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CHEMICAL REACTION AND SORET EFFECT ON HYDRO MAGNETIC OSCILLATORY FLOW THROUGH A POROUS MEDIUM BOUNDED BY TWO VERTICAL POROUS PLATES WITH HEAT SOURCE

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ABSTRACT

Hydro magnetic oscillatory flow through a porous medium bounded by vertical porous plates with heat source and soret effect in presence of chemical reaction has been studied. One plate of the channel is kept stationary and the other is oscillating with uniform velocity. The plates of the channel are subjected to constant injection and suction velocities respectively. Exact solutions of the governing equations are obtained for the velocity, temperature and concentration profiles. Effects of the various parameters entering into the problem on the velocity, temperature, skin friction and the rate of heat and mass transfer coefficient are numerically evaluated and discussed with the help of graphs.

Keywords: *Hydro magnetic, Oscillatory flow, porous medium, chemical reaction, Heat source, soret effect.*

INTRODUCTION

Magneto hydrodynamics free convection flows bounded by two vertical plates are studied because of their wide application and hence it has attracted the attention of many research scholars, investigators and scientists. MHD is applied to study the stellar and solar structure, interstellar matter, radio propagation through the ionosphere etc. The ionised gas or plasma can be made to interact with the magnetic field and can frequently alter heat transfer on the bounding surface. Heat transfer by thermal radiation is becoming of great importance when we are concerned with space applications, higher operating temperatures and also power engineering. In processes such as drying, evaporation at the surface of water body, energy transfer in a wet cooling tower and the flow in a desert, cooler, heat and mass transfer occurs simultaneously. The various applications of MHD flows in technological fields have been compiled by Moreau [4]. P. Mohapatra and N. Senapati [5] have been analyzed magneto hydrodynamic free convection flow with mass transfer past a vertical plate.

Oscillatory flows are known to result in higher rates of heat and mass transfer. Many studies have been done to understand its characteristics in different systems such as reciprocating engines, pulse combustors and chemical reactors etc. Stokes first found the exact solution of Navier-Stokes equation which is concerned with flow of viscous incompressible fluid past a horizontal plate oscillating in its own plane. Then Soundalgekar [2] has studied the effect of natural convection on stokes problem. The same problem was considered by Revankar [3] for an impulsive started or oscillating plate. Cooper *et al.* [6] have made a detailed study on fluid mechanics of oscillatory and modulated flows and associated applications in heat and mass transfer. Muthucumaraswamy [10] has studied the effect of heat and mass transfer on flow past an oscillatory vertical plate with variable temperature.

To study the underground water resources, seepage of water in river beds, filtration and water purification processes in chemical engineering, one need the knowledge of the fluid flow through porous medium. The porous medium is in fact a non homogeneous medium but for the sake of analysis, it may be possible to replace it with a homogeneous fluid which has dynamical properties equal to those of non homogeneous continuum. Model studies of the above phenomena of MHD convection have been made by many researchers. Ram and Mishra [1] studied MHD flow of conducting fluid through porous media. Ahmed *et al.* [7] discussed three dimensional free convective flow and heat transfer through a porous medium. Geindreau *et al.* [9] studied the effect of magnetic field in flow through porous medium.

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The soret effect or thermophoresis is a phenomenon observed in mixtures of mobile particles where the different particles exhibit different responses to the force of a temperature gradient. The term soret effect is most often applied to aerosol mixtures, but may also commonly refer to the phenomenon in all phases of matter. It has been used in commercial precipitators for applications similar to electro static precipitators, manufacturing of optical fibre in vapour deposition processes, facilitating drug discovery by allowing the detection of aptamer binding by comparison of the bound versus unbound motion of the target molecule. It is also used to separate different polymer particles in field flow fractionation. M. Anghel *et al.* [8] studied Dufour effect and Soret effect on free convection boundary layer over a vertical surface embedded in porous medium. N. Ahmed [12] studied MHD convection with soret and Dufour effect in a three dimensional flow past an infinite vertical porous plate. Recently Chand *et al.* [14] have studied hydro magnetic oscillatory flow through a porous medium bounded by two vertical porous plates with heat source and soret effect.

Combined heat and mass transfer problems with chemical reaction are of importance in many processes and have therefore received a considerable amount of attention in recent years. Possible applications of this type of flow can be found in many industries. The effect of chemical reaction depends whether the reaction is homogeneous or heterogeneous, the rate of reaction depends on the concentration of species itself. Muthucumaraswamy *et al.* [11] have studied the mass transfer effect on isothermal vertical oscillating plate in presence of chemical reaction. Senapati *et al.* [13] have studied magnetic effect on mass and heat transfer of hydrodynamic flow past a vertical oscillating plate in presence of chemical reaction.

The objective of this paper is to analyze hydro magnetic oscillatory flow through a porous medium bounded by vertical porous plates with heat source and soret effect in presence of chemical reaction.

FORMULATION OF PROBLEM

Consider the flow of an electrically conducting viscous incompressible fluid through saturated porous medium bounded by two insulated vertical porous plates distance‘d’ apart in the presence of the heat source. A coordinate system is chosen with origin at the stationary plate which is subjected to a constant injection velocity V_0 .The other plate is oscillating in its own plane with a velocity $U'(t')$ about a nonzero constant mean velocity U_0 and is subjected to same constant suction velocity V_0 . A homogeneous magnetic field of strength B_0 is applied normal to the plane of the plates. The plates of the channel are assumed infinite in extent. Hence all the physical properties of the fluid will be function of y' and t' except the pressure.

