}}{(Pr+b_{12})^2-(Pr+b_{12})-\left(M+\frac{1}{K}+\omega i\right)},A_{34}=\frac{2GrA_{14}}{4(Pr)^2-2(Pr)-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{35}=\frac{2GmA_{11}}{(Sc+b_{11})^2-(Sc+b_{11})-\left(M+\frac{1}{K}+\omega i\right)},A_{36}=\frac{2GmA_{12}}{4(Sc)^2-2(Sc)-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{37}=1-(A_{33}+A_{34}+A_{35}+A_{36})$$

$$A_{38}=-\frac{PrA_{24}}{\omega i},A_{39}=\frac{2Prb_{13}A_{18}}{4b_{13}^2-2Prb_{13}-Pr\omega i},A_{40}=\frac{4PrA_{19}}{12Pr-\omega i},A_{41}=\frac{2PrScA_{20}}{4Sc^2-2ScPr-Pr\omega}$$

$$A_{42}=\frac{PrA_{21}(2Pr+b_{13})}{(2Pr+b_{13})^2-Pr(2Pr+b_{13})-Pr\omega i},A_{43}=\frac{2Pr(2Pr+Sc)}{(2Pr+Sc)^2-Pr(2Pr+Sc)-Pr\omega i}$$

$$A_{44}=\frac{Pr(Sc+b_{13})}{(Sc+b_{13})^2-Pr(Sc+b_{13})-Pr\omega i}A_{45}=\frac{-(2Prb_{13}A_{17}b_{14}A_{37}+2PrMA_{17}A_{37})}{(b_{14}+b_{13})^2-Pr(b_{14}+b_{13})-Pr\omega i}$$

$$A_{46}=\frac{-(2Prb_{13}A_{17}(b_{12}+Pr)+2PrMA_{17}A_{33})}{(b_{12}+Pr+b_{13})^2-Pr(b_{12}+Pr+b_{13})-Pr\omega i}$$

$$A_{47}=\frac{-\left(2PrMA_{17}A_{34}+4A_{34}b_{13}A_{17}Pr^2\right)}{(2Pr+b_{13})^2-Pr(2Pr+b_{13})-Pr\omega i}$$

$$A_{48}=\frac{-(2Prb_{13}A_{17}(Sc+b_{11})+2PrMA_{17}A_{35})}{(Sc+b_{11}+b_{13})^2-Pr(Sc+b_{11}+b_{13})-Pr\omega i},A_{49}=\frac{-(4Prb_{13}A_{17}A_{36}Sc+2PrMA_{17}A_{36})}{(2Sc+b_{13})^2-Pr(2Sc+b_{13})-Pr\omega i}$$

$$A_{50}=\frac{-\left(4Pr^2b_{14}A_{15}A_{37}+2PrMA_{15}A_{37}\right)}{(2Pr+b_{14})^2-Pr(2Pr+b_{14})-Pr\omega i},A_{51}=\frac{-\left(4Pr^2(b_{12}+Pr)A_{15}A_{33}+2PrMA_{15}A_{33}\right)}{(3Pr+b_{12})^2-Pr(3Pr+b_{12})-Pr\omega i}$$

$$A_{52}=\frac{-(2PrScA_{16}(Pr+b_{12})A_{33}+2PrMA_{16}A_{33})}{(Sc+Pr+b_{12})^2-Pr(Sc+Pr+b_{12})-Pr\omega i},A_{53}=\frac{-\left(8Pr^2ScA_{15}A_{36}+2PrMA_{15}A_{36}\right)}{(2Pr+2Sc)^2-Pr(2Pr+2Sc)-Pr\omega i}$$

$$A_{54}=\frac{-(2PrScA_{16}A_{37}b_{14}+2PrMA_{16}A_{37})}{(b_{14}+Sc)^2-Pr(b_{14}+Sc)-Pr\omega i},A_{55}=\frac{-\left(4PrSc^2A_{16}A_{36}+2PrMA_{16}A_{36}\right)}{(3Sc)^2-Pr(3Sc)-Pr\omega i}$$

$$A_{56}=\frac{-(2PrScA_{16}(Sc+b_{11})+2PrMA_{16}A_{35})}{(2Sc+b_{11})^2-Pr(2Sc+b_{11})-Pr\omega i},A_{57}=\frac{-\left(4Pr^2A_{15}(Sc+b_{11})A_{35}+2PrMA_{15}A_{35}\right)}{(b_{11}+Sc+2Pr)^2-Pr(b_{11}+Sc+2Pr)-Pr\omega i}$$

$$A_{58}=-(A_{38}+A_{39}+A_{40}+A_{41}+A_{42}+A_{43}+A_{44}+A_{45}+A_{46}+A_{47}+A_{48}+A_{49}+A_{50}+A_{51}+A_{52}+A_{53}+A_{54}+A_{55}+A_{56}+A_{57})$$

