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ORIGINAL RESEARCH PAPER

Mathematics

EFFECT OF CHEMICAL REACTION ON MHD FREE CONVECTIVE OSCILLATORY FLOW PAST A POROUS PLATE

KEY WORDS: Free convective , osicillatory flow, MHD, chemical reaction etc.

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ABSTRACT

An attempt has been made to study the two dimensional MHD free convective oscillatory flow of an electically conducting incompressible viscous fluid past an infinite vertical porous plate, through which suction occurs with costant velocity and soret effect in a presence of heat sink. A uniform magnetic field is assumed to be applied transversely to the directon of free line stream taking into an account of induced magnetic field. The governing equations involved in the present analysis are solved by using the perturbation technique. The velocity, temperature and concentration fields are studied for different parameters such as Grashof number, modified Grashof number. Magnetic field parameter, schimdt number prandtl number, soret number etc.

Introduction

The heat and mass transfer from different geomeries embedded in porous media has many engineering and geophysical applications suah as drying of porous solids , thermal insulations, cooling of nuclear reactors, crude oil extraction, undergroud energy transport, etc. The effect of radiation on MHD flow and heat transfer problem have become more important industrially. At high operating temperature, radiation effect can be quite significant. Many processes in engineering areas occur at high temperature and a knowledge of radiation heat transfer becomes very important for the design of the pertinent equipment. Nuclear power plants, gas turbines and the various propulsion devices for aircraft, missiles, satellites and space vehicles are examples of such engineering areas. Bestman [1] examined the natural convection boundary layer with suction and mass transfer in a porous medium. His results confirmed the hypothesis that suction stabilises the boundary layer and affords the most efficient method in boundary layer control yet known. AbdusSattar and Hamid Kalim [2] investigated the unsteady free convection interaction with thermal radiation in a boundary layer flow past a vertical porous plate.

In recent years, the problems of free convective heat and mass transfer flows through a porous medium under the influence of magnetic field have been attracted the attention of a number of researchers because of their possible applications in many branches of science and technology, such as transportation cooling of re-entry vehicles and rocker boosters, cross-hatching on ablative surfaces and film vaporization in combustion chambers. Magnetohydrodynamics is currently undergoing a period of great enlargement and differentiation of subject matter. In light of these applications, steady MHD free convective flow past a heated vertical flat plate has been studied by many researchers such as Gupta [3], Lykoudis [4] and Nanda and Mohanty [5]. Chaudhary and Sharma [6] considered combined heat and mass transfer by laminar mixed convection flow from a vertical surface with induced magnetic field.

The effects of chemical reaction and radiation absorption on free convective flow through a porous medium with a variable suction in the presence of uniform magnetic field were studied bySudheer Babu and Satyanarayana [7]. Ahmed and Alam Sarker [8] presented the problem of a steady two - dimensional natural convective flow of a viscous incompressible and electrically conducting fluid past a vertical impermeable flat plate in the presence of a uniform transverse magnetic field. Saravana et al. [9] studied the effects of mass transfer on the MHD viscous flow past an impulsively started infinite vertical plate with constant mass flux.

Mathematical Analysis:

We consider the unsteady two dimensional MHD free convective oscillatory flow of an electrically conducting incompressible viscous fluid past an infinite vertical porous plate,through which suction occurs with constant velocity and chemical reaction in the presence of heat sink.The x'-axis is the along the plate in the upward direction and y'-axis is normal to it.A uniform magnetic field is applied in the direction perpendicular to the plate.Reynolds number is much less than unity and the induced magnetic field is negligible in comparision with the applied magnetic field.It is also assumed that all the fluid properties are constant except that of the influence of the density variation with the temperature and concentration in the body force term(Boussinesq's approximation).Also,there is a chemical reaction between the diffusing species and the fluid.The forien mass present in the flow is assumed to be a low level and hence Soret and Dufour effects are negligible.Under these assumptions,the governing equations of the flow field are:

Continuity equation

$$\frac{dv'}{dy'} = 0 \quad (1)$$

Momentum equation

$$\rho\left(\frac{\partial u'}{\partial t'} + v'\frac{\partial u'}{\partial y'}\right) = -\frac{\partial \rho'}{\partial x'} - \rho g_{x'} + v\rho\frac{\partial^2 u'}{\partial y'^2} - (\sigma B_o^2)(u') \quad (2)$$

Energy equation

$$\frac{\partial T'}{\partial t'} + v'\frac{\partial T'}{\partial y'} = \frac{k}{\rho c_p}\frac{\partial^2 T'}{\partial y'^2} + \frac{v}{c_p}\left(\frac{\partial u'}{\partial y'}\right)^2 \quad (3)$$

Diffusion equation

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

Where u' and v' are the components of the velocity parallel and perpendicular to the plate, t'-the time,p'-the pressure,ρ-the fluid density,g_x'-the acceleration due to gravity,T' –the fluid temperature,v-the kinematic viscosity,c_p-the specific heat at constant pressure,k-thermal conductivity ,C'-the concentration and D-the chemical diffusivity.