Under the usual Boussinesq approximations the flow is governed by the following equations

$$\frac{\partial u'}{\partial y'} = 0 \Rightarrow u' = V_0 \tag{1}$$

$$\frac{\partial u'}{\partial t'} + V_0\frac{\partial u'}{\partial y'} = -\frac{1}{\rho}\frac{\partial p'}{\partial x'} + \nu\frac{\partial^2 u'}{\partial y'^2} - \frac{\sigma {B_0}^2 u'}{\rho} - \frac{\nu u'}{K'} + g\beta(T' - T_d) + g\beta_c(C' - C_d) \tag{2}$$

$$\frac{\partial T'}{\partial t'} + V_0\frac{\partial T'}{\partial y'} = \frac{K}{\rho C_p}\frac{\partial^2 T'}{\partial y'^2} + \frac{Q'}{\rho C_p}(T' - T_d) \tag{3}$$

$$\frac{\partial C'}{\partial t'} + V_0\frac{\partial C'}{\partial y'} = D\frac{\partial^2 T'}{\partial y'^2} + D_1\frac{\partial^2 T'}{\partial y'^2} - R'(C' - C_d) \tag{4}$$

With the following boundary conditions

$$\left.\begin{array}{ll} u' = 0, T' = T_0 + \varepsilon(T_0 - T_d)cos\omega' t', C' = C_0 + \varepsilon(C_0 - C_d)cos\omega' t' & at\ y = 0 \\ u' = U'(t') = U_0(1 + cos\omega' t'),\ T' = T_d\ ,\ C' = C_d & at\ y = d \end{array}\right\} \tag{5}$$

Eliminating the modified pressure gradient under the usual boundary layer approximation equation (2) reduces to

$$\frac{\partial u'}{\partial t'} + V_0\frac{\partial u'}{\partial y'} = \frac{\partial U'}{\partial t'} + \nu\frac{\partial^2 u'}{\partial y'^2} - \frac{\sigma {B_0}^2(u' - U')}{\rho} - \frac{\nu(u' - U')}{K'} + g\beta(T' - T_d) + g\beta_c(C' - C_d) \tag{6}$$

On introducing the following non dimensional parameters

$$y = \frac{y'}{d}, t = \frac{t'V_0}{d}, u = \frac{u'}{U_0}, \theta = \frac{T' - T_d}{T_0 - T_d}, C = \frac{C' - C_d}{C_0 - C_d}\ , Pe = \frac{\rho C_p V_0 d}{k}$$
$$Sc = \frac{\nu}{D}, R = \frac{R'd}{V_0}, K = \frac{K'V_0}{\nu d}, M = B_0 d\sqrt{\frac{\sigma}{\mu}}, Re = \frac{V_0 d}{\nu}, S = \frac{Q'd}{\rho C_p V_0}, U = \frac{U'}{U_0}$$

$$\omega = \frac{\omega' d}{V_0}, Gr = \frac{\nu g\beta\,(T_0 - T_d)}{U_0 {V_0}^2}, Gm = \frac{\nu g\beta\,(C_0 - C_d)}{U_0 {V_0}^2}, So = \frac{D_1(T_0 - T_d)}{dV_0(C_0 - C_d)} \tag{7}$$

in equations (1), (3), (4) and (6), we get the following non dimensional governing equations:

$$\frac{\partial u}{\partial t} + \frac{\partial u}{\partial y} = \frac{\partial U}{\partial t} + \frac{1}{Re}\frac{\partial^2 u}{\partial y^2} - \left(\frac{M^2}{Re} + \frac{1}{K}\right)(u - U) + GrRe\theta + GmReC \tag{8}$$

$$\frac{\partial \theta}{\partial t} + \frac{\partial \theta}{\partial y} = \frac{1}{Pe}\frac{\partial^2 \theta}{\partial y^2} + S\theta \tag{9}$$

$$\frac{\partial C}{\partial t} + \frac{\partial C}{\partial y} = \frac{1}{ScRe}\frac{\partial^2 C}{\partial y^2} + So\frac{\partial^2 \theta}{\partial y^2} - RC \tag{10}$$

With the following boundary conditions

$$\left.\begin{array}{ll} u = 0, \theta = 1 + \frac{\varepsilon}{2}(e^{i\omega t} + e^{-i\omega t}),\ \ C = 1 + \frac{\varepsilon}{2}(e^{i\omega t} + e^{-i\omega t}) & at\ y = 0 \\ u = 1 + \frac{\varepsilon}{2}(e^{i\omega t} + e^{-i\omega t}), \theta = 0,\ \ C = 0 & at\ y = 1 \end{array}\right\} \tag{11}$$

To solve equation (8), (9) and (10) for purely oscillatory flow, we assume the solution of the form

$$\theta = \theta_0(y) + \frac{\varepsilon}{2}\theta_1(y)e^{i\omega t} + \frac{\varepsilon}{2}\theta_2(y)e^{-i\omega t}$$

$$C = C_0(y) + \frac{\varepsilon}{2}C_1(y)e^{i\omega t} + \frac{\varepsilon}{2}C_2(y)e^{-i\omega t}$$

$$u = u_0(y) + \frac{\varepsilon}{2}u_1(y)e^{i\omega t} + \frac{\varepsilon}{2}u_2(y)e^{-i\omega t} \tag{12}$$

Using equation (12) into (8) to (10) we get the following set of equations

$$\frac{\partial^2 \theta_0}{\partial y^2} - Pe\frac{\partial \theta_0}{\partial y} + SPe\theta_0 = 0 \tag{13}$$

$$\frac{\partial^2 \theta_1}{\partial y^2} - Pe\frac{\partial \theta_1}{\partial y} + (S - i\omega)Pe\theta_1 = 0 \tag{14}$$

$$\frac{\partial^2 \theta_2}{\partial y^2} - Pe\frac{\partial \theta_2}{\partial y} + (S + i\omega)Pe\theta_2 = 0 \tag{15}$$

$$\frac{\partial^2 C_0}{\partial y^2} - ScRe\frac{\partial C_0}{\partial y} - ScReRC_0 = -SoScRe\frac{\partial^2 \theta_0}{\partial y^2} \tag{16}$$

$$\frac{\partial^2 C_1}{\partial y^2} - ScRe\frac{\partial C_1}{\partial y} - ScRe(R + i\omega)C_1 = -SoScRe\frac{\partial^2 \theta_1}{\partial y^2} \tag{17}$$

$$\frac{\partial^2 C_2}{\partial y^2} - ScRe\frac{\partial C_2}{\partial y} - ScRe(R - i\omega)C_2 = -SoScRe\frac{\partial^2 \theta_2}{\partial y^2} \tag{18}$$

