Effect of Mass Transfer on Free Convective Fluctuating MHD Flow through Porous Medium Past a Vertical Plate with Variable Temperature and Heat Source

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Abstract: **Effect of Mass Transfer on Free Convective Fluctuating MHD Flow through Porous Medium Past a Vertical Plate with Variable Temperature and Heat Source has been studied. The dimensionless governing equations are solved using double perturbation parameter equations to remove the coupler equations. The main objective of this paper is to study the effects of mass transfer coupler with velocity and temperature through graphs and tables in velocity field and temperature field.**

***Key Words*: Mass Transfer, Free Convection, Heat Source, MHD, Porosity, Sinusoidal temperature.**

I. INTRODUCTION

The study related to free convection with variable temperature and heat source has drawn considerable attention of many researches during last few decades because of its wide application in astrophysical science, aerospace technology, chemical engineering etc. Presence of mass transfer with MHD flow has many more application in industrial fields, nuclear reactor, sodium cooling system and electrical power generation. Unsteady forced and free convective flow past an infinite vertical porous plate with oscillating wall temperature and constant suction has been discussed by Soundalgekar et al.[1]. Raptis et al[2] have analysised about Magneto hydrodynamics free convection flow and mass transfer through a porous medium bounded by an infinite vertical porous plate with constant heat flux. Transient free convection flow between two vertical parallel plates have been discussed by Singh et al[3,4]. Free convection flow between two long vertical parallel plates with variable temperature at one boundary has discussed by Narahari[5]. Unsteady flow past an accelerated infinite vertical plate with variable temperature and uniform mass diffusion is presented by Muthucumaraswamy et al[6]. Effect of heat and mass transfer on MHD free convection flow past in oscillating vertical plate with variable temperature embedded in porous medium.is dicussed by Senapati et al[7]. Free convective fluctuating MHD flow through porous medium past a vertical porous plate with variable temperature is presented by Das et al[8].

This paper deals with the study of effect of mass transfer on free convective fluctuating MHD flow through porous medium past a vertical plate with variable temperature and heat source.

II. FORMULATION OF THE PROBLEM

An unsteady flow of a viscous incompressible electrically conducting fluid through porous medium past an insulated infinite hot porous plate lying vertically on $x' - z'$ plane with mass transfer has been considered. The x'-axis is oriented in the direction of the buoyancy force and y' axis is taken perpendicular to the plane.A uniform magnetic field of strength of B_0 is applied along $y' - axis$ .let us consider $(u', v', 0)$ be the components of velocity in the direction (x', y', z') respectively. As the plate being considered infinite along x' axis ,so all the physical quantities are independent of x'. Span wise co sinusoidal temperature has been considered. Then by usual Boussinesq's approximation the unsteady flow is governed by the following equations.

$$\frac{\partial v'}{\partial y'} = 0 \qquad \Rightarrow\ v' = -V(constant) \tag{1}$$

$$\frac{\partial u'}{\partial t'} - V\frac{\partial u'}{\partial y'} = \nu\left(\frac{\partial^2 u'}{\partial y'^2} + \frac{\partial^2 u'}{\partial z'^2}\right) + g\beta(T' - T'_\infty) + g\beta_c(C' - C'_\infty) - \frac{\sigma B_0^2}{\rho}u' - \frac{\nu}{K'_p}u' \tag{2}$$

$$\frac{\partial T'}{\partial t'} - V\frac{\partial T'}{\partial y'} = \frac{k}{\rho C_p}\left(\frac{\partial^2 T'}{\partial y'^2} + \frac{\partial^2 T'}{\partial z'^2}\right) + \frac{\mu}{\rho C_p}\left(\left(\frac{\partial u'}{\partial y'}\right)^2 + \left(\frac{\partial u'}{\partial z'}\right)^2\right) - S'(T' - T'_\infty) \tag{3}$$

$$\frac{\partial C'}{\partial t'} - V\frac{\partial C'}{\partial y'} = D\left(\frac{\partial^2 C'}{\partial y'^2} + \frac{\partial^2 C'}{\partial z'^2}\right) \tag{4}$$

with the boundary conditions

$$\left.\begin{aligned} &y' = 0: u' = 0\,, v' = -V\,, T' = T'_0 + \in (T'_0 - T'_\infty)\cos\left(\frac{\pi z'}{l} - \omega' t'\right), C' = C'_0 \\ &y' \to \infty: u' \to 0, T' \to T'_\infty, C' \to C'_\infty, \end{aligned}\right\} \tag{5}$$

Introducing the following non-dimensional quantities in (2) to (5)

$$u = \frac{\nu u'}{lV^2}, t = \frac{\omega \nu t'}{l^2}, y = \frac{y'}{l}, z = \frac{z'}{l}, T = \frac{T' - T'_\infty}{T'_0 - T'_\infty}, Ec = \frac{V^2}{C_p(T'_0 - T'_\infty)},$$
$$Re = \frac{lV}{\nu}, M^2 = \frac{B_0^2 l^2 \sigma}{\mu}, Gr = \frac{g\beta\nu(T'_0 - T'_\infty)}{V^3}, Pr = \frac{k}{\mu C_p}, S = \frac{S' l}{V},$$
$$Sc = \frac{\nu}{D}, Gm = \frac{g\beta_C \nu(C'_0 - C'_\infty)}{V^3}, K = \frac{K_p}{l^2} \quad (6)$$

where D is the mass diffusion, Gr is Grashof number, Gm is modified Grashof number ,K is permeability of porous medium, M is magnetic parameter ,Sc is Schmidt number, Re is Reynolds number, Pr is Prandtl number, $B_0 = \mu_e H_0$ and S is heat source parameter.