$$A_{59}=\frac{2Gr(A_{38}+A_{13}A_{24})}{(b_{12}+Pr)^2-(b_{12}+Pr)-\left(M+\frac{1}{K}+\omega i\right)},A_{60}=\frac{2Gr(A_{38}+A_{14}A_{24})}{(2Pr)^2-(2Pr)-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{61}=\frac{2Gr(A_{39}+A_{14}A_{18})}{(2b_{13}+Pr)^2-(2b_{13}+Pr)-\left(M+\frac{1}{K}+\omega i\right)},A_{62}=\frac{2Gr(A_{40}+A_{14}A_{19})}{(5Pr)^2-(5Pr)-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{63}=\frac{2Gr(A_{41}+A_{14}A_{20})}{(2Sc+Pr)^2-(2Sc+Pr)-\left(M+\frac{1}{K}+\omega i\right)},A_{64}=\frac{2Gr(A_{43}+A_{14}A_{21})}{(Sc+3Pr)^2-(Sc+3Pr)-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{65}=\frac{2Gr(A_{44}+A_{14}A_{23})}{(b_{13}+Sc+Pr)^2-(b_{13}+Sc+Pr)-\left(M+\frac{1}{K}+\omega i\right)},A_{66}=\frac{2Gr(A_{47}+A_{14}A_{21})}{(b_{13}+3Pr)^2-(b_{13}+3Pr)-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{67}=\frac{2Gr(A_{51}+A_{13}A_{19})}{(b_{12}+4Pr)^2-(b_{12}+4Pr)-\left(M+\frac{1}{K}+\omega i\right)},A_{68}=\frac{2Gr(A_{42})}{(b_{11}+3Pr)^2-(b_{11}+3Pr)-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{69}=\frac{2Gr(A_{45})}{(b_{13}+b_{14}+Pr)^2-(b_{13}+b_{14}+Pr)-\left(M+\frac{1}{K}+\omega i\right)},A_{70}=\frac{2Gr(A_{46})}{(b_{13}+b_{14}+2Pr)^2-(b_{13}+b_{14}+2Pr)-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{71}=\frac{2Gr(A_{48})}{(b_{13}+b_{11}+Sc+Pr)^2-(b_{13}+b_{11}+Sc+Pr)-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{72}=\frac{2Gr(A_{49})}{(b_{13}+2Sc+Pr)^2-(b_{13}+2Sc+Pr)-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{73}=\frac{2Gr(A_{50})}{(b_{14}+3Pr)^2-(b_{14}+3Pr)-\left(M+\frac{1}{K}+\omega i\right)},A_{74}=\frac{2Gr(A_{52}+A_{13}A_{22})}{(b_{12}+Sc+2Pr)^2-(b_{12}+Sc+2Pr)-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{75}=\frac{2Gr(A_{53})}{(2Sc+3Pr)^2-(2Sc+3Pr)-\left(M+\frac{1}{K}+\omega i\right)},A_{76}=\frac{2GrA_{54}}{(Sc+Pr+b_{14})^2-(Sc+Pr+b_{14})-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{77}=\frac{2Gr(A_{55})}{(3Sc+Pr)^2-(3Sc+Pr)-\left(M+\frac{1}{K}+\omega i\right)},A_{78}=\frac{2Gr(A_{56})}{(2Sc+Pr+b_{11})^2-(2Sc+Pr+b_{11})-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{79}=\frac{2Gr(A_{57})}{(Sc+3Pr+b_{11})^2-(Sc+3Pr+b_{11})-\left(M+\frac{1}{K}+\omega i\right)},A_{80}=\frac{2Gr(A_{13}A_{18})}{(b_{12}+2b_{13})^2-(b_{12}+2b_{13})-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{81}=\frac{2Gr(A_{13}A_{20})}{(b_{12}+2Sc)^2-(b_{12}+2Sc)-\left(M+\frac{1}{K}+\omega i\right)},A_{82}=\frac{2Gr(A_{13}A_{21})}{(b_{12}+b_{13}+2Pr)^2-(b_{12}+b_{13}+2Pr)-\left(M+\frac{1}{K}+\omega i\right)}$$

$$A_{83} = -(A_{59} + A_{60} + A_{61} + A_{62} + A_{63} + A_{64} + A_{65} + A_{66} + A_{67} + A_{68} + A_{69} + A_{70} + A_{71} + A_{72} + A_{73} + A_{74} + A_{75} + A_{76} + A_{77} + A_{78} + A_{79} + A_{80} + A_{81} + A_{82})$$

Graphical Results and Discussion

In this paper , Unsteady free convective, electrically conducting viscous and MHD flow of water at 4^0C past a vertical permeable semi vertical moving plate through porous medium has been studied.. The effect of the parameters Gr, Gm, M, K, ω , t and Sc at constant value of Pr=11.4 at 4 ^{0}C on flow characteristics have been studied and shown by means of graphs. In order to have physical correlations, we choose suitable values of flow parameters. The graphs of velocities, heat and mass concentration are taken w.r.t. y and the absolute values Skin friction, Nusselt number and Sherwood Number with the tangent value of phase angle are shown in tables

.

Velocity profiles: The velocity profiles are depicted in Figs 1-4. Figure-(1) shows the effect of the parameters K and M on velocity profile at any point of the fluid when Gr=2, Sc=0.23, Pr=11.4, ω=0.5 t=0.5,E=0.002, and $\mathrm{Gm} = 2$. It is noticed that the velocity increases with the increase of magnetic parameter (M), where as decreases with the increase of permeability of porous medium (K).

Figure-(2) shows the effect of the parameter Sc on Velocity profile at any point of the fluid when, Gr=2, Pr=11.4, ω=0.5 t=0.5,E=0.002,K=3,M=3 and $\mathrm{Gm} = 2$. It is noticed that the velocity decreases with the increase of Schmidt number (Sc).

Figure-(3) shows the effect of the parameters ω and t on Velocity profile at any point of the fluid, when Gr=2, Pr=11.4, Sc=0.23,E=0.002,K=3,M=3 and $\mathrm{Gm} = 2$.It is noticed that the velocity increases with the increase of oscillating frequence (ω) and time (t).

Figure-(4) shows the effect of the parameters Gr and Gm on Velocity profile at any point of the fluid, when Pr=11.4, Sc=0.23,E=0.002,K=3,M=3, $\omega = 0.5$ and t=0.5.It is noticed that the velocity increases with the increase of Grashof number (Gr),whereas decreases with the increase of Modified Grashof number (Gm).