$$\frac{\partial^2 u_0}{\partial y^2} - Re\frac{\partial u_0}{\partial y} - \left(M^2 + \frac{Re}{K}\right)u_0 = -GrRe^2\theta_0 - GmRe^2C_0 - \left(M^2 + \frac{Re}{K}\right)U_0 \tag{19}$$

$$\frac{\partial^2 u_1}{\partial y^2} - Re\frac{\partial u_1}{\partial y} - \left(M^2 + \frac{Re}{K} + i\omega Re\right)u_1 = -GrRe^2\theta_1 - GmRe^2C_1 - \left(M^2 + \frac{Re}{K} + i\omega Re\right)U_0 \tag{20}$$

$$\frac{\partial^2 u_2}{\partial y^2} - Re\frac{\partial u_2}{\partial y} - \left(M^2 + \frac{Re}{K} - i\omega Re\right)u_2 = -GrRe^2\theta_2 - GmRe^2C_2 - \left(M^2 + \frac{Re}{K} - i\omega Re\right)U_0 \tag{21}$$

Solving the equations (13) to (21), we get

$$\theta = A_1e^{m_1y} + A_2e^{m_2y} + \frac{\varepsilon}{2}(A_3e^{m_3y} + A_4e^{m_4y})e^{i\omega t} + \frac{\varepsilon}{2}(A_5e^{m_5y} + A_6e^{m_6y})e^{-i\omega t} \tag{22}$$

$$\begin{aligned} C = {} & A_9e^{m_7y} + A_{10}e^{m_8y} + A_7e^{m_1y} + A_8e^{m_2y} \\ & + \frac{\varepsilon}{2}(A_{13}e^{m_9y} + A_{14}e^{m_{10}y} + A_{11}e^{m_3y} + A_{12}e^{m_4y})e^{i\omega t} \\ & + \frac{\varepsilon}{2}(A_{17}e^{m_{11}y} + A_{18}e^{m_{12}y} + A_{15}e^{m_5y} + A_{16}e^{m_6y})e^{-i\omega t} \end{aligned} \tag{23}$$

$$u = A_{27}e^{m_{13}y} + A_{28}e^{m_{14}y} + A_{19}e^{m_1 y} + A_{20}e^{m_2 y} + A_{21}e^{m_7 y} + A_{22}e^{m_8 y} + A_{23}e^{m_1 y} + A_{24}e^{m_2 y} + U_0 + \frac{\varepsilon}{2}(A_{37}e^{m_{15}y} + A_{38}e^{m_{16}y} + A_{29}e^{m_3 y} + A_{30}e^{m_4 y} + A_{31}e^{m_9 y} + A_{32}e^{m_{10}y} + A_{33}e^{m_3 y} + A_{34}e^{m_4 y} + U_0)e^{i\omega t} + \frac{\varepsilon}{2}(A_{47}e^{m_{17}y} + A_{48}e^{m_{18}y} + A_{39}e^{m_5 y} + A_{40}e^{m_6 y} + A_{41}e^{m_{11}y} + A_{42}e^{m_{12}y} + A_{43}e^{m_5 y} + A_{44}e^{m_6 y} + U_0)e^{-i\omega t} \quad (24)$$

The non dimensional skin friction at the moving plate of the channel is given by

$$\tau = -\mu\left(\frac{\partial u}{\partial y}\right)_{y=1}$$
$$= -(A_{27}m_{13}e^{m_{13}} + A_{28}m_{14}e^{m_{14}} + A_{19}m_1e^{m_1} + A_{20}m_2e^{m_2} + A_{21}m_7e^{m_7} + A_{22}m_8e^{m_8} + A_{23}m_1e^{m_1} + A_{24}m_2e^{m_2}) - \frac{\varepsilon}{2}\begin{pmatrix} A_{37}m_{15}e^{m_{15}} + A_{38}m_{16}e^{m_{16}} + A_{29}m_3e^{m_3} + A_{30}m_4e^{m_4}z \\ +A_{31}m_9e^{m_9} + A_{32}m_{10}e^{m_{10}} + A_{33}m_3e^{m_3} + A_{34}m_4e^{m_4} \end{pmatrix} e^{i\omega t}, - \frac{\varepsilon}{2}\begin{pmatrix} A_{47}m_{17}e^{m_{17}} + A_{48}m_{18}e^{m_{18}} + A_{39}m_5e^{m_5} + A_{40}m_6e^{m_6} \\ +A_{41}m_{11}e^{m_{11}} + A_{42}m_{12}e^{m_{12}} + A_{43}m_5e^{m_5} + A_{44}m_6e^{m_6} \end{pmatrix} e^{-i\omega t}, \quad (25)$$

The rate of heat transfer at the moving plate of the channel in terms of non dimensional Nusselt number is given by

$$Nu = -\left(\frac{\partial\theta}{\partial y}\right)_{y=1} = -(A_1m_1e^{m_1} + A_2m_2e^{m_2}) - \frac{\varepsilon}{2}(A_3m_3e^{m_3} + A_4m_4e^{m_4})e^{i\omega t} - \frac{\varepsilon}{2}(A_5m_5e^{m_5} + A_6m_6e^{m_6})e^{-i\omega t} \quad (26)$$

The rate of mass transfer coefficient at the moving plate of the channel in terms of non dimensional Sherwood number is given by

$$Sh = -\left(\frac{\partial C}{\partial y}\right)_{y=1} = -(A_9m_7e^{m_7} + A_{10}m_8e^{m_8} + A_7m_1e^{m_1} + A_8m_2e^{m_2}) - \frac{\varepsilon}{2}(A_{13}m_9e^{m_9} + A_{14}m_{10}e^{m_{10}} + A_{11}m_3e^{m_3} + A_{12}m_4e^{m_4})e^{i\omega t} - \frac{\varepsilon}{2}(A_{17}m_{11}e^{m_{11}} + A_{18}m_{12}e^{m_{12}} + A_{15}m_5e^{m_5} + A_{16}m_6e^{m_6})e^{-i\omega t}$$