We get

$$\omega\frac{\partial u}{\partial t} - Re\frac{\partial u}{\partial y} = \left(\frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) + ReGrT + ReGmC - \left(M^2 + \frac{1}{K}\right)u \quad (7)$$

$$\omega Pr\frac{\partial T}{\partial t} - PrRe\frac{\partial T}{\partial y} = \left(\frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right) + PrRe^2Ec\left(\left(\frac{\partial u}{\partial y}\right)^2 + \left(\frac{\partial u}{\partial z}\right)^2\right) - ST \quad (8)$$

$$\omega Sc\frac{\partial C}{\partial t} - ReSc\frac{\partial C}{\partial y} = \frac{\partial^2 C}{\partial y^2} + \frac{\partial^2 C}{\partial z^2} \quad (9)$$

with boundary conditions

$$\left.\begin{aligned} &y = 0:\ u = 0, T = 1 + \in \cos(\pi z - \omega t), C = 1 \\ &y \to \infty: u = 0, T = 0, C = 0 \end{aligned}\right\} \quad (10)$$

III. METHOD OF SOLUTION

In order to solve the problem, we assume the solutions of following form because the $\in$ of the permeability variation is very small:

$$\left.\begin{aligned} u(y,z,t) &= u_0(y) + \in u_1(y,z.t) + o(\in^2) \\ T(y,z,t) &= T_0(y) + \in T_1(y,z.t) + o(\in^2) \\ C(y,z,t) &= C_0(y) + \in C_1(y,z.t) + o(\in^2) \end{aligned}\right\} \quad (11)$$

Comparing the coefficients of like powers of $\in$ after substituting (11) in (7) to (10) ,we get the following zeroth order equations

$$\frac{\partial^2 u_0}{\partial y^2} + Re\frac{\partial u_0}{\partial y} - \left(M^2 + \frac{1}{K_p}\right)u_0 = -ReGrT_0 - ReGmC_0 \quad (12)$$

$$\frac{\partial^2 T_0}{\partial y^2} + RePr\frac{\partial T_0}{\partial y} - ST_0 = -PrRe^2Ec\left(\frac{\partial u_0}{\partial y}\right)^2 \quad (13)$$

$$\frac{\partial^2 C_0}{\partial y^2} + ReSc\frac{\partial C_0}{\partial y} = 0 \quad (14)$$

with boundary conditions

$$\left.\begin{aligned} &u_0 = 0, T_0 = 1, C_0 = 1 \ \ at\ y = 0 \\ &u_0 = 0, T_0 = 0, C_0 = 0 \ \ as\ y \to \infty \end{aligned}\right\} \quad (15)$$

Solving equation (14),we get

$$C_0 = e^{-ReScy} \quad (16)$$

For solving the above coupled equations we use the following perturbed equation with perturbation parameter Ec

$$\left.\begin{aligned} u_0 &= u_{01} + Ecu_{02} + o(Ec^2) \\ T_0 &= T_{01} + EcT_{02} + o(Ec^2) \end{aligned}\right\} \quad (17)$$

Substituting (17) in (12),(13) and (15) ,we get the following zeroth and first order equation of Ec

$$\frac{\partial^2 u_{01}}{\partial y^2} + Re\frac{\partial u_{01}}{\partial y} - \left(M^2 + \frac{1}{K}\right)u_{01} = -ReGrT_{01} - ReGmC_0 \quad (18)$$

$$\frac{\partial^2 u_{02}}{\partial y^2} + Re\frac{\partial u_{02}}{\partial y} - \left(M^2 + \frac{1}{K}\right)u_{02} = -ReGrT_{02} \quad (19)$$

$$\frac{\partial^2 T_{01}}{\partial y^2} + RePr\frac{\partial T_{01}}{\partial y} - ST_{01} = 0 \quad (20)$$

$$\frac{\partial^2 T_{02}}{\partial y^2} + RePr\frac{\partial T_{02}}{\partial y} - ST_{02} = -PrRe^2\left(\frac{\partial u_{01}}{\partial y}\right)^2 \quad (21)$$

The corresponding boundary conditions are

$$\left.\begin{aligned} &u_{01} = 0, T_{01} = 1, u_{02} = 0, T_{02} = 0 \ \ at\ y = 0 \\ &u_{01} = 0, T_{01} = 0, u_{02} = 0, T_{02} = 0 \ \ as\ y \to \infty \end{aligned}\right\} \quad (22)$$

By solving from (18) to (21) ,we get

$$\left.\begin{aligned} T_{01} &= e^{-m_1 y} \\ u_{01} &= a_3 e^{-m_3 y} + a_2 e^{-m_1 y} + a_1 e^{-ScRey} \\ T_{02} &= a_{10}e^{-m_1 y} + a_4 e^{-2m_2 y} + a_5 e^{-2m_1 y} + a_6 e^{-2ScRey} + a_7 e^{-(m_1+m_2)y} + a_8 e^{-(ScRe+m_1)y} + a_9 e^{-(ScRe+m_2)y} \\ u_{02} &= a_{18}e^{-m_2 y} + a_{11}e^{-m_1 y} + a_{12}e^{-2m_2 y} + a_{13}e^{-2m_1 y} + a_{14}e^{-2ScRey} + a_{15}e^{-(m_1+m_2)y} + a_{16}e^{-(ScRe+m_1)y} + a_{17}e^{-(ScRe+m_2)y} \end{aligned}\right\} \quad (23)$$

The terms of the coefficients of $\in$ give the following first order equations

$$\left.\begin{aligned} &\omega\frac{\partial u_1}{\partial t} - Re\frac{\partial u_1}{\partial y} = \frac{\partial^2 u_1}{\partial y^2} + \frac{\partial^2 u_1}{\partial z^2} + GrRe\,T_1 + GmReC_1 - \left(M^2 + \frac{1}{K}\right)u_1 \\ &\omega Pr\frac{\partial T_1}{\partial t} - RePr\frac{\partial T_1}{\partial y} = \frac{\partial^2 T_1}{\partial y^2} + \frac{\partial^2 T_1}{\partial z^2} - ST_1 + PrRe^2T_1\frac{\partial u_1}{\partial y}\frac{\partial u_0}{\partial y} \\ &\omega Sc\frac{\partial C_1}{\partial t} - ReSc\frac{\partial C_1}{\partial y} = \frac{\partial^2 C_1}{\partial y^2} + \frac{\partial^2 C_1}{\partial z^2} \end{aligned}\right\} \quad (24)$$

In order to solve (24) ,it is convenient to adopt complex function for velocity ,temperature and mass concentration profile as

$$\left.\begin{aligned} u_1(y,z.t) &= \phi(y)e^{i(\pi z-t)} \\ T_1(y,z.t) &= \psi(y)e^{i(\pi z-t)} \\ C_1(y,z.t) &= \varphi(y)e^{i(\pi z-t)} \end{aligned}\right\} \quad (25)$$

The solution obtained in term of complex functions, real parts of which have physical significance.