The boundary conditions are:

$$\left.\begin{aligned} & u' = 0, v' = -v_o, \frac{\partial T'}{\partial y'} = -\frac{q'}{k}, C' = C_w' \; at \; y' = 0 \\ & u' \to U' = U_o\left(1 + \varepsilon e^{iw't'}\right), T' \to T_\infty', C' \to C_\infty' as \; y' \to \infty \end{aligned}\right\} \quad (5)$$

Where v_o is the constant suction velocity and the negative indicates that it is towards the plate ,q'-the constant heat flux.C_w'-the species concentration at the plate,C_∞'-the species concentration far away from the plate,U_o-the mean free stream velocity,w'-the frequency of vibration of the fluid ,and $\varepsilon(\varepsilon < 1)$-a constant quantity.

For the free stream ,equation(2) becomes:

$$\rho\frac{dU'}{dt'} = -\frac{\partial p'}{\partial x'} - \rho_\infty g_x' - \sigma B_o^2 U' \quad (6)$$

On eliminating $\frac{\partial p'}{\partial x'}$ between (2) and (6) we get:

$$\rho\left(\frac{\partial u'}{\partial t'} + v'\frac{\partial u'}{\partial x'}\right) = \rho\frac{dU'}{dt'} + g_x'(\rho_\infty - \rho) + vp\frac{\partial^2 u'}{\partial y'^2} - (\sigma B_o^2)\big(u' - U'(t')\big) \quad (7)$$

The state equation is

$$g_x'(\rho_\infty - \rho) = g_x'\rho\beta(T' - T_\infty') + g_x'\rho\beta^*(C' - C_\infty') \quad (8)$$

Where β is the coefficient of thermal expansion and β^* is the coefficient of concentration expansion

Equation (1) gives:

$$v' = v_o(v_o > 0) \quad (9)$$

On substituting equation (8),(9) in equations (3),(4) and (7) we take:

$$\frac{\partial u'}{\partial t'} - v_o\frac{\partial u'}{\partial y'} = \frac{dU'}{dt'} + g_x'\beta^*(C' - C_\infty') + g_x'\beta(T' - T_\infty') + v\frac{\partial^2 u'}{\partial y'^2} - \left(\frac{\sigma B_o^2}{\rho}\right)(u' - U'(t'))$$

$$\frac{\partial T'}{\partial t'} - v_o\frac{\partial T'}{\partial y'} = \frac{k}{pc_p}\frac{\partial^2 T'}{\partial y'^2} + \frac{v}{c_p}\left(\frac{\partial u'}{\partial y'}\right)^2 \quad (11)$$

$$\frac{\partial C'}{\partial t'} - v_o\frac{\partial C'}{\partial y'} = D\frac{\partial^2 C'}{\partial y'^2} - K_r'(C' - C_\infty') \quad (12)$$

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Using the transformations:

$y = \frac{y' v_o}{v}, t = \frac{t' v_o^2}{4v}, T = \frac{T' - T'_\infty}{\frac{vq'}{kv_o}}, C = \frac{C' - C'_\infty}{C'_w - C'_\infty}, u = \frac{U'}{U_o}, \omega = \frac{4v\omega'}{v_o^2}, Gr = \frac{g'_x \beta v^2 q'}{kU_o v_o^3}$(Grashof number), $Gc = \frac{vg\beta^*(C'_w - C'_\infty)}{U_o v_o^2}$(modified grashof number), $Pr = \frac{\rho v c_p}{k}$(prandtl number), $Ec = \frac{kU_o^2 v_o}{c_p v q'}$(Eckert number), $M = \frac{v^2 Q'}{\rho v_o^2}$(Magnetic parameter), $Sc = \frac{v}{D}$(Schmidt number), $Q = \frac{v^2 Q'}{k v_o^2}$(Heat generation /absorption), $Kr = \frac{Kr' v}{v_o^2}$(Chemical reaction parameter) (13)

With the help of the non-dimensional quantities (13),equation (10)-(12) reduce to:

$$\frac{1}{4}\frac{\partial u}{\partial t} - \frac{\partial u}{\partial y} = \frac{1}{4}\frac{\partial U}{\partial t} + GrT + GcC + \frac{\partial^2 u}{\partial y^2} - M(u - U) \quad (14)$$

$$Pr\left(\frac{1}{4}\frac{\partial T}{\partial t} - \frac{\partial T}{\partial y}\right) = \frac{\partial^2 T}{\partial y^2} + PrEc\left(\frac{\partial u}{\partial y}\right)^2 \quad (15)$$

$$Sc\left(\frac{1}{4}\frac{\partial C}{\partial t} - \frac{\partial C}{\partial y}\right) = \frac{\partial^2 C}{\partial y^2} - KrScC \quad (16)$$

With the boundary conditions:

$$\left.\begin{aligned} &u = 0, \frac{\partial T}{\partial y} = 1, C = 1 \ at \ y = 0 \\ &u \to U(t) = 1 + \varepsilon e^{i\omega t}, T \to 0, C \to 0 \ as \ y \to \infty \end{aligned}\right\} \quad (17)$$