Heat Profile: The Heat profiles are depicted in Figs 5-8. Figure-(5) shows the effect of the parameters $\boldsymbol{\omega}$ and t on Heat profile at any point of the fluid, when Gr=2, Sc=0.23, Pr=11.4,M=2,K=2 and $\mathrm{Gm} = 2$. It is noticed that the temperature falls in the increase of oscillating frequence (ω) and time (t).

Figure-(6) shows the effect of the parameters Gr and Gm on Heat profile at any point of the fluid, when t=0.9, Sc=0.23, Pr=11.4,M=2,K=2 and $\omega = 0.5$.It is noticed that the temperature falls in the increase of Modified Grashof number (Gm) $, whereas$ rises with the increase of Grashof number (Gr).

Figure-(7) shows the effect of the M and K on Heat profile at any point of the fluid, when t=0.9, Sc=0.23, Pr=11.4,Gr=2,Gm=2 and $\omega = 0.5$.It is noticed that the temperature falls in the increase of permeability of porous medium (K) ,whereas rises in the increase of magnetic parameter (M).

Figure-(8) shows the effect of the parameters Sc on Heat profile at any point of the fluid, when t=0.9, ,K=2,M=2 .Pr=11.4,Gr=2,Gm=2 and $\omega = 0.5$.It is noticed that the temperature falls in the increase of Schmidt number (Sc).

Mass concentration profile: The Mass concentration profiles are depicted in Figs 9-10.Figure-(9) shows the effect of the parameters Sc on mass concentration profile at any point of the fluid, when t=0.5, and $\omega = 0.5$ It is noticed that the mass concentration decreases with the increase of Schmidt number (Sc).

Figure-(10) shows the effect of the parameters t and ω on mass concentration profile at any point of the fluid,when Sc=0.23.It is noticed that the mass concentration decreases with the increase of oscillating frequence (ω) whereas increases with time (t).

Skin friction: The absolute value of Skin friction and tangent value of phase angle are depicted in Table –(1).which illustrates the effect of the parameters Gr,Gm,M, K, ω, t and Sc on Skin friction at plate. It is noticed that absolute value of Skin friction at plate decreases with the increase of permeability of porous medium (K)and time(t) ,whereas increases with the increase of Grashof number (Gr), Modified Grashof number (Gm) and magnetic parameter (M).Also tangent value of phase angle(tan(θ))increases with the increase of Grashof number (Gr), Modified Grashof number (Gm), permeability of porous medium (K) and oscillating frequence (ω).

Nusselt Number: The absolute value of Nusselt number and tangent value of its phase angle are depicted in Table-(2).which illustrates the effect of the parameters Gr,Gm,M, K, and Sc,whenE=0.002,$\omega = 0.5, t = 0.5$ .It is noticed that absolute value of Nusselt number and tangent value of its phase angle(tan($\boldsymbol{\beta}$)) at plate decreases with the increase of Grashof number (Gr),whereas increases for all other parameters.

Sherwood Number: Table-(3) shows the effect of the parameters ω Sc and t on absolute value of Sherwood number and tangent value of its phase angle ($\boldsymbol{tan}(\boldsymbol{\gamma})$) at plate, It is observed that absolute value of Sherwood number and tangent value of its phase angle ($\boldsymbol{tan}(\boldsymbol{\gamma})$) at the plate decreases with the increase of time (t) and oscillating frequence (ω), whereas increases with the increase of Schmidt number (Sc).

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Table-(1) Effect of K,M Gr,Gm , ω ,t and Sc on absolute value and $tan(\theta)$ Skin friction(τ)

Sc	M	K	Gr	Gm	ω	t	Abslute Value of Skin friction$(\uparrow \tau)$	tanθ
0.23	3	3	2	2	0.5	1.5	3.7762	0.0004
0.3	3	3	2	2	0.5	1.5	3.7644	0.0004
0.6	3	3	2	2	0.5	1.5	3.9245	0.0004
0.23	5	3	2	2	0.5	1.5	3.9401	0.0004
0.23	10	3	2	2	0.5	1.5	4.5296	0.0004
0.23	3	5	2	2	0.5	1.5	3.7723	0.0005
0.23	3	10	2	2	0.5	1.5	3.7703	0.0004
0.23	3	3	10	2	0.5	1.5	4.1265	0.0009
0.23	3	3	20	2	0.5	1.5	4.5633	0.0013
0.23	3	3	2	10	0.5	1.5	8.9673	0.0008
0.23	3	3	2	20	0.5	1.5	15.4945	0.0011
0.23	3	3	2	2	1	1.5	3.7758	0.0005
0.23	3	3	2	2	1.5	1.5	3.7758	0.0005
0.23	3	3	2	2	0.5	2	3.7755	0.0005
0.23	3	3	2	2	0.5	3	3.5579	0.0004

Table-(2) Effect of K,M Gr,Gm and Sc on absolute value and $\boldsymbol{tan(\beta)}$ Nusselt Number(Nu)

Sc	M	K	Gr	Gm	Absolute value of **Nu**	$\boldsymbol{tan(\beta)}$
0.23	2	2	2	2	11.6705	0.0062
0.3	2	2	2	2	11.6912	0.0064
0.6	2	2	2	2	11.8860	0.0091
0.23	5	2	2	2	11.7342	0.0070
0.23	10	2	2	2	11.7559	0.0074
0.23	2	5	2	2	11.7080	0.0071
0.23	2	10	2	2	11.7233	0.0075
0.23	2	2	5	2	11.6684	0.0062
0.23	2	2	10	2	11.6648	0.0061
0.23	2	2	2	5	12.0657	0.0164
0.23	2	2	2	10	13.0495	0.0418

Table-(3) Effect of t, $\boldsymbol{\omega}$ and Sc on absolute value and $\boldsymbol{tan(\gamma)}$ Sherwood Number(Sh)