Now Substituting (25) into (24) we get the following coupled equations.

$$\frac{\partial^2\phi}{\partial y^2}+Re\frac{\partial\phi}{\partial y}+\left[\omega i-\pi^2-\left(M^2+\frac{1}{K_p}\right)\right]\phi=-ReGr\psi-ReGm\varphi \quad (26)$$

$$\frac{\partial^2\psi}{\partial y^2}+PrRe\frac{\partial\psi}{\partial y}+(\omega Pri-\pi^2-S)\psi=-2Re^2Pr\frac{\partial u_0}{\partial y}\frac{\partial\phi}{\partial y} \quad (27)$$

$$\frac{\partial^2\varphi}{\partial y^2}+Re\frac{\partial\varphi}{\partial y}+[\omega i-\pi^2]\varphi=0 \quad (28)$$

By solving equation (28), we get $\varphi=0$

To solve equations (26) & (27), we assume the following perturbed forms with the same reasoning mentioned above and equating the coefficient of like power of Ec.

$$\left.\begin{aligned} \phi &= \phi_0+Ec\phi_1+o(Ec^2) \\ \psi &= \psi_0+Ec\psi_1+o(Ec^2) \end{aligned}\right\} \quad (29)$$

We get

$$\left.\begin{aligned} &\frac{\partial^2\phi_0}{\partial y^2}+Re\frac{\partial\phi_0}{\partial y}+\left[\omega i-\pi^2-\left(M^2+\frac{1}{K}\right)\right]\phi_0=-ReGr\psi_0 \\ &\frac{\partial^2\phi_1}{\partial y^2}+Re\frac{\partial\phi_1}{\partial y}+\left[\omega i-\pi^2-\left(M^2+\frac{1}{K_p}\right)\right]\phi_1=-ReGr\psi_1 \\ &\frac{\partial^2\psi_0}{\partial y^2}+PrRe\frac{\partial\psi_0}{\partial y}+(\omega Pri-\pi^2-S)\psi_0=0 \\ &\frac{\partial^2\psi_1}{\partial y^2}+PrRe\frac{\partial\psi_1}{\partial y}+(\omega Pri-\pi^2-S)\psi_1=-2Re^2Pr\frac{\partial u_{01}}{\partial y}\frac{\partial\phi_0}{\partial y} \end{aligned}\right\} \quad (30)$$

Corresponding boundary conditions

$$\left.\begin{aligned} &\phi_0=0\,,\phi_1=0,\psi_0=1\,,\psi_1=0 \ at\ y=0 \\ &\phi_0=0\,,\phi_1=0,\psi_0=0\,,\psi_1=0 \ as\ y\to\infty \end{aligned}\right\} \quad (31)$$

By solving (30) using (31) ,we get

$$\left.\begin{aligned} \phi_0 &= a_{19}(e^{-m_3y}-e^{-m_4y}) \\ \psi_0 &= e^{-m_3y} \\ \psi_1 &= a_{26}\,e^{-m_3y}+a_{20}e^{-2m_3y}+a_{21}e^{-(m_3+m_1)y} \\ &\quad +a_{22}e^{-(m_3+ScRe)y}+a_{23}e^{-(m_3+m_4)y} \\ &\quad +a_{24}e^{-(m_1+m_4)y}+a_{25}e^{-(m_4+ScRe)y} \\ \phi_1 &= a_{27}(e^{-m_4y}-e^{-m_3y}) \end{aligned}\right\} \quad (32)$$

Now by using equations (13),(16),(23),(25),(29) and(32) ,we get

$$u=\left\{(a_3e^{-m_3y}+a_2e^{-m_1y}+a_1e^{-ScRey})+Ec\left(a_{18}e^{-m_2y}+a_{11}e^{-m_1y}+a_{12}e^{-2m_2y}+a_{13}e^{-2m_1y}+a_{14}e^{-2ScRey}+a_{15}e^{-(m_1+m_2)y}+a_{16}e^{-(ScRe+m_1)y}+a_{17}e^{-(ScRe+m_2)y}\right)\right\}+\in\left\{\left[\left(a_{19}(e^{-m_3y}-e^{-m_4y})\right)+Ec\left(a_{27}(e^{-m_4y}-e^{-m_3y})\right)\right]e^{i(\pi z-t)}\right\} \quad (33)$$

$$T=\left\{(e^{-m_1y})+Ec\left(a_{10}e^{-m_1y}+a_4e^{-2m_2y}+a_5e^{-2m_1y}+a_6e^{-2ScRey}+a_7e^{-(m_1+m_2)y}+a_8e^{-(ScRe+m_1)y}+a_9e^{-(ScRe+m_2)y}\right)\right\}+\in\left\{\left[(e^{-m_3y})+Ec\left(a_{26}\,e^{-m_3y}+a_{20}e^{-2m_3y}+a_{21}e^{-(m_3+m_1)y}+a_{22}e^{-(m_3+ScRe)y}+a_{23}e^{-(m_3+m_4)y}+a_{24}e^{-(m_1+m_4)y}+a_{25}e^{-(m_4+ScRe)y}\right)\right]e^{i(\pi z-t)}\right\} \quad (34)$$

$$C=e^{-ReScy} \quad (35)$$

The dimensional rate of heat transfer,

$$Nu=-\left(\frac{\partial T}{\partial y}\right)_{y=0}=\{(m_1)+Ec(a_{10}m_1+2a_4m_2+2a_5m_1+2ScRea_6+(m_1+m_2)a_7+(ScRe+m_1)a_8+(ScRe+m_2)a_9)\}+\in\left\{[(m_3)+Ec(m_3a_{26}+2m_3a_{20}+(m_3+m_1)a_{21}+(m_3+ScRe)a_{22}+(m_3+m_4)a_{23}+(m_1+m_4)a_{24}+(m_4+ScRe)a_{25})]e^{i(\pi z-t)}\right\} \quad (36)$$