Here $m_1 = \frac{Pe+\sqrt{Pe^2-4SPe}}{2}, m_2 = \frac{Pe-\sqrt{Pe^2-4SPe}}{2}, m_3 = \frac{Pe+\sqrt{Pe^2-4(S-i\omega)Pe}}{2}, m_4 = \frac{Pe-\sqrt{Pe^2-4(S-i\omega)Pe}}{2}$

$m_5 = \frac{Pe+\sqrt{Pe^2-4(S+i\omega)Pe}}{2}, m_6 = \frac{Pe-\sqrt{Pe^2-4(S-i\omega)Pe}}{2}, m_7 = \frac{ScRe+\sqrt{Sc^2Re^2+4ScReR}}{2}, m_8 = \frac{ScRe-\sqrt{Sc^2Re^2+4ScReR}}{2},$

$m_9 = \frac{ScRe+\sqrt{Sc^2Re^2+4ScRe\,(R+i\omega)}}{2}, m_{10} = \frac{ScRe-\sqrt{Sc^2Re^2+4ScRe\,(R+i\omega)}}{2},$

$m_{11} = \frac{ScRe+\sqrt{Sc^2Re^2+4ScRe\,(R-i\omega)}}{2}, m_{12} = \frac{ScRe-\sqrt{Sc^2Re^2+4ScRe\,(R-i\omega)}}{2}, m_{13} = \frac{Re+\sqrt{Re^2+4(M^2+\frac{Re}{K})}}{2},$

$m_{14} = \frac{Re-\sqrt{Re^2+4\left(M^2+\frac{Re}{K}\right)}}{2}, m_{15} = \frac{Re+\sqrt{Re^2+4\left(M^2+\frac{Re}{K}+i\omega Re\right)}}{2}, m_{16} = \frac{Re-\sqrt{Re^2+4\left(M^2+\frac{Re}{K}+i\omega Re\right)}}{2},$

$m_{17} = \frac{Re+\sqrt{Re^2+4(M^2+\frac{Re}{K}-i\omega Re)}}{2}, m_{18} = \frac{Re-\sqrt{Re^2+4(M^2+\frac{Re}{K}-i\omega Re)}}{2}$

$A_1 = \frac{-e^{m_2}}{e^{m_1}-e^{m_2}}, A_2 = \frac{e^{m_1}}{e^{m_1}-e^{m_2}}, A_3 = \frac{-e^{m_4}}{e^{m_3}-e^{m_4}}, A_4 = \frac{e^{m_3}}{e^{m_3}-e^{m_4}}, A_5 = \frac{-e^{m_6}}{e^{m_5}-e^{m_6}}, A_6 = \frac{e^{m_5}}{e^{m_3}-e^{m_4}}$

$A_7 = \frac{-S_oScRe\,A_1m_1^2}{m_1^2-ScRe\,m_1-ScReR}, A_8 = \frac{-S_oScRe\,A_2m_2^2}{m_2^2-ScRe\,m_2-ScReR}, A_9 = \frac{-e^{m_8}+A_7(e^{m_8}-e^{m_1})+A_8(e^{m_8}-e^{m_2})}{e^{m_7}-e^{m_8}}$

$A_{10} = \frac{e^{m_7}-A_7(e^{m_7}-e^{m_1})-A_8(e^{m_7}-e^{m_2})}{e^{m_7}-e^{m_8}}, A_{11} = \frac{-S_oScRe\,A_3m_3^2}{m_3^2-ScRe\,m_3-ScRe\,(R+i\omega)}, A_{12} = \frac{-S_oScRe\,A_4m_4^2}{m_4^2-ScRe\,m_4-ScRe\,(R+i\omega)}$

$A_{13} = \frac{-e^{m_{10}}+A_{11}(e^{m_{10}}-e^{m_3})+A_{12}(e^{m_{10}}-e^{m_4})}{e^{m_9}-e^{m_{10}}}, A_{14} = \frac{e^{m_{10}}-A_{11}(e^{m_9}-e^{m_3})-A_{12}(e^{m_9}-e^{m_4})}{e^{m_9}-e^{m_{10}}}$

$A_{15} = \frac{-S_oScRe\,A_5m_5^2}{m_5^2-ScRe\,m_5-ScRe\,(R-i\omega)}, A_{16} = \frac{-S_oScRe\,A_6m_6^2}{m_6^2-ScRe\,m_6-ScRe\,(R-i\omega)}, A_{17} = \frac{-e^{m_{12}}+A_{14}(e^{m_{12}}-e^{m_5})+A_{15}(e^{m_{12}}-e^{m_6})}{e^{m_{11}}-e^{m_{12}}},$

$$A_{18} = \frac{e^{m_{11}} - A_{14}(e^{m_{11}} - e^{m_5}) - A_{15}(e^{m_{11}} - e^{m_6})}{e^{m_{11}} - e^{m_{12}}}$$

$$A_{19} = \frac{-Gr\,Re^2 A_1}{m_1^2 - Re\,m_1 - \left(M^2 + \frac{Re}{K}\right)}, A_{20} = \frac{-Gr\,Re^2 A_2}{m_2^2 - Re\,m_2 - \left(M^2 + \frac{Re}{K}\right)}, A_{21} = \frac{-Gm\,Re^2 A_9}{m_7^2 - Re\,m_7 - \left(M^2 + \frac{Re}{K}\right)},$$

$$A_{22} = \frac{-Gm\,Re^2 A_{10}}{m_8^2 - Re\,m_8 - \left(M^2 + \frac{Re}{K}\right)}, A_{23} = \frac{-Gm\,Re^2 A_7}{m_1^2 - Re\,m_1 - \left(M^2 + \frac{Re}{K}\right)}, A_{24} = \frac{-Gm\,Re^2 A_8}{m_2^2 - Re\,m_2 - \left(M^2 + \frac{Re}{K}\right)},$$

$$A_{25} = A_{19} + A_{20} + A_{21} + A_{22} + A_{23} + A_{24} + U_0,$$

$$A_{26} = A_{19}e^{m_1} + A_{20}e^{m_2} + A_{21}e^{m_7} + A_{22}e^{m_8} + A_{23}e^{m_1} + A_{24}e^{m_2} + U_0,$$