Sc	t	ω	Absolute value of **Sh**	$\boldsymbol{tan(\gamma)}$
0.23	0.5	0.7	0.2317	125.29
0.3	0.5	0.7	0.3021	145.1773
0.6	0.5	0.7	0.6036	218.0103
0.23	0.7	0.7	0.2314	112.0474
0.23	0.9	0.7	0.2311	103.1257
0.23	0.5	0.9	0.2316	101.4712
0.23	0.5	1.5	0.2308	69.5982

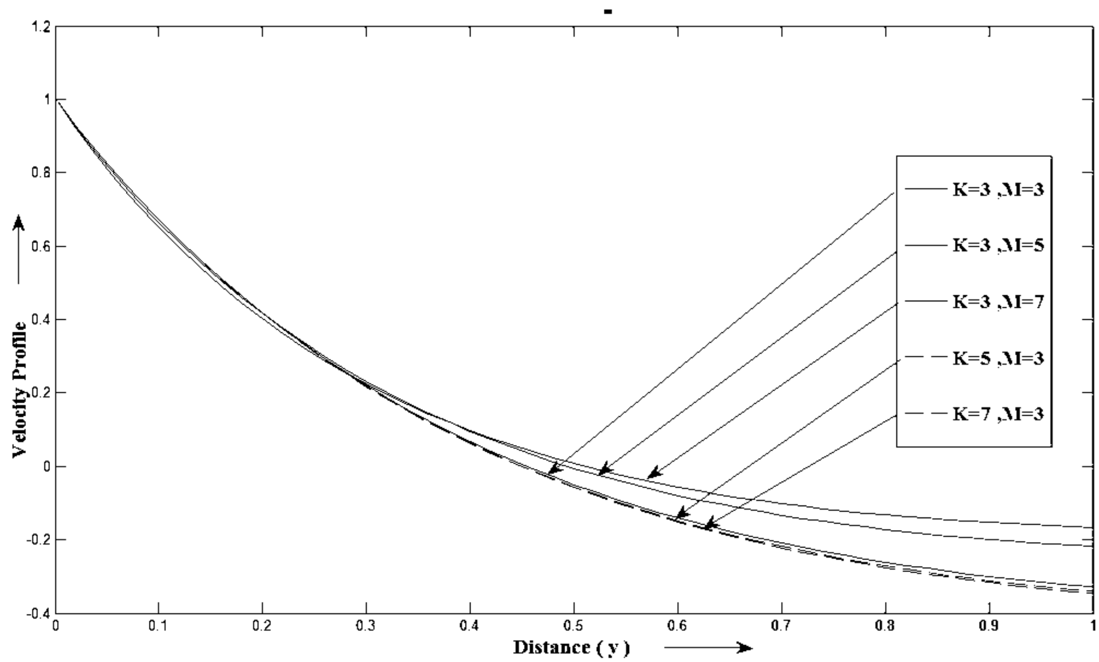

Fig-**(1)-Effect of K and M on Velocity profile when Gr=2, Sc=0.23, Pr=11.4, ω=0.5 t=0.5,E=0.002, and $Gm = 2$.**

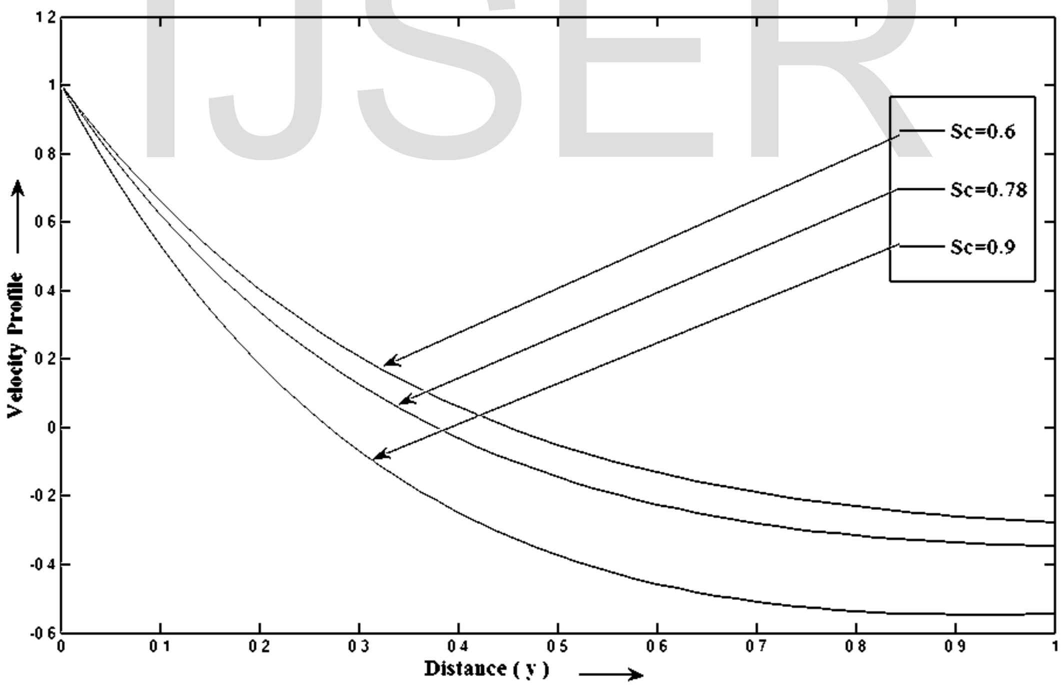

Fig-**(2)-Effect of Sc on Velocity profile when Gr=2, Pr=11.4, ω =0.5 t=0.5,E=0.002,K=3,M=3 and $Gm = 2$.**