The dimensionless rate of mass transfer ,

$$Sh=-\left(\frac{\partial C}{\partial y}\right)_{y=0}=ReSc \quad (37)$$

The non-dimensional Skin friction at the wall from the equations (33) is given by

$$\tau_0=\left(\frac{\partial u}{\partial y}\right)_{y=0}=-\{(m_3a_3+m_1a_2+ScRea_1)+Ec(m_2a_{18}+m_1a_{11}+2m_2a_{12}+2m_1a_{13}+2ScRea_{14}+(m_1+m_2)a_{15}+(ScRe+m_1)a_{16}+(ScRe+m_2)a_{17})\}+\in\left\{\left[\left(a_{19}(m_4-m_3)\right)+Ec\left(a_{27}(m_3-m_4)\right)\right]e^{i(\pi z-t)}\right\} \quad (38)$$

where

$m_1=\frac{PrRe+\sqrt{(RePr)^2+4S}}{2}$, $m_2=\frac{Re+\sqrt{Re^2+4\left(M^2+\frac{1}{K}\right)}}{2}$, $m_3=\frac{PrRe+\sqrt{(RePr)^2+4(\omega Pri-\pi^2-S)}}{2}$

$m_4=\frac{Re+\sqrt{Re^2-4\left(\omega i-\pi^2-\left(M^2+\frac{1}{K}\right)\right)}}{2}$,

$a_1=\frac{-ReGm}{(ScRe)^2-ScRe-\left(M^2+\frac{1}{K}\right)}$, $a_2=\frac{-ReGr}{(m_1)^2-m_1-\left(M^2+\frac{1}{K}\right)}$,

$a_3=-(a_2+a_1)$, $a_4=\frac{-Re^2Pra_3^2}{4m_2^2-2m_2RePr-S}$, $a_5=\frac{-Re^2Pra_2^2}{4m_1^2-2m_1RePr-S}$

$a_6 = \frac{-Re^2 Pra_1^2}{4Sc^2Re^2 - 2ScRe^2Pr - S}$, $a_7 = \frac{-2Re^2Pra_3a_2}{(m_1+m_2)^2-(m_1+m_2)RePr-S}$,

$a_8 = \frac{-2Re^2Pra_1a_2}{(m_1+ScRe)^2-(m_1+ScRe)RePr-S}$,

$a_9 = \frac{-2Re^2Pra_1a_3}{(m_2+ScRe)^2-(m_2+ScRe)RePr-S}$, $a_{10} = -(a_4 + a_5 + a_6 + a_7 + a_8 + a_9)$

$a_{11} = \frac{-ReGra_{10}}{(m_1)^2 - Rem_1 - \left(M^2+\frac{1}{K}\right)}$, $a_{12} = \frac{-ReGra_4}{4(m_2)^2-2Rem_2-\left(M^2+\frac{1}{K}\right)}$

$a_{13} = \frac{-ReGra_5}{4(m_1)^2-2Rem_1-\left(M^2+\frac{1}{K}\right)}$, $a_{14} = \frac{-ReGra_6}{4Sc^2Re^2-2ScRe^2-\left(M^2+\frac{1}{K}\right)}$

$a_{15} = \frac{-ReGra_7}{(m_1+m_2)^2-(m_1+m_2)Re-\left(M^2+\frac{1}{K}\right)}$,

$a_{16} = \frac{-ReGra_8}{(m_1+ScRe)^2-(m_1+ScRe)Re-\left(M^2+\frac{1}{K}\right)}$

$a_{17} = \frac{-ReGra_9}{(m_2+ScRe)^2-(m_2+ScRe)Re-\left(M^2+\frac{1}{K}\right)}$,

$a_{18} = -(a_{11} + a_{12} + a_{13} + a_{14} + a_{15} + a_{16} + a_{17})$

$a_{19} = \frac{ReGr}{(m_3)^2+Rem_3+\left(\omega i-\pi^2-\left(M^2+\frac{1}{K}\right)\right)}$, $a_{20} = \frac{-2PrRe^2m_3^2a_3a_{19}}{4m_3^2-2m_3PrRe+(\omega Pri-\pi^2-S)}$

$a_{21} = \frac{-2PrRe^2a_2a_{19}m_3m_1}{(m_3+m_1)^2-(m_3+m_1)PrRe+(\omega Pri-\pi^2-S)}$,

$a_{22} = \frac{-2PrRe^3Sca_1a_{19}m_3}{(m_3+ScRe)^2-(m_3+ScRe)PrRe+(\omega Pri-\pi^2-S)}$,

$a_{23} = \frac{-2PrRe^2a_3a_{19}m_3m_4}{(m_3+m_4)^2-(m_3+m_4)PrRe+(\omega Pri-\pi^2-S)}$,

$a_{24} = \frac{-2PrRe^2a_2a_{19}m_1m_4}{(m_1+m_4)^2-(m_1+m_4)PrRe+(\omega Pri-\pi^2-S)}$,

$a_{25} = \frac{-2PrScRe^3a_1a_{19}m_4}{(ScRe+m_4)^2-(ScRe+m_4)PrRe+(\omega Pri-\pi^2-S)}$,

$a_{26} = -(a_{20} + a_{21} + a_{22} + a_{23} + a_{24} + a_{25})$

$a_{27} = \frac{ReGr}{m_3^2-Rem_3+\left(\omega i-\pi^2-\left(M^2+\frac{1}{K}\right)\right)}$

IV. RESULTS AND DISCUSSION

In this paper the effect of mass transfer on free convective fluctuating MHD flow through porous medium past a vertical plate with variable temperature and heat source have been studied. The effect of the parameters Gr, Gm, M, K, S, Re, Pr, and Sc on flow characteristics have been studied and shown by means of graphs and tables. In order to have physical correlations, we choose suitable values of flow parameters. The graphs of velocities and temperature are taken w.r.t y. Shearing Stress and Nusselt number at plate is obtained in the tables for different parameters..