$$A_{27} = \frac{-1 + A_{26} - A_{25}e^{m_{14}}}{e^{m_{14}} - e^{m_{13}}}, A_{28} = \frac{1 - A_{26} + A_{25}e^{m_{13}}}{e^{m_{14}} - e^{m_{13}}}, A_{29} = \frac{-Gr\,Re^2 A_3}{m_3^2 - Re\,m_3 - \left(M^2 + \frac{Re}{K} + i\omega Re\right)},$$

$$A_{30} = \frac{-Gr\,Re^2 A_4}{m_4^2 - Re\,m_4 - \left(M^2 + \frac{Re}{K} + i\omega Re\right)}, A_{31} = \frac{-Gm\,Re^2 A_{13}}{m_9^2 - Re\,m_9 - \left(M^2 + \frac{Re}{K} + i\omega Re\right)}, A_{32} = \frac{-Gm\,Re^2 A_{14}}{m_{10}^2 - Re\,m_{10} - \left(M^2 + \frac{Re}{K} + i\omega Re\right)}$$

$$A_{33} = \frac{-Gm\,Re^2 A_{11}}{m_3^2 - Re\,m_3 - \left(M^2 + \frac{Re}{K} + i\omega Re\right)}, A_{34} = \frac{-Gm\,Re^2 A_{12}}{m_4^2 - Re\,m_4 - \left(M^2 + \frac{Re}{K} + i\omega Re\right)},$$

$$A_{35} = A_{29} + A_{30} + A_{31} + A_{32} + A_{33} + A_{34} + U_0,$$

$$A_{36} = A_{29}e^{m_3} + A_{30}e^{m_4} + A_{31}e^{m_9} + A_{32}e^{m_{10}} + A_{33}e^{m_3} + A_{34}e^{m_4} + U_0$$

$$A_{37} = \frac{-1 + A_{36} - A_{35}e^{m_{16}}}{e^{m_{16}} - e^{m_{15}}}, A_{38} = \frac{1 - A_{36} + A_{35}e^{m_{15}}}{e^{m_{16}} - e^{m_{15}}}, A_{39} = \frac{-Gr\,Re^2 A_5}{m_5^2 - Re\,m_5 - \left(M^2 + \frac{Re}{K} - i\omega Re\right)},$$

$$A_{40} = \frac{-Gr\,Re^2 A_6}{m_6^2 - Re\,m_6 - \left(M^2 + \frac{Re}{K} - i\omega Re\right)}, A_{41} = \frac{-Gm\,Re^2 A_{17}}{m_{11}^2 - Re\,m_{11} - \left(M^2 + \frac{Re}{K} - i\omega Re\right)}, A_{42} = \frac{-Gm\,Re^2 A_{18}}{m_{12}^2 - Re\,m_{12} - \left(M^2 + \frac{Re}{K} - i\omega Re\right)},$$

$$A_{43} = \frac{-Gm\,Re^2 A_{15}}{m_5^2 - Re\,m_5 - \left(M^2 + \frac{Re}{K} - i\omega Re\right)}, A_{44} = \frac{-Gm\,Re^2 A_{16}}{m_6^2 - Re\,m_6 - \left(M^2 + \frac{Re}{K} - i\omega Re\right)},$$

$$A_{45} = A_{39} + A_{40} + A_{41} + A_{42} + A_{43} + A_{44} + U_0,$$

$$A_{46} = A_{39}e^{m_5} + A_{40}e^{m_6} + A_{41}e^{m_{11}} + A_{42}e^{m_{12}} + A_{43}e^{m_5} + A_{44}e^{m_6} + U_0,$$

$$A_{47} = \frac{-1 + A_{46} - A_{45}e^{m_{18}}}{e^{m_{18}} - e^{m_{17}}}, A_{48} = \frac{1 - A_{46} + A_{45}e^{m_{17}}}{e^{m_{18}} - e^{m_{17}}}$$

RESULTS AND DISCUSSION

Physical significances of various parameters have been shown through graphs.

Figure.1: It is observed that velocity increases with increase in Reynolds number Re, Lorentz force parameter i.e. Hartmann number M, heat source parameter S, Grashoff number Gr and Modified Grashoff number Gm. It is also clear from this figure that for behaviour species i.e. with increase in Schmidt number, the velocity decreases.

Figure.2: It is evident that the velocity increases with increase in frequency of oscillation ω, parameter Uo and peclet number Pe. Moreover it is observed that velocity shows opposite effects that of the parameters permeability K, soret muber So and Chemical reaction R.

Figure.3: Here it is noticed that temperature rises for the increase of the parameters S and Pe.

Figure.4: This shows the variations in concentration profiles with y for various parameters involved. It is noticed that increase in frequency of oscillation ω , concentration increases. On the other hand Re, Pe, S, Sc, R and So adversely affect the concentration profiles.

Figure.5: It is observed that there is a periodic variation in skin friction profiles with time. Further it is seen that with the increase of Schmidt number Sc and Reynolds number Re, skin friction increases. Again the parameters Gr, Gm, M and S show reverse effect.

Figure.6: This figure also shows the periodic variation of skin friction profiles. Moreover it is observed that with the increase in Uo, R, So and K, skin friction increases.

Figure.7: This figure shows the variation of Sherwood number profiles with various parameters. These profiles are periodic in nature. With decrease in R and So Sherwood number increases. Further increase in the value of Re, Pe, Sc and S lead to decreased value in Sherwood number.

Figure.8: Variations of Nusselt number Nu are illustrated in this figure. It is noticed that increase in Pe, S and ω result an increase in the Nusselt number.

CONCLUSION

Results are presented graphically to illustrate the variation of velocity, temperature, concentration, Shearing stress and Nusselt number with parameters. In this study, the following conclusions are set out

- Velocity increases for the increase of Re, M, S, Gr, Gm, Uo, Pe and decreases when R, K, So, Sc increases.
- Temperature rises when S and Pe increase.
- The parameters R, Re, S, Sc, Pe and So adversely affect the concentration profiles.
- Skin friction increases when Sc, Re, Uo, R, So and K increase and decreases for the increase of Gr, Gm, M, S.
- Sherwood number increases with decrease in R, Re, Pe, So, Sc and S.
- Increase in Pe and S result an increase in the Nusselt number.