In order to solve the system of differential equations (14)-(16) we assume that:

$$u(y,t) = u_o(y) + \varepsilon e^{i\omega t} u_1(y) + \cdots \quad (18)$$

$$T(y,t) = T_o(y) + \varepsilon e^{i\omega t} T_1(y) + \cdots \quad (19)$$

$$C(y,t) = C_o(y) + \varepsilon e^{i\omega t} C_1(y) + \cdots \quad (20)$$

On substituting equations (18)-(20) in equation (14)-(16) we get the following system of differential equations:

$$\frac{d^2 u_0}{dy^2} + \frac{du_0}{dy} - Mu_0 = -[GrT_0 + GcC_0 + M] \quad (21)$$

$$\frac{d^2 u_1}{dy^2} + \frac{du_1}{dy} - \left(\frac{i\omega}{4} - M\right)u_1 = -\left[GrT_1 + GcC_1 + \left(\frac{i\omega}{4} + M\right)\right] \quad (22)$$

$$\frac{d^2 T_0}{dy^2} + Pr\frac{dT_0}{dy} = -PrEc\left(\frac{du_0}{dy}\right)^2 \quad (23)$$

$$\frac{d^2 T_1}{dy^2} + Pr\frac{dT_1}{dy} - \frac{i\omega}{4}PrT_1 = -2PrEc\left(\frac{du_0}{dy}\right)\left(\frac{du_1}{dy}\right) \quad (24)$$

$$\frac{d^2 C_0}{dy^2} + Sc\frac{dC_0}{dy} - KrScC_0 = 0 \quad (25)$$

$$\frac{d^2 C_1}{dy^2} + Sc\frac{dC_1}{dy} - Sc\left[\frac{i\omega}{4} - Kr\right]C_1 = 0 \quad (26)$$

The corresponding boundary conditions (17) are:

$$\left.\begin{aligned} &u_o = 0, u_1 = 0, \frac{dT_o}{dy} = 1, \frac{dT_1}{dy} = 0, C_o = 1, C_1 = 0 \ \ at \ y = 0 \\ &u_o \to 1, u_1 \to 1, T_o \to 0, T_1 \to 0, C_o \to 1, C_1 \to 0 \ \ at \ y \to \infty \end{aligned}\right\} \quad (27)$$

In order to solve the system of the differential equations (21)-(26) we put:

$$\left.\begin{aligned} &u_0(y) = u_{01}(y) + Ecu_{02}(y) \\ &T_0(y) = T_{01}(y) + EcT_{02}(y) \\ &C_0(y) = C_{01}(y) + EcC_{02}(y) \end{aligned}\right\} \quad (28)$$

$$\left.\begin{aligned} &u_1(y) = u_{11}(y) + Ecu_{12}(y) \\ &T_1(y) = T_{11}(y) + EcT_{12}(y) \\ &C_1(y) = C_{11}(y) + EcC_{12}(y) \end{aligned}\right\} \quad (29)$$

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In this system,equating the coefficients of Ec^o and Ec^1 we get:

$$\frac{d^2u_{01}}{dy^2}+\frac{du_{o1}}{dy}-Mu_{01}=-[GrT_{01}+GcC_{01}+M] \qquad (30)$$

$$\frac{d^2u_{02}}{dy^2}+\frac{du_{02}}{dy}-Mu_{02}=-[GrT_{02}+GcC_{02}] \qquad (31)$$

$$\frac{d^2T_{01}}{dy^2}+Pr\frac{dT_{01}}{dy}=0 \qquad (32)$$

$$\frac{d^2T_{02}}{dy^2}+Pr\frac{dT_{02}}{dy}=-PrEc\left(\frac{du_{01}}{dy}\right)^2 \qquad (33)$$

$$\frac{d^2C_{01}}{dy^2}+Sc\frac{dC_{01}}{dy}-KrScC_{01}=0 \qquad (34)$$

$$\frac{d^2C_{02}}{dy^2}+Sc\frac{dC_{02}}{dy}-KrScC_{02}=0 \qquad (35)$$

$$\frac{d^2u_{11}}{dy^2}+\frac{du_{11}}{dy}-\left(\frac{i\omega}{4}+M\right)u_{11}=-\left[GrT_{11}+GcC_{11}+\left(\frac{i\omega}{4}+M\right)\right] \qquad (36)$$

$$\frac{d^2u_{12}}{dy^2}+\frac{du_{12}}{dy}-\left(\frac{i\omega}{4}+M\right)u_{12}=-[GrT_{12}+GcC_{12}] \qquad (37)$$

$$\frac{d^2T_{11}}{dy^2}+Pr\frac{dT_{11}}{dy}-\frac{i\omega}{4}PrT_{11}=0 \qquad (38)$$

$$\frac{d^2T_{12}}{dy^2}+Pr\frac{dT_{12}}{dy}-\frac{i\omega}{4}PrT_{12}=-2PrEc\left(\frac{du_{01}}{dy}\right)\left(\frac{du_{11}}{dy}\right) \qquad (39)$$

$$\frac{d^2C_{11}}{dy^2}+Sc\frac{dC_{11}}{dy}-Sc\left[\frac{i\omega}{4}-Kr\right]C_{11}=0 \qquad (40)$$

$$\frac{d^2C_{12}}{dy^2}+Sc\frac{dC_{12}}{dy}-Sc\left[\frac{i\omega}{4}-Kr\right]C_{12}=0 \qquad (41)$$