Velocity profiles : The velocity profiles are depicted in Figs 1-4. Figure-(1) shows the effect of the parameters M and K on velocity at any point of the fluid, when Gr=2, Gm=2, Sc=0.22, Pr=0.71,Re=2, $\omega = 1, t = 2$ and S=2.It is noticed that the velocity decreases with the increase magnetic parameter(M),whereas increases with the increase of permeability of porous medium (K).

Figure-(2) shows the effect of the parameters Gm and Gr velocity at any point of the fluid , when M=2, K=2, Sc=0.22, Pr=0.71,Re=2, $\omega = 1, t = 2$ and S=2.. It is noticed that the velocity increases with the increase of Grashoff number (Gr) and modified Grashoff number (Gm).

Figure-(3) shows the effect of the parameters Re and S on velocity at any point of the fluid, when Gr=2, Gm=2, Sc=0.22, Pr=0.71,M=2, $\omega = 1, t = 2$ and K=2.It is noticed that the velocity increases with the increase of heat source parameter(S) and Reynolds number (Re) .

Figure-(4) shows the effect of the parameters Sc and Pr on velocity at any point of the fluid, when Gr=2, Gm=2, M=2, K=2,Re=2,$\omega = 1, t = 2$ and S=2.It is noticed that the velocity increases with the increase of Schmidt number (Sc) and Prandtl number (Pr) .

Temperature profile: The temperature profiles are depicted in Figs 5-7. Figure-(5) shows the effect of the parameters Gr and Gm on Temperature profile at any point of the fluid when Sc=0.22, Pr=0.71, M=2, K=2,Re=2,$\omega = 1, t = 2$ and S=2. It is noticed that the temperature rises in the increase of Grashoff number (Gr) and modified Grashoff number (Gm).

Figure-(6) shows the effect of the parameters K and M on Temperature profile at any point of the fluid when Sc=0.22, Pr=0.71, Gr=2, Gm=2,Re=2, $\omega = 1, t = 2$ and S=2.It is noticed that the temperature rises in the increase of permeability of porous medium (K) ,whereas fall in the increase of magnetic parameter(M).But it was reverse just before y=0.4.

Figure-(7) shows the effect of the parameters Pr and Re on Temperature profile at any point of the fluid when Sc=0.22, Gm=2, M=2, K=2,Gr=2,$\omega = 1, t = 2$ and S=2.It is noticed that the temperature rises in the increase of Prandtl number (Pr) and Reynolds number (Re) .

Table-(1) shows the effects of different parameters on Shearing stress at the plate .It is noticed that shearing stress increases in the increase of Grashoff number (Gr), permeability of porous medium (K) , Reynolds number (Re) ,Prandtl number (Pr),Schmidt number (Sc), heat source parameter(S),oscillating frequency(ω) and modified Grashoff number (Gm).whereas decreases in the increase of magnetic parameter(M) and time (t).

Table-(2) shows the effects of Sc,Pr,Gr,Gm,S and Re on Nusselt number at the plate .It is noticed that Nusselt number increases in the increase of Grashoff number (Gm), whereas decreases in the increase of modified Grashoff number (Gm) and Schmidt number (Sc) .also fluctuate for other parameters.

Table-(1) Effect of different parameters on Shearing Stress at the plate

Sc	Pr	Gr	Gm	M	K	Re	S	ω	t	Shearing Stress (τ)
0.22										14.8228
0.3										15.0031
0.6										15.6582
	0.8									19.1906
	0.9									38.2889
		3								19.2464
		4								23.5099
			3							22.7130
			4							37.8674
				3						4.9161
				4						2.6531
					3					16.1404
					4					16.9276
						3				19.8179
						4				71.8671
							2.2			16.5873
							2.4			19.0760
								1.2		14.8064
								1.4		14.7914
									2.2	14.8221
									2.4	14.8219

Table-(2) Effect of different parameters on rate of heat transfer/ Nusselt Number

Sc	Pr	Gr	Gm	S	Re	Nusselt Number (Nu)
0.22	0.71	2	2	2	2.4	2.5918
0.3	0.71	2	2	2	2.4	2.5754
0.6	0.71	2	2	2	2.4	2.5541
0.22	0.8	2	2	2	2.4	1.2877
0.22	1.2	2	2	2	2.4	3.1762
0.22	0.71	3	2	2	2.4	2.6546
0.22	0.71	4	2	2	2.4	2.7021
0.22	0.71	2	3	2	2.4	2.4913
0.22	0.71	2	4	2	2.4	1.8944
0.22	0.71	2	2	3	2.4	2.3754
0.22	0.71	2	2	4	2.4	2.8864
0.22	0.71	2	2	2	2.6	2.9945
0.22	0.71	2	2	2	2.8	0.2877