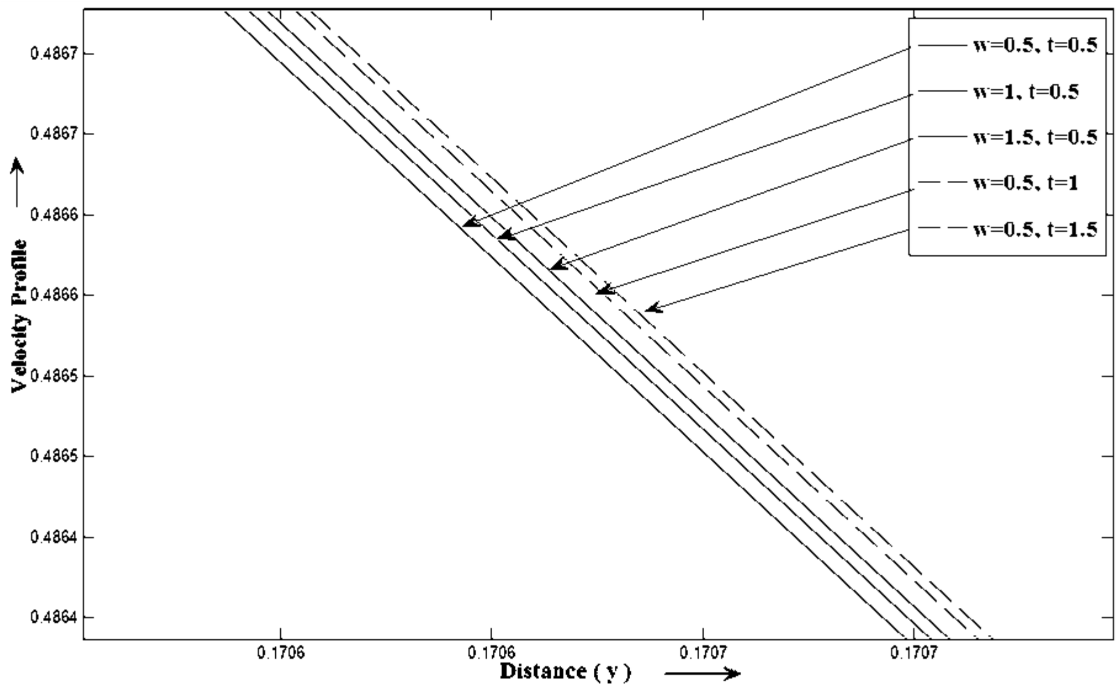

Fig-**(3)-Effect of ω and t on Velocity profile when Gr=2, Pr=11.4, Sc=0.23,E=0.002,K=3,M=3 and $Gm = 2$.**

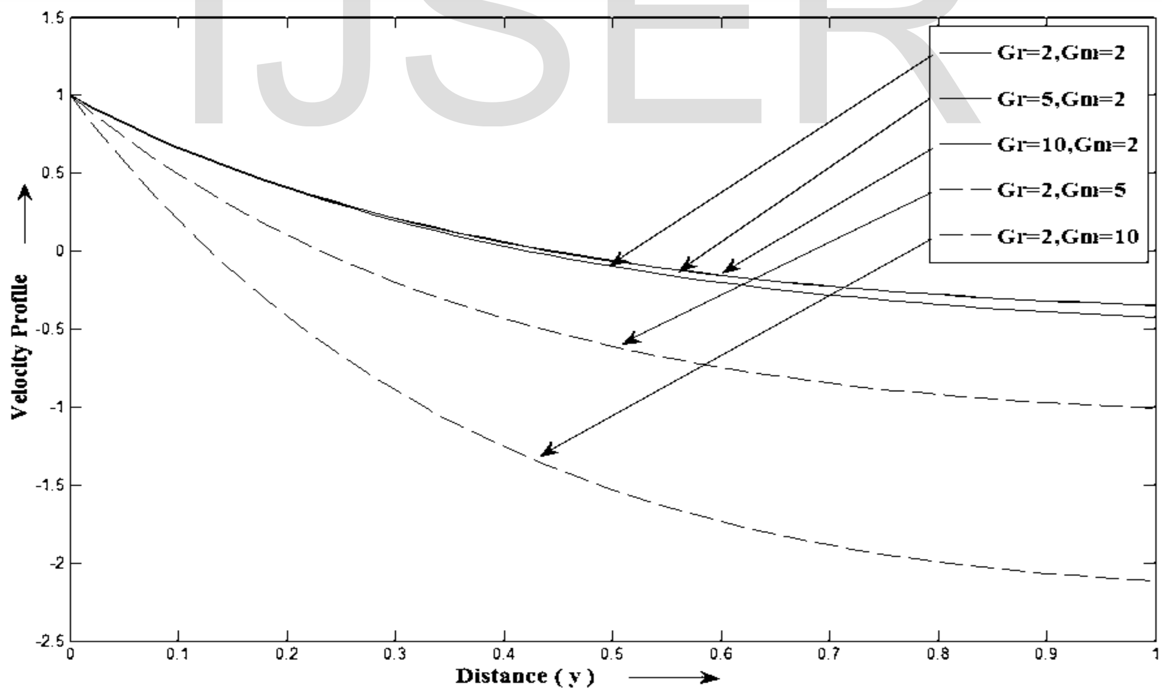

Fig-**(4)-Effect of Gr and Gm on Velocity profile when Pr=11.4, Sc=0.23,E=0.002,K=3,M=3, $\omega = 0.5$ and t=0.5.**