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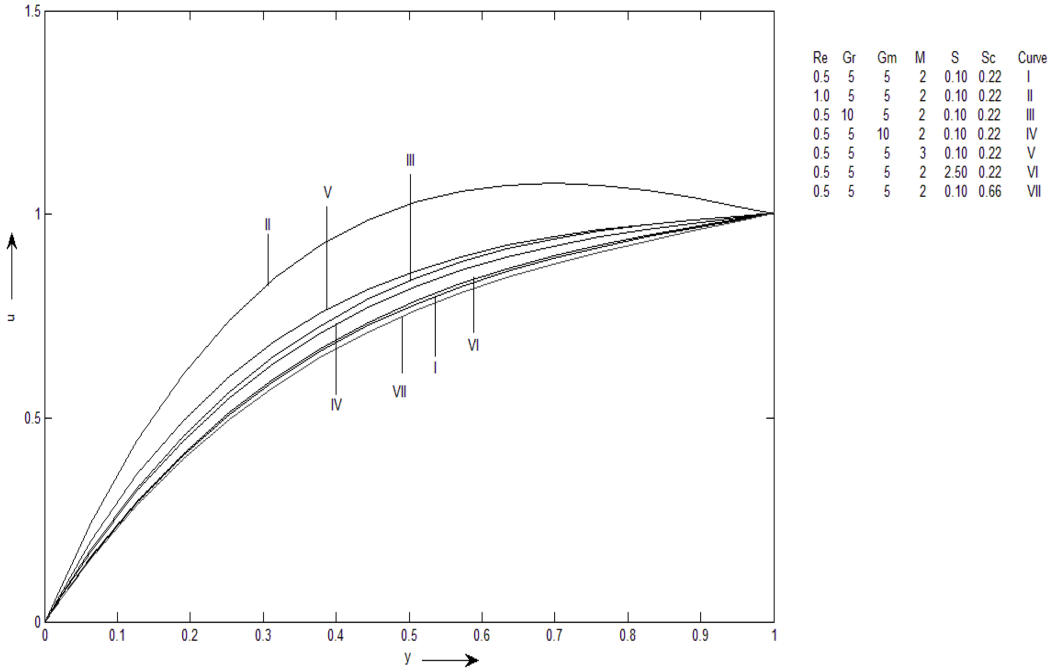