The corresponding boundary conditions (27) become:

$$\left.\begin{aligned} &u_{01}=0,u_{02}=0,u_{11}=0,u_{12}=0\\ &\frac{dT_{01}}{dy}=1,\frac{dT_{02}}{dy}=0,\frac{dT_{11}}{dy}=0,\frac{dT_{12}}{dy}=0\\ &C_{01}=1,C_{02}=0,C_{11}=0,C_{12}=0\end{aligned}\right\}\ \text{At } y=0$$

$$\left.\begin{aligned} &u_{01}\to 1,u_{02}\to 0,u_{11}\to 1,u_{12}\to 0\\ &T_{01}\to 0,T_{02}\to 0,T_{11}\to 1,T_{12}\to 0\\ &C_{01}\to 0,C_{02}\to 0,C_{11}\to 1,C_{12}\to 0\end{aligned}\right\}\ \text{as } y\to\infty$$

Solution of the Problem:

Solving these differential equations from (30)-(41),using boundary conditions (42), and then making use of equations (28)-(29),finally with the help of equations (18),(19) and (20) we obtain the velocity,temperature and concentration fields are as follows:

$$u_{01}=e^{q_1y}+A_{12}e^{q_2y}+A_{13}e^{z_2y}+A_{14}e^{\alpha_2y}$$

$$u_{02}=A_{51}e^{x_1y}+A_{52}e^{x_2y}+A_{53}e^{j_2y}+A_{54}e^{2q_1y}+A_{55}e^{2q_2y}+A_{56}e^{(q_1+q_2)y}+A_{57}e^{2z_2y}+A_{58}e^{2\alpha_2y}+A_{59}e^{(z_2+\alpha_2)y}+A_{60}e^{(q_1+z_2)y}$$
$$+A_{61}e^{(q_2+z_2)y}+A_{62}e^{(q_1+\alpha_2)y}+A_{63}e^{(z_2+\alpha_2)y}$$

$$u_0(y)=u_{01}(y)+Ecu_{02}(y)$$

$$u_0(y)=e^{q_1y}+A_{12}e^{q_2y}+A_{13}e^{z_2y}+A_{14}e^{\alpha_2y}+Ec[A_{51}e^{x_1y}+A_{52}e^{x_2y}+A_{53}e^{j_2y}+A_{54}e^{2q_1y}+A_{55}e^{2q_2y}+A_{56}e^{(q_1+q_2)y}+A_{57}e^{2z_2y}$$
$$+A_{58}e^{2\alpha_2y}+A_{59}e^{(z_2+\alpha_2)y}+A_{60}e^{(q_1+z_2)y}+A_{61}e^{(q_2+z_2)y}+A_{62}e^{(q_1+\alpha_2)y}+A_{63}e^{(z_2+\alpha_2)y}]$$

$$u_{11}=e^{n_1y}-e^{n_2y}$$

$$u_{12}=A_{39}e^{g_1y}+A_{40}e^{g_2y}+A_{41}e^{d_1y}+A_{42}e^{d_2y}+A_{43}e^{(q_1+n_1)y}+A_{44}e^{(q_2+n_1)y}+A_{45}e^{(z_2+n_1)y}+A_{46}e^{(\alpha_2+n_1)y}+A_{47}e^{(q_1+n_2)y}$$
$$+A_{48}e^{(q_2+n_2)y}+A_{49}e^{(z_2+n_2)y}+A_{50}e^{(\alpha_2+n_2)y}$$

$$u_1(y)=u_{11}(y)+Ecu_{12}(y)$$

$$u_1(y)=e^{n_1y}-e^{n_2y}+Ec[A_{39}e^{g_1y}+A_{40}e^{g_2y}+A_{41}e^{d_1y}+A_{42}e^{d_2y}+A_{43}e^{(q_1+n_1)y}+A_{44}e^{(q_2+n_1)y}+A_{45}e^{(z_2+n_1)y}+A_{46}e^{(\alpha_2+n_1)y}$$
$$+A_{47}e^{(q_1+n_2)y}+A_{48}e^{(q_2+n_2)y}+A_{49}e^{(z_2+n_2)y}+A_{50}e^{(\alpha_2+n_2)y}]$$

$$T_{01}=e^{z_2y}$$

$$T_{02}=A_{17}+A_{18}e^{j_2y}+A_{19}e^{2q_1y}+A_{20}e^{2q_2y}+A_{21}e^{(q_1+q_2)y}+A_{22}e^{2z_2y}+A_{23}e^{2\alpha_2y}+A_{24}e^{(z_2+\alpha_2)y}+A_{25}e^{(q_1+z_2)y}+A_{26}e^{(q_2+z_2)y}$$
$$+A_{27}e^{(q_1+\alpha_2)y}+A_{28}e^{(q_2+\alpha_2)y}$$