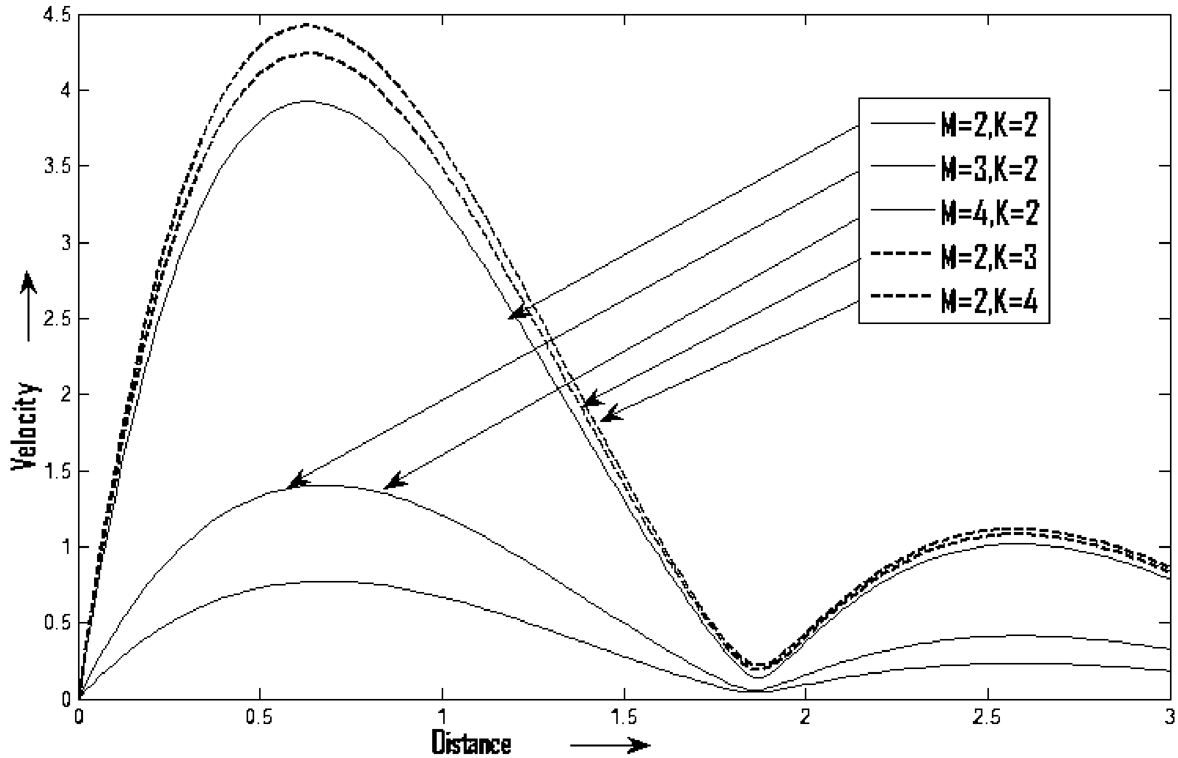

Fig-(1)-Effect of M and K on velocity profile, when Gr=2, Gm=2, Sc=0.22, Pr=0.71,Re=2,$\omega = 1, t = 2$ and S=2.

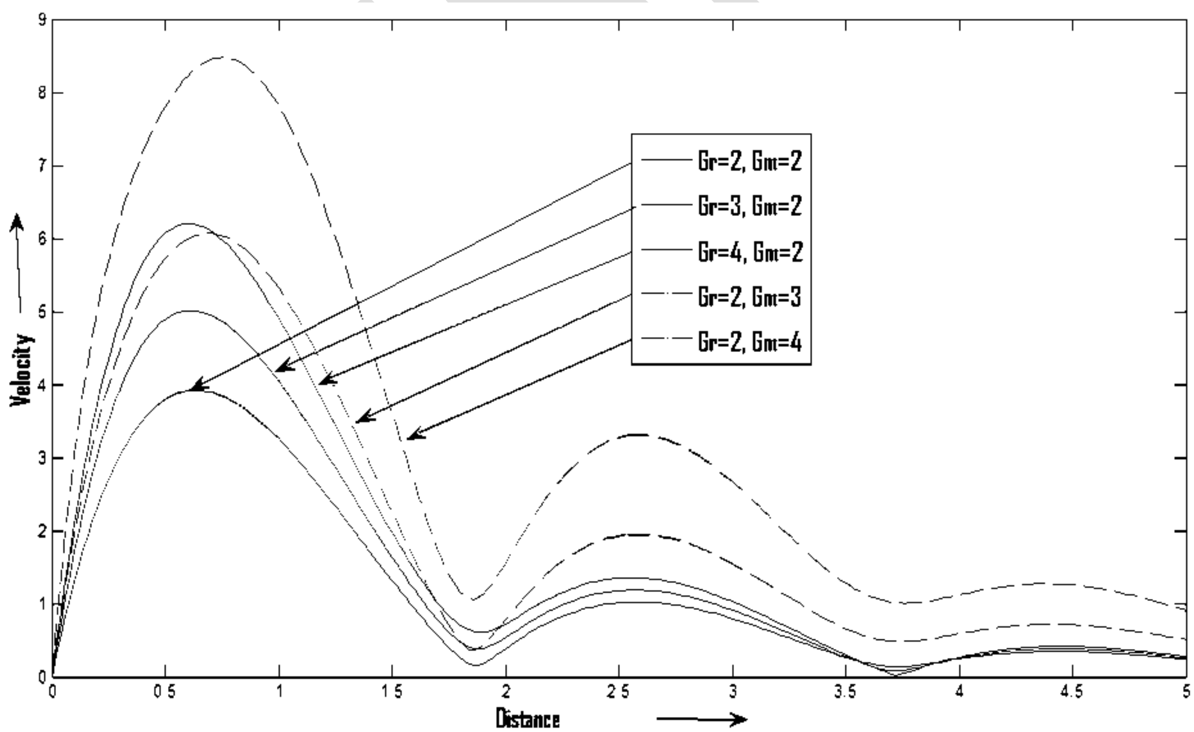

Fig-(2)-Effect of Gr and Gm on velocity profile, when M=2, K=2, Sc=0.22, Pr=0.71,Re=2,$\omega = 1, t = 2$ and S=2.