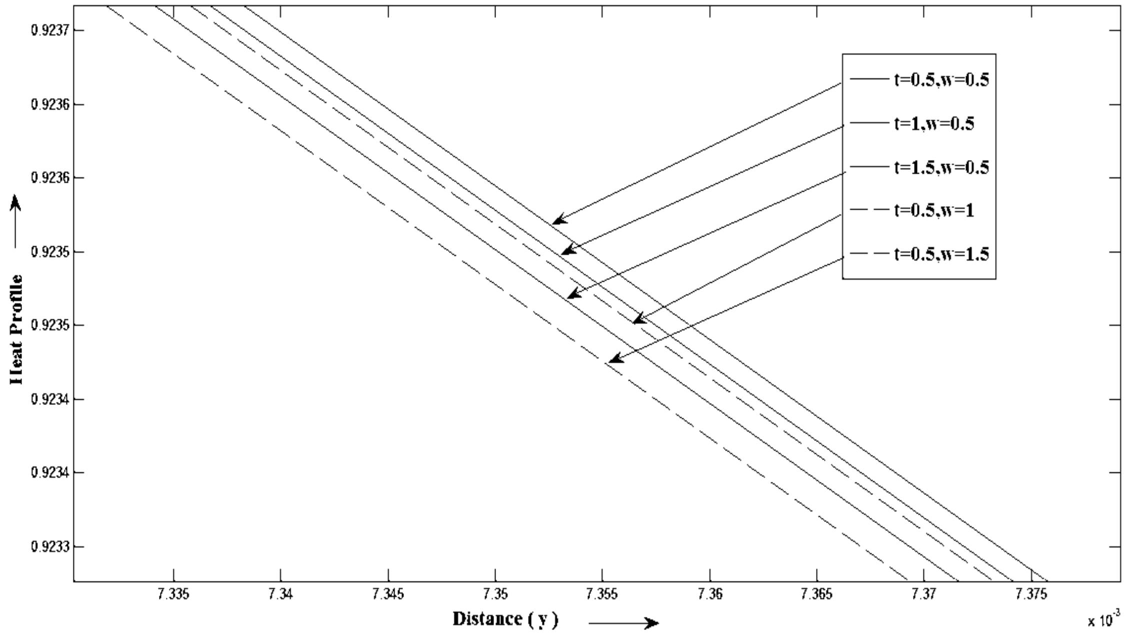

Fig-**(5)-Effect of ω and t on Heat profile when Gr=2, Sc=0.23, Pr=11.4,M=2,K=2,Gm=2 and $Gm = 2$**

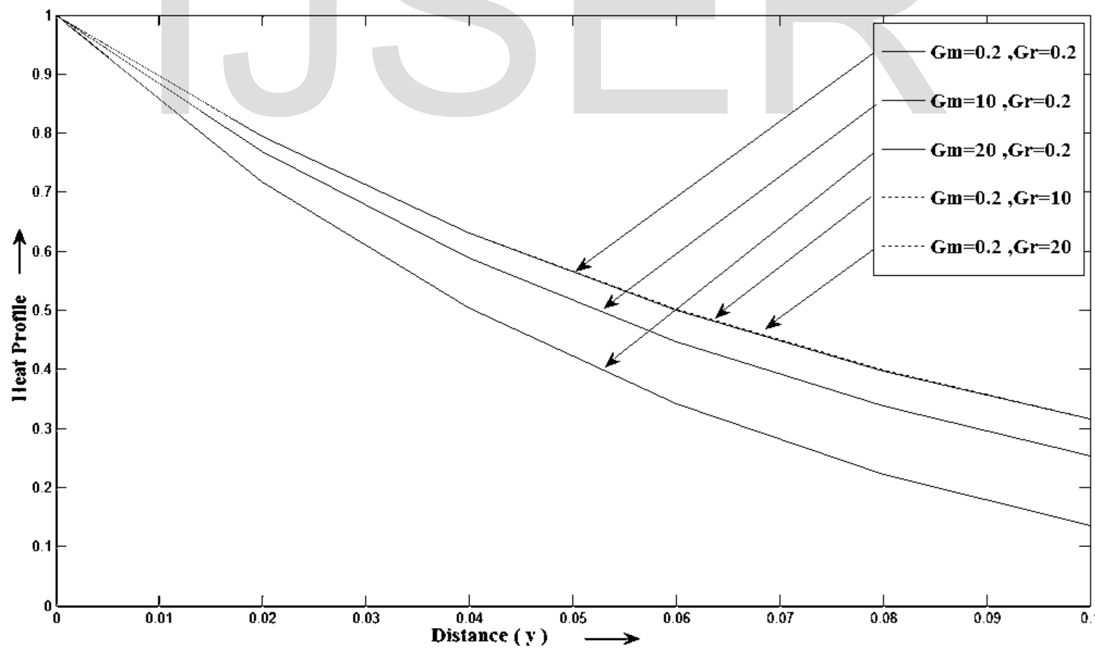

Fig-**(6)-Effect of Gr and Gm on Heat profile when t=0.9, Sc=0.23, Pr=11.4,M=2,K=2 and $\omega = 0.5$**