Fig.1:Velocity profile for So=6.89, K=0.5, Pe=1, w=5, Uo=1, R=5

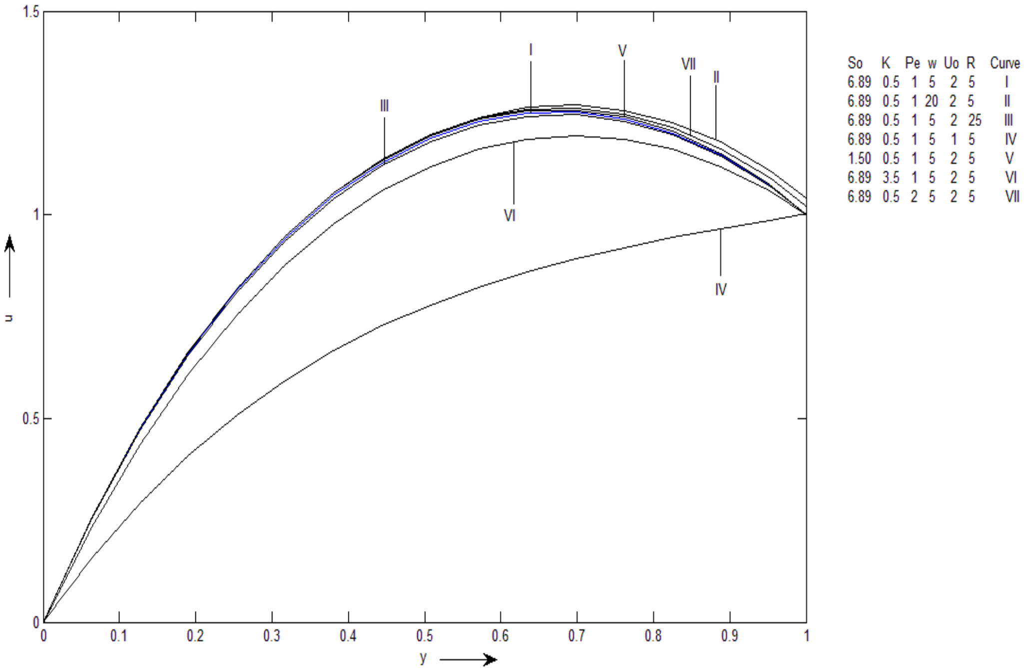


Fig.2:Velocity profiles for Gr =5,Gm=5, M=2, S=0.10, Sc=0.22, Re=0.5, t=0

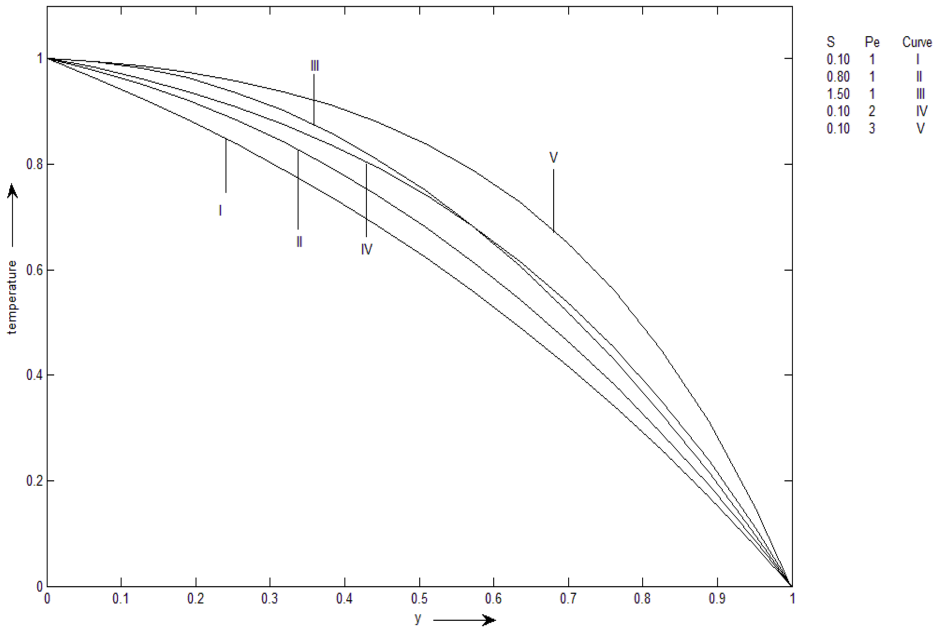


Fig 3. The temperature profiles

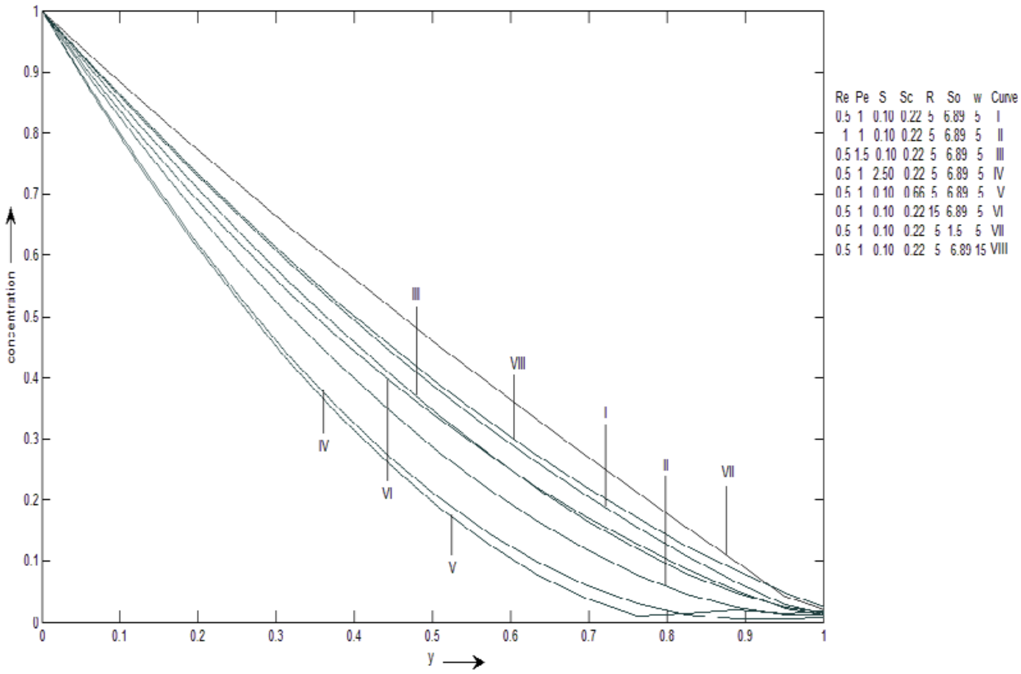
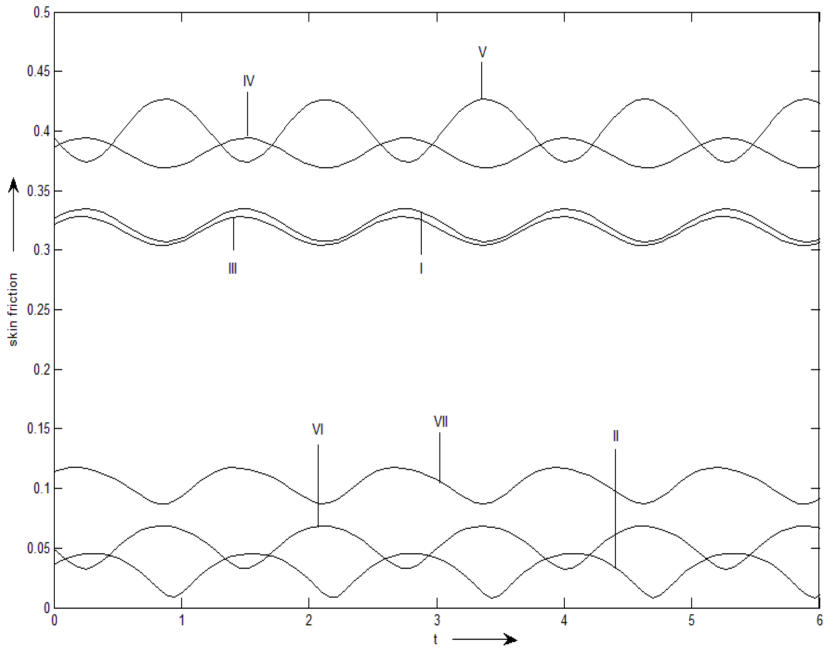
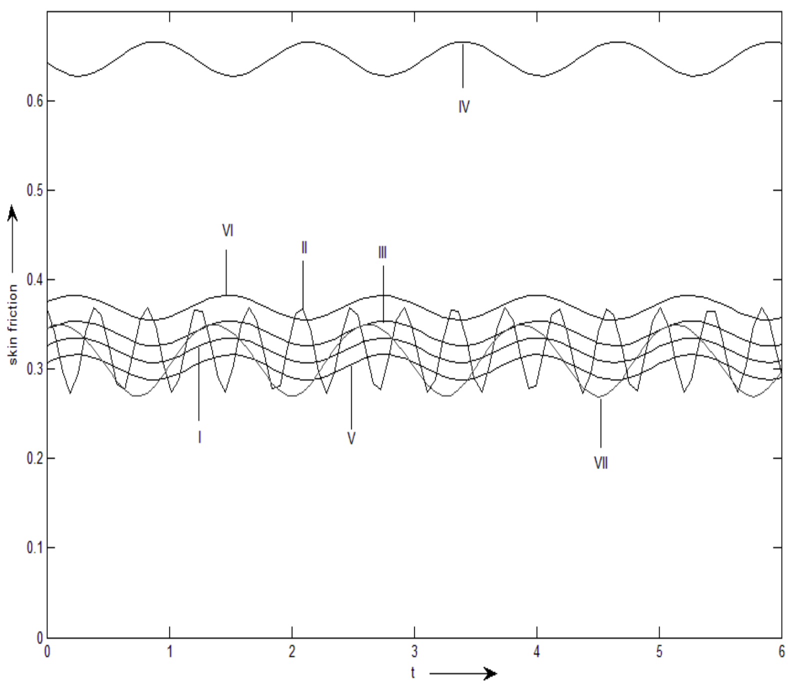