$$T_0(y)=T_{01}(y)+EcT_{02}(y)$$

$$T_0(y)=e^{z_2y}+Ec[A_{17}+A_{18}e^{j_2y}+A_{19}e^{2q_1y}+A_{20}e^{2q_2y}+A_{21}e^{(q_1+q_2)y}+A_{22}e^{2z_2y}+A_{23}e^{2\alpha_2y}+A_{24}e^{(z_2+\alpha_2)y}+A_{25}e^{(q_1+z_2)y}$$
$$+A_{26}e^{(q_2+z_2)y}+A_{27}e^{(q_1+\alpha_2)y}+A_{28}e^{(q_2+\alpha_2)y}]$$

$$T_{11}=0$$

$$T_{12} = A_{29}e^{d_1y} + A_{30}e^{d_2y} + A_{31}e^{(q_1+n_1)y} + A_{32}e^{(q_2+n_1)y} + A_{33}e^{(z_2+n_1)y} + A_{34}e^{(\alpha_2+n_1)y} + A_{35}e^{(q_1+n_2)y} + A_{36}e^{(q_2+n_2)y} + A_{37}e^{(z_2+n_2)y} + A_{38}e^{(\alpha_2+n_2)y}$$

$$T_1(y) = T_{11}(y) + EcT_{12}(y)$$

$$T_1(y) = 0 + Ec[A_{29}e^{d_1y} + A_{30}e^{d_2y} + A_{31}e^{(q_1+n_1)y} + A_{32}e^{(q_2+n_1)y} + A_{33}e^{(z_2+n_1)y} + A_{34}e^{(\alpha_2+n_1)y} + A_{35}e^{(q_1+n_2)y} + A_{36}e^{(q_2+n_2)y} + A_{37}e^{(z_2+n_2)y} + A_{38}e^{(\alpha_2+n_2)y}]$$

$$C_{01} = e^{\alpha_2y}$$
$$C_{02} = 0$$
$$C_0(y) = C_{01}(y) + EcC_{02}(y)$$
$$C_0(y) = e^{\alpha_2y}$$
$$C_{11} = 0$$
$$C_{12} = 0$$
$$C_1(y) = C_{11}(y) + EcC_{12}(y)$$
$$C_1(y) = 0$$
$$u(y) = u_0 + \varepsilon(\cos(wt) + isin(wt))u_1$$

$$u(y) = e^{q_1y} + A_{12}e^{q_2y} + A_{13}e^{z_2y} + A_{14}e^{\alpha_2y} + Ec\big[A_{51}e^{x_1y} + A_{52}e^{x_2y} + A_{53}e^{j_2y} + A_{54}e^{2q_1y} + A_{55}e^{2q_2y} + A_{56}e^{(q_1+q_2)y} + A_{57}e^{2z_2y} + A_{58}e^{2\alpha_2y} + A_{59}e^{(z_2+\alpha_2)y} + A_{60}e^{(q_1+z_2)y} + A_{61}e^{(q_2+z_2)y} + A_{62}e^{(q_1+\alpha_2)y} + A_{63}e^{(z_2+\alpha_2)y}\big] + \varepsilon\big(\cos(wt) + isin(wt)\big)[e^{n_1y} - e^{n_2y} + Ec\big[A_{39}e^{g_1y} + A_{40}e^{g_2y} + A_{41}e^{d_1y} + A_{42}e^{d_2y} + A_{43}e^{(q_1+n_1)y} + A_{44}e^{(q_2+n_1)y} + A_{45}e^{(z_2+n_1)y} + A_{46}e^{(\alpha_2+n_1)y} + A_{47}e^{(q_1+n_2)y} + A_{48}e^{(q_2+n_2)y} + A_{49}e^{(z_2+n_2)y} + A_{50}e^{(\alpha_2+n_2)y}\big]]$$

$$T(y) = T_0 + \varepsilon\big(\cos(wt) + isin(wt)\big)T_1$$

$$T(y) = e^{z_2y} + Ec\big[A_{17} + A_{18}e^{j_2y} + A_{19}e^{2q_1y} + A_{20}e^{2q_2y} + A_{21}e^{(q_1+q_2)y} + A_{22}e^{2z_2y} + A_{23}e^{2\alpha_2y} + A_{24}e^{(z_2+\alpha_2)y} + A_{25}e^{(q_1+z_2)y} + A_{26}e^{(q_2+z_2)y} + A_{27}e^{(q_1+\alpha_2)y} + A_{28}e^{(q_2+\alpha_2)y}\big] + \varepsilon\big(\cos(wt) + isin(wt)\big)[Ec\big[A_{29}e^{d_1y} + A_{30}e^{d_2y} + A_{31}e^{(q_1+n_1)y} + A_{32}e^{(q_2+n_1)y} + A_{33}e^{(z_2+n_1)y} + A_{34}e^{(\alpha_2+n_1)y} + A_{35}e^{(q_1+n_2)y} + A_{36}e^{(q_2+n_2)y} + A_{37}e^{(z_2+n_2)y} + A_{38}e^{(\alpha_2+n_2)y}\big]]$$

$$C(y) = C_0 + \varepsilon\big(\cos(wt) + isin(wt)\big)C_1$$
$$C(y) = e^{\alpha_2y}$$