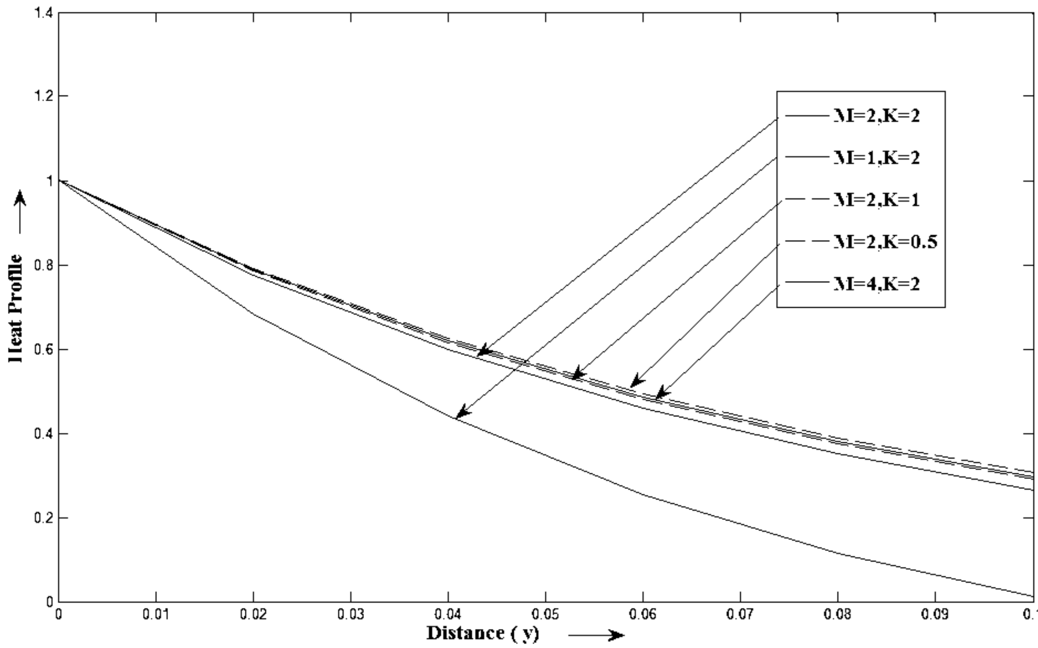

Fig-**(7)-Effect of M and K on Heat profile when t=0.9, Sc=0.23, Pr=11.4,Gr=2,Gm=2 and** $\boldsymbol{\omega = 0.5}$

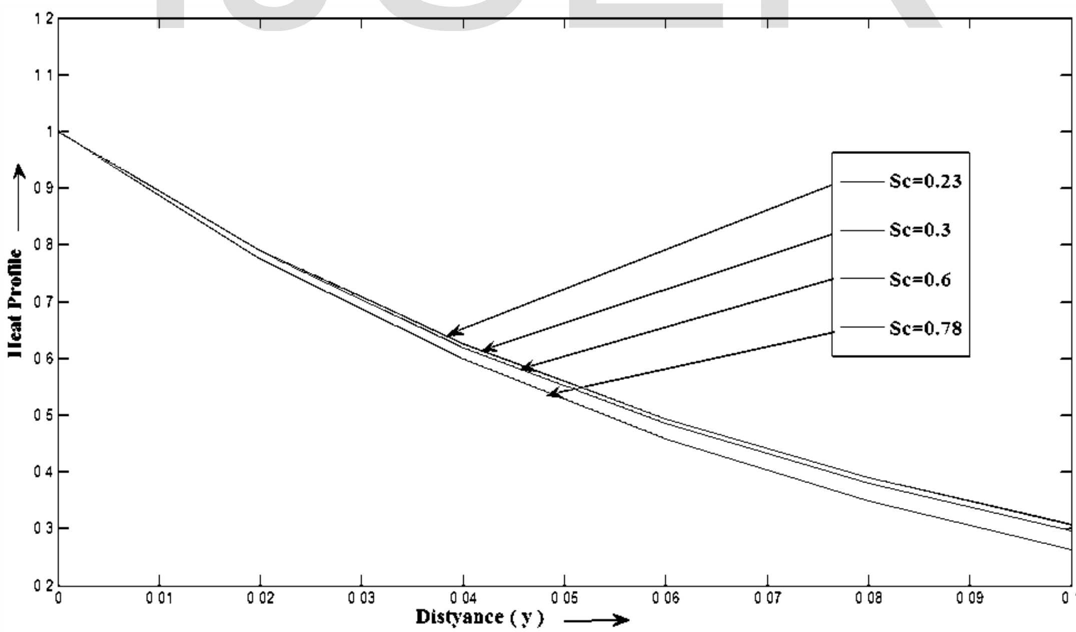

Fig-**(8)-Effect of Sc on Heat profile when t=0.9, ,K=2,M=2 .Pr=11.4,Gr=2,Gm=2 and** $\boldsymbol{\omega = 0.5}$