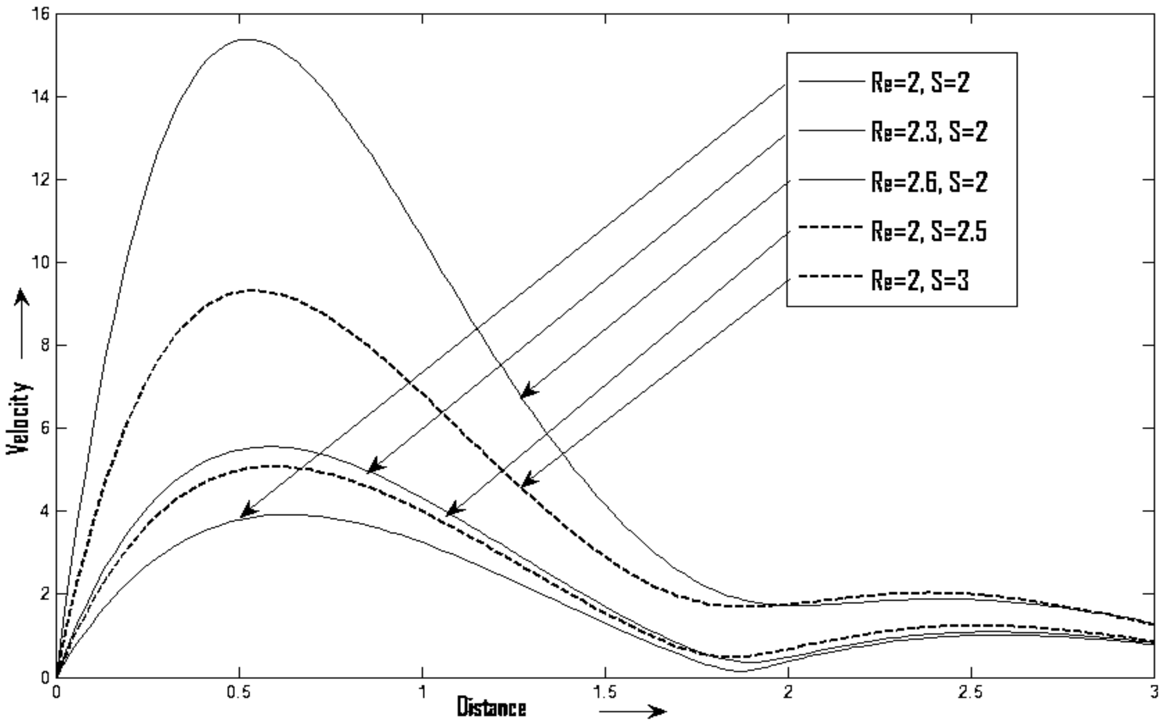

Fig-(3)-Effect of Re and S on velocity profile, when Gr=2, Gm=2, Sc=0.22, Pr=0.71,M=2,$\omega = 1, t = 2$ and K=2.

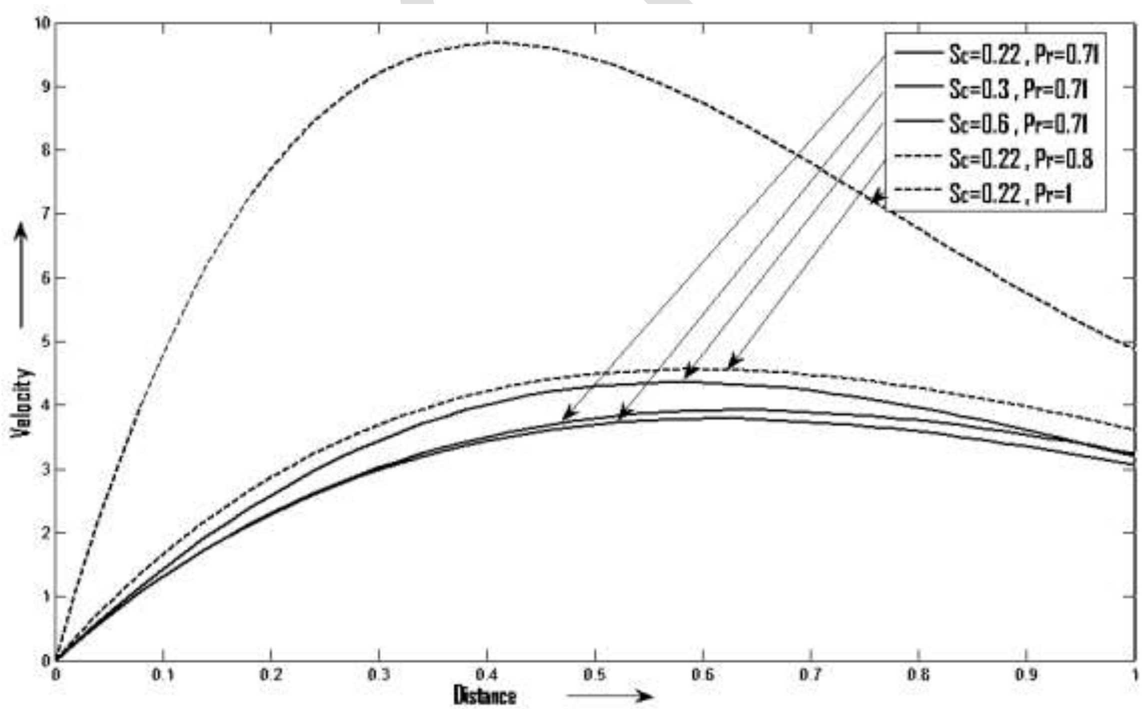

Fig-(4)-Effect of Sc and Pr on velocity profile, when Gr=2, Gm=2, M=2, K=2,Re=2,$\omega = 1, t = 2$ and S=2.