Results and discussion:

The chemical reaction effects on MHD free convevtive oscillatory flow past a porous plate in the presence of heat sink have been studied.The governing equations are solved by using perturbation method and approximate solutions are obtained for velocity,temperature and concentration fields.The effects of the flow parameters such as magnetic parameter(*M*),suction parameter(S),Grashof number for heat and mass transfer(*Gr,Gc*),Schmidt number (*Sc*),Chemical reaction parameter(*Kr*),Prandtl number(*Pr*) and Eckert number (*Ec*) on the velocity,temperature and concentration profiles of the flow fields are presented with help of velocity profiles(*Figures 1-5*),temperature profiles(*Figures 6*) and concentration profiles(*Figures 7,8*).

The velocity(u) profiles for different values of the thermal Grashof number *Gr* are described in *Figure 1*.It is observed that an increase in *Gr* leads to rise in the values of velocity.For the case of different values of modified Grashof number Gc,the velocity profiles are shown in the *Figure 2*.It is observed that an increase in *Gc* leads to a rise in the values of velocity.

Figure 3 and *Figure 8* Illustrates the velocity(*u*) and concentration profiles (C) for Schmidt number (*Sc*) .It is observed that the effect of increasing value of *Sc* is leads to rise in the values of velocity.and It is also observed that the effect of increasing value of *Sc* is decreases the values of concentration.

Figure 5 and *Figure 6* Illustrates the velocity(*u*) and temperature profiles (C) for Prandtl number (*Pr*) .It is observed that the effect of increasing value of *Pr* is leads to rise in the values of velocity.and It is also observed that the effect of increasing value of *Pr* is decreases the values of temperature.

The velocity(u) profiles for different values of the magnetic parameter *M* are described in *Figure 4*.It is observed that an increase in *M* leads to rise in the values of velocity.

The concentration(C) profiles for different values of the chemical reaction parameter *Kr* are described in *Figure 7*.It is observed that an increase in *Kr* leads to decreases the values of concentration.

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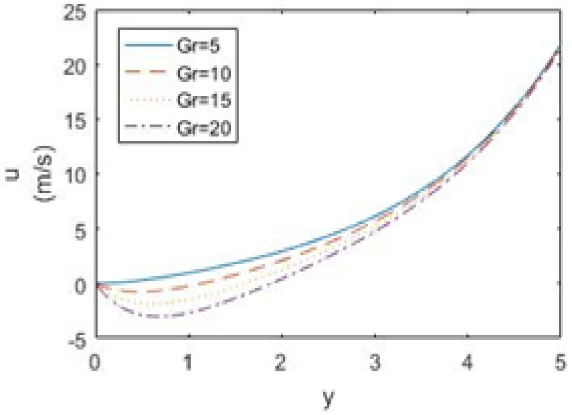

Fig.1.

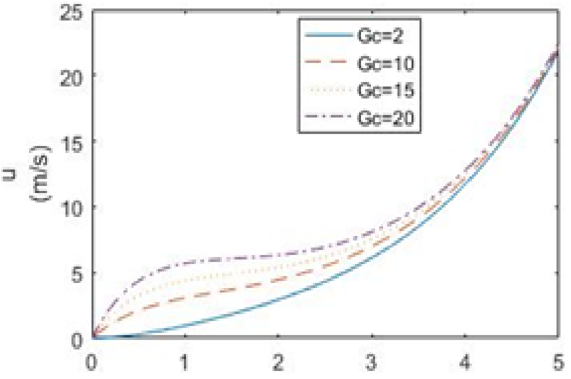

Fig.2.

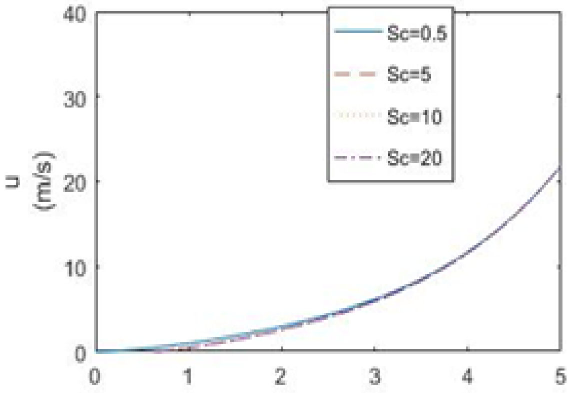

Fig.3.

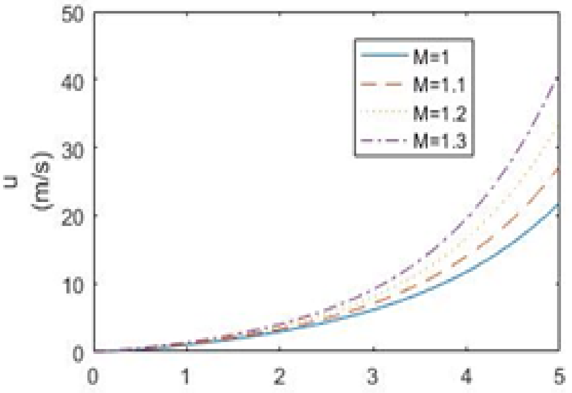

Fig.4.