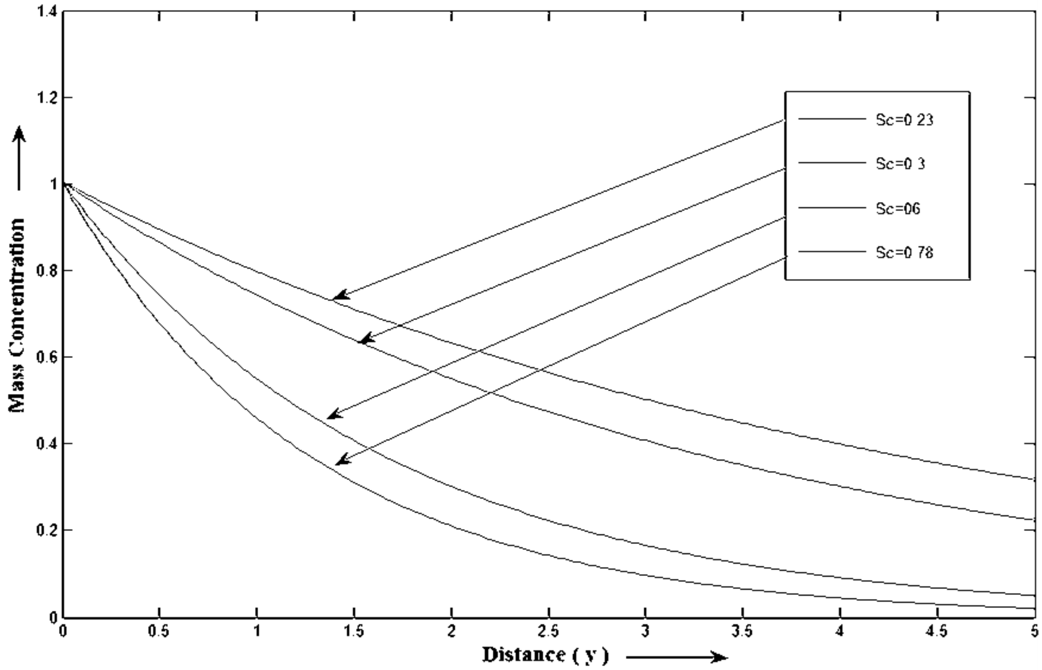

Fig-**(9)-Effect of Sc on mass concentration profile when t=0.5, and $\omega = 0.5$**

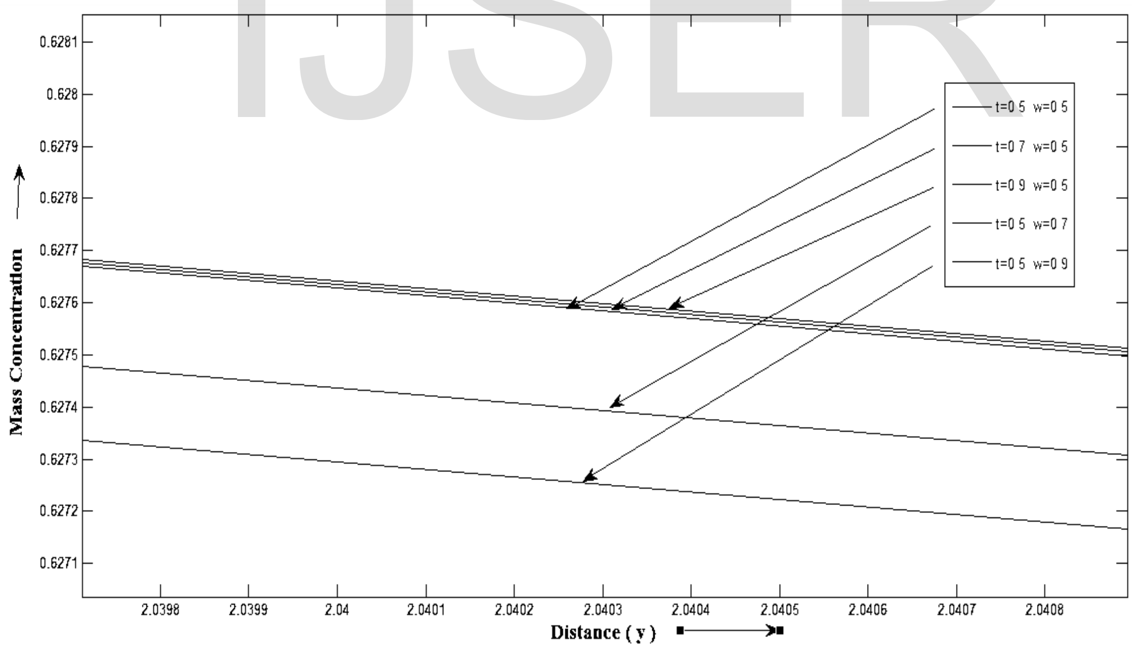

Fig-(10)-Effect of t and ω on mass concentration profile when Sc=0.23.

CONCLUSIONS

The following results are obtained for water at 4^0C

i. The velocity increases with the increase in Gr, and M .which indicate flow increase when magnetic force dominate the viscous force or convective amount due to cooling.Also Gr and M play the opposite role in Heat.

ii. The mass profile decreases for the increasing of S_c.

iii. The absolute value skin-friction at plate increases with an increase in Grashof number(Gr) and magnetic parameter (M) .But in Nusselt number decreases convective amount due to cooling which is the reverse of magnetic force dominate the viscous force

REFERENCES

1. Soundagekar,V.(1976) Free convection effects on oscillatory flow of water at 40 C past an infinite vertical porous plate with constant suction.,Heat and Mass Transfer,Vol-9,pp-111-115.
2. Pop,I. and Raptil, A. A note on transient free convection of water at 40 C over a doubly infinite vertical porous plate , journal of heat Transfer-Transactions of ASME,Vol-104,pp-800-802.
3. Raptis,A. and Pop, I.Combined convection flow of water at 40C through a porous medium bounded by avertical surface ,Letters in Heat and Mass Transfer,Vol-9,pp-309-318.
4. Thkhar and Perdikis (1986)The steady and forced convective flow of water at 40C through a porous medium bounded by a semi infinite vertical plate.,Int.comm.heat mass transfer 13(5),pp-605-609.
5. Gorla and Stratman (1986) The influence of transverse curvature on laminar free convective boundary layer flow of water at 40C over a cone. Int.comm.heat mass transfer, 13,pp-403-411.
6. Mohapatra,P. and Senapati,N. (1989).The effect of mass transfer on a Magnetohydrodynamics free convective flow of water at 40C through a porous medium N., J. Nat. Acad. Math., 7, 79-98 .
7. Dhal, R.K. and Senapati,N. (2010) ,The radiation effect of mass transfer on Magnetohydrodynamics free convection flow of water at 40C and liquid sodium at 200 C through porous medium, Bulletin of Pure and Applied Science,Vol-29E(1) pp-155-168.
8. Jhankal,A.K.(2017)Unsteady MHD free convection of water at 40 C and heat transfer through porous medium bounded by an Isothermal porous vertical plate in presence of variable suction and heat generation absorption, International Journal of Dynamic fluids,Vol-13.pp-79-88