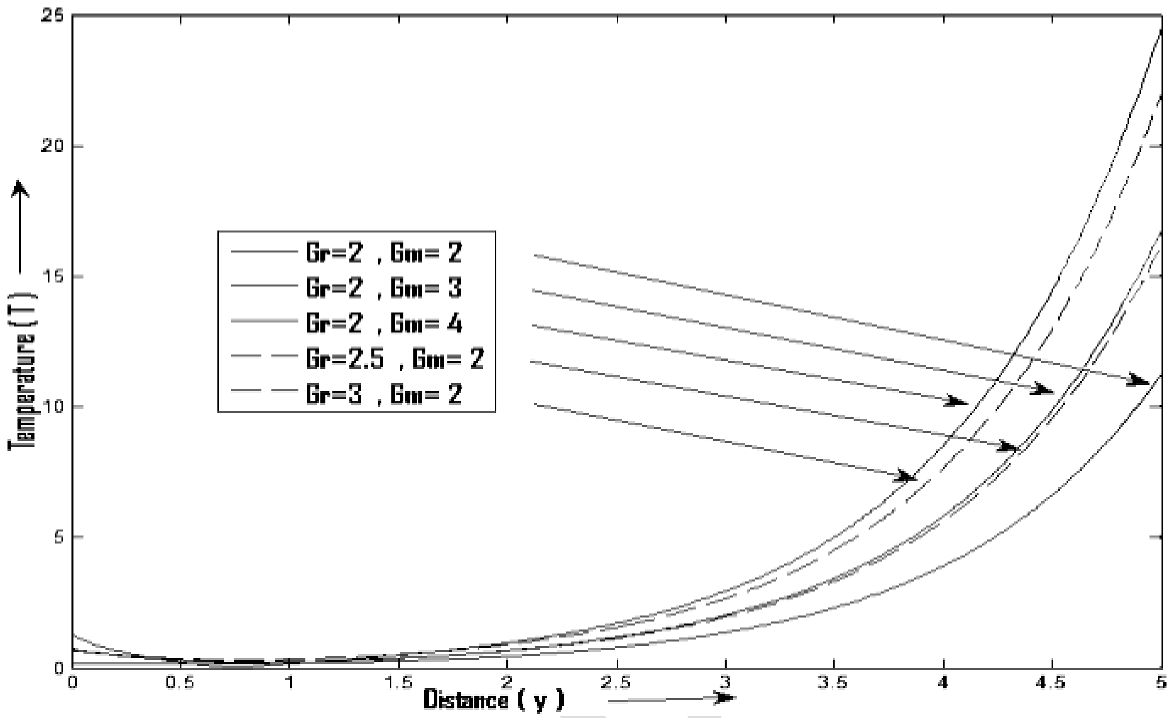

Fig-(5)-Effect of Gr and Gm on Temperature profile, when Sc=0.22, Pr=0.71, M=2, K=2,Re=2,$\omega = 1, t = 2$ and S=2.

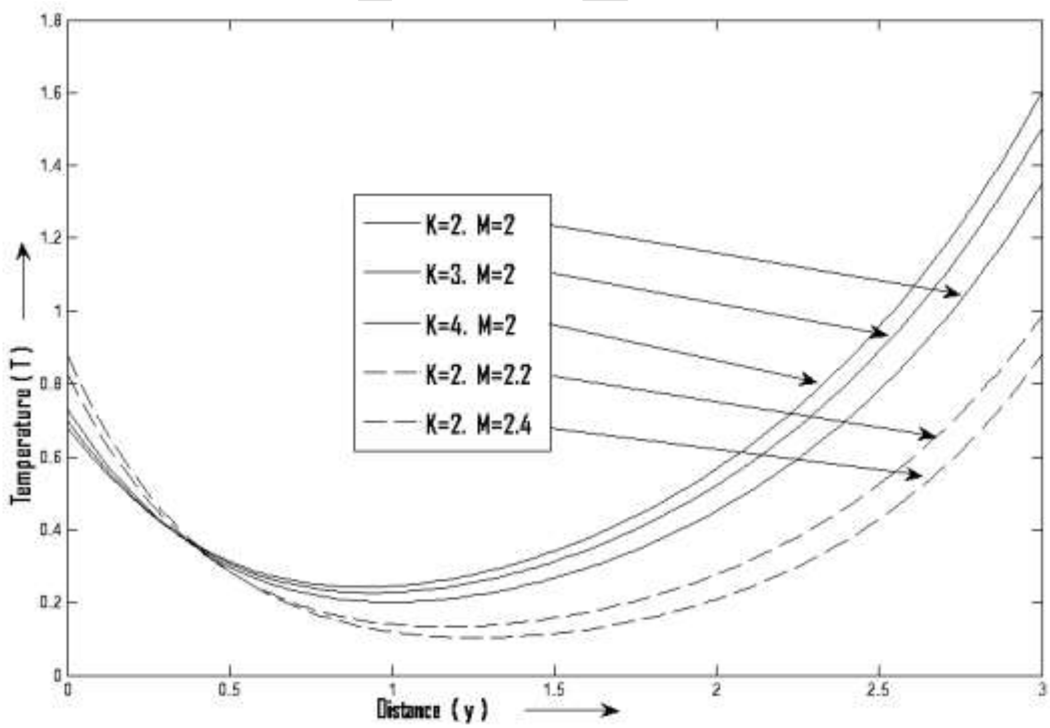

Fig-(6)-Effect of K and M on Temperature profile, when Sc=0.22, Pr=0.71, Gr=2, Gm=2,Re=2,$\omega = 1, t = 2$ and S=2.

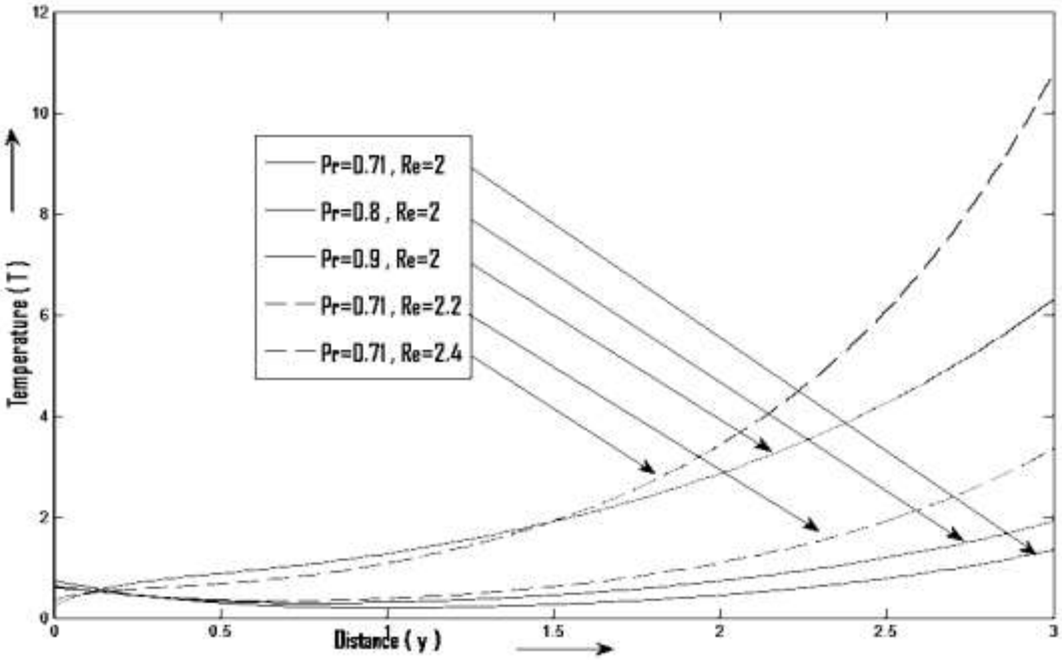

Fig-(7)-Effect of Pr and Re on Temperature profile, when Sc=0.22, Gm=2, M=2, K=2,Gr=2,$\omega = 1, t = 2$ and S=2.

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