Fig 4: The Concentration profiles



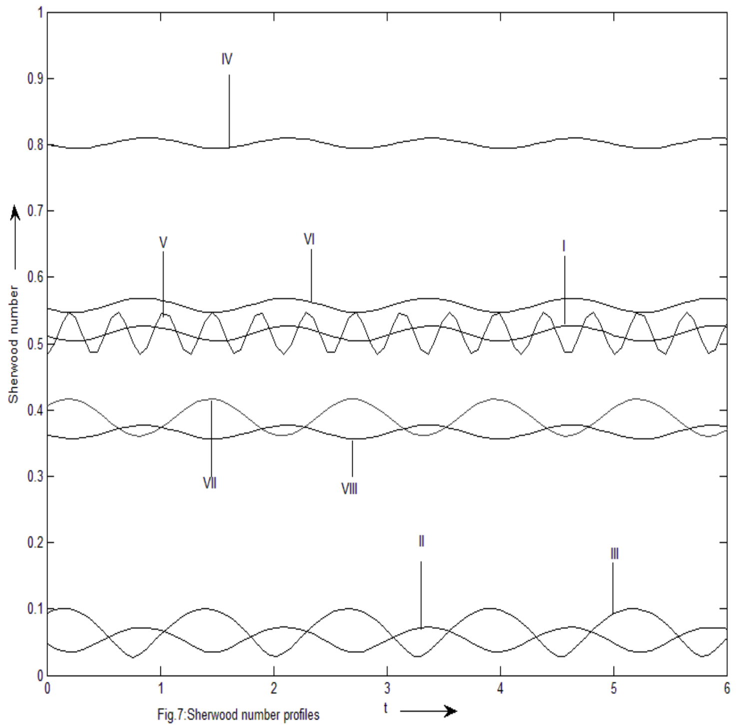
Re	Gr	Gm	M	S	Sc	Curve
0.5	5	5	2	0.10	0.22	I
0.5	5	5	4	0.10	0.22	II
0.5	5	5	2	0.80	0.22	III
0.5	5	5	2	0.10	0.66	IV
1.0	5	5	2	0.10	0.22	V
0.5	15	5	2	0.10	0.22	VI
0.5	5	15	2	0.10	0.22	VII

Fig.5:The skin friction profile



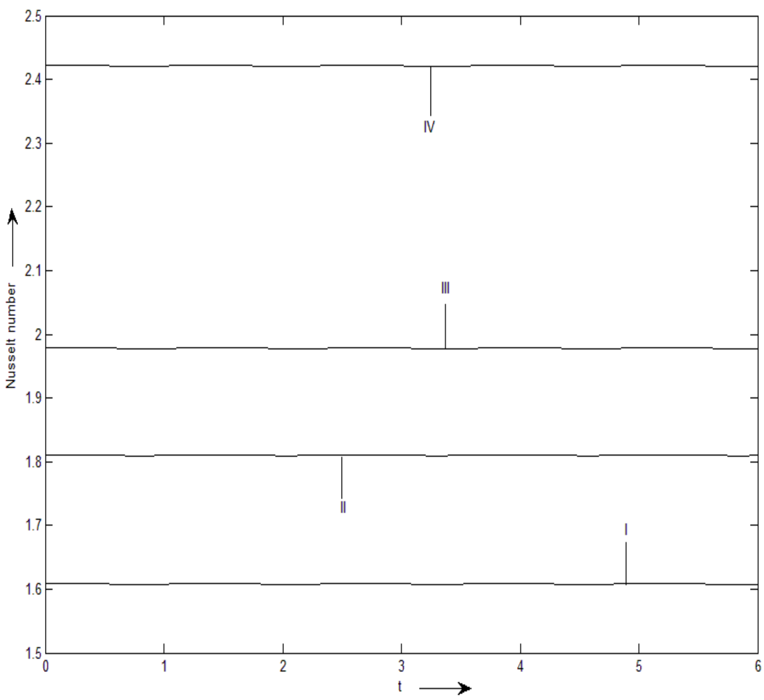
w	R	Uo	So	K	Pe	Curve
5	5	1	6.89	0.5	1	I
15	5	1	6.89	0.5	1	II
5	20	1	6.89	0.5	1	III
5	5	1.5	6.89	0.5	1	IV
5	5	1	2.50	0.5	1	V
5	5	1	6.89	2.5	1	VI
5	5	1	6.89	0.5	2	VII

Fig.6:The Skin friction profiles



Re	Pe	So	w	R	Sc	S	Curve
0.5	1	6.89	5	5	0.22	0.10	I
1	1	6.89	5	5	0.22	0.10	II
0.5	2	6.89	5	5	0.22	0.10	III
0.5	1	2.50	5	5	0.22	0.10	IV
0.5	1	6.89	15	5	0.22	0.10	V
0.5	1	6.89	5	2	0.22	0.10	VI
0.5	1	6.89	5	5	0.66	0.10	VII
0.5	1	6.89	5	5	0.22	0.80	VIII

Fig.7:Sherwood number profiles



S	w	Pe	Curve
0.10	5	1	I
0.80	5	1	II
0.10	5	1.5	III
0.10	15	1	IV

Fig.8: Nusselt number profiles

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