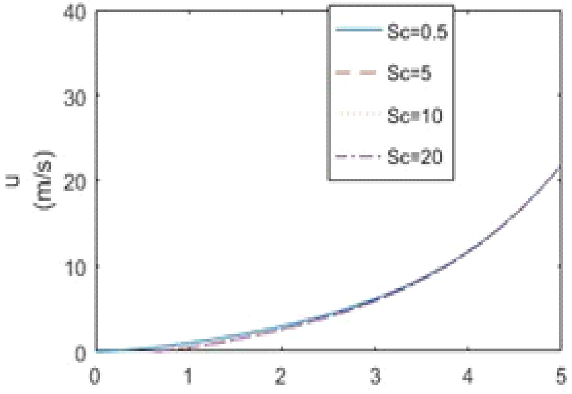

Fig.5.

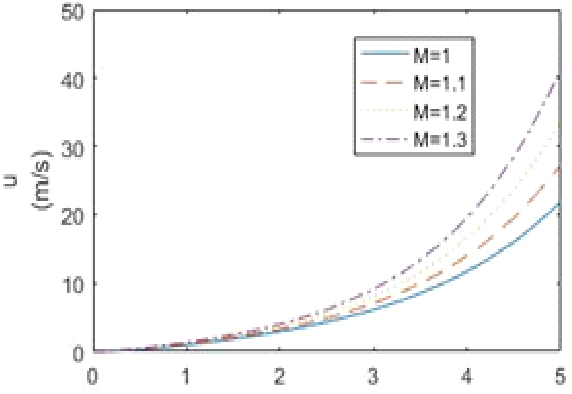

Fig.6.

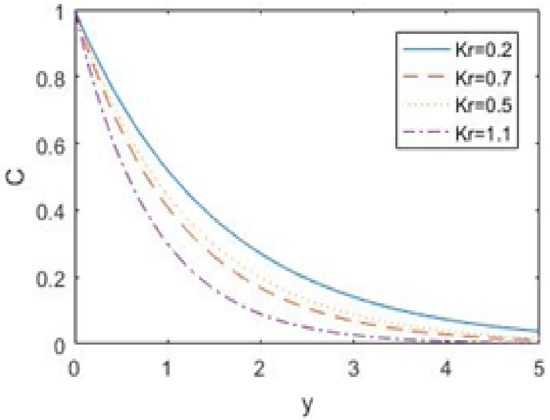

Fig.7.

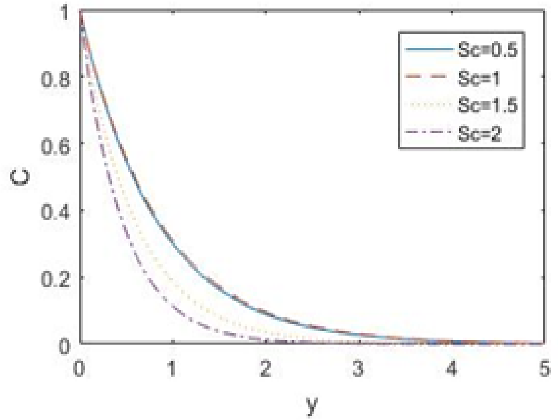

Fig.8.

Appendix:

$$A_{13} = \frac{Gr}{(z_2)^2+z_2-M}, A_{14} = \frac{-Gc}{(\alpha_2)^2+\alpha_2-M}$$

$$A_{12} = -A_{13} - A_{14} - 1$$

$$A_{53} = \frac{-GrA_{18}}{(j_2)^2+j_2-M}, A_{54} = \frac{-GrA_{19}}{(2q_1)^2+2q_1-M}, A_{55} = \frac{-GrA_{20}}{(2q_2)^2+2q_2-M}, A_{56} = \frac{-GrA_{21}}{(q_1+q_2)^2+(q_1+q_2)-M}, A_{57} = \frac{-GrA_{22}}{(2z_2)^2+2z_2-M}$$

$$A_{58} = \frac{-GrA_{23}}{(2\alpha_2)^2+2\alpha_2-M}, A_{59} = \frac{-GrA_{24}}{(z_2+\alpha_2)^2+(z_2+\alpha_2)-M}, A_{60} = \frac{-GrA_{25}}{(q_1+z_2)^2+(q_1+z_2)-M}, A_{61} = \frac{-GrA_{26}}{(q_2+z_2)^2+(q_2+z_2)-M}$$

$$A_{62} = \frac{-GrA_{27}}{(q_1+\alpha_2)^2+(q_1+\alpha_2)-M}, A_{63} = \frac{-GrA_{28}}{(q_2+\alpha_2)^2+(q_2+\alpha_2)-M}$$

$$A_{51} = -A_{54}, A_{52} = -(A_{51}+A_{53}+A_{55}+A_{56}+A_{57}+A_{58}+A_{59}+A_{60}+A_{61}+A_{62}+A_{63})$$

$$A_{41} = \frac{-GrA_{29}}{(d_1)^2+Scd_1-Sc(\frac{iw}{4}-Kr)}, A_{42} = \frac{-GrA_{30}}{(d_2)^2+Scd_2-Sc(\frac{iw}{4}-Kr)}, A_{43} = \frac{-GrA_{31}}{(q_1+n_1)^2+Sc(q_1+n_1)-Sc(\frac{iw}{4}-Kr)}$$

$$A_{44} = \frac{-GrA_{32}}{(q_2+n_1)^2+Sc(q_2+n_1)-Sc(\frac{iw}{4}-Kr)}, A_{45} = \frac{-GrA_{33}}{(z_2+n_1)^2+Sc(z_2+n_1)-Sc(\frac{iw}{4}-Kr)}, A_{46} = \frac{-GrA_{34}}{(\alpha_2+n_1)^2+Sc(\alpha_2+n_1)-Sc(\frac{iw}{4}-Kr)}$$

$$A_{47} = \frac{-GrA_{35}}{(q_1+n_2)^2+Sc(q_1+n_2)-Sc(\frac{iw}{4}-Kr)}, A_{48} = \frac{-GrA_{36}}{(q_2+n_2)^2+Sc(q_2+n_2)-Sc(\frac{iw}{4}-Kr)}, A_{49} = \frac{-GrA_{37}}{(z_2+n_2)^2+Sc(z_2+n_2)-Sc(\frac{iw}{4}-Kr)}$$

$$A_{50} = \frac{-GrA_{38}}{(\alpha_2+n_2)^2+Sc(\alpha_2+n_2)-Sc(\frac{iw}{4}-Kr)}, A_{39} = -(A_{41}+A_{43})$$

$$A_{40} = -(A_{39}+A_{41}+A_{42}+A_{43}+A_{44}+A_{45}+A_{46}+A_{47}+A_{48}+A_{49}+A_{50})$$

$$A_{19} = \frac{-PrEcq_1^2}{(2q_1)^2+2q_1Pr}, A_{20} = \frac{-PrEcq_2^2A_{12}^2}{(2q_2)^2+2q_2Pr}, A_{21} = \frac{-PrEc2q_1q_2A_{12}}{(q_1+q_2)^2+(q_1+q_2)Pr}, A_{22} = \frac{-PrEcz_2^2A_{13}^2}{(2z_2)^2+2z_2Pr}, A_{23} = \frac{-PrEc\alpha_2^2A_{14}^2}{(2\alpha_2)^2+2\alpha_2Pr}$$

$$A_{24} = \frac{-PrEc2z_2A_{13}\alpha_2A_{14}}{(z_2+\alpha_2)^2+(z_2+\alpha_2)Pr}, A_{25} = \frac{-PrEc2z_2A_{13}q_1}{(z_2+q_1)^2+(z_2+q_1)Pr}, A_{26} = \frac{-PrEc2z_2A_{13}q_2A_{12}}{(z_2+q_2)^2+(z_2+q_2)Pr}, A_{27} = \frac{-PrEc2q_1A_{14}\alpha_2}{(\alpha_2+q_1)^2+(\alpha_2+q_1)Pr}$$

$$A_{28} = \frac{-PrEc2\alpha_2A_{12}q_2A_{14}}{(\alpha_2+q_2)^2+(\alpha_2+q_2)Pr}, A_{17} = -A_{19}$$

$$A_{18} = -(A_{17}+A_{19}+A_{20}+A_{21}+A_{22}+A_{23}+A_{24}+A_{25}+A_{26}+A_{27}+A_{28})$$

$$A_{31} = \frac{-2PrEcq_1n_1}{(q_1+n_1)^2+Pr(q_1+n_1)-\frac{iw}{4}Pr}, A_{32} = \frac{-2PrEcq_2n_1A_{12}}{(q_2+n_1)^2+Pr(q_2+n_1)-\frac{iw}{4}Pr}, A_{33} = \frac{-2PrEcz_2n_1A_{13}}{(z_2+n_1)^2+Pr(z_2+n_1)-\frac{iw}{4}Pr}$$

$$A_{34} = \frac{-2PrEc\alpha_2n_1A_{14}}{(\alpha_2+n_1)^2+Pr(\alpha_2+n_1)-\frac{iw}{4}Pr}, A_{35} = \frac{2PrEcq_1n_2}{(q_1+n_2)^2+Pr(q_1+n_2)-\frac{iw}{4}Pr}, A_{36} = \frac{2PrEcq_2n_2A_{12}}{(q_2+n_2)^2+Pr(q_2+n_2)-\frac{iw}{4}Pr}$$

$$A_{37} = \frac{2PrEcz_2n_2A_{13}}{(z_2+n_2)^2+Pr(z_2+n_2)-\frac{iw}{4}Pr}, A_{38} = \frac{2PrEc\alpha_2n_2A_{14}}{(\alpha_2+n_2)^2+Pr(\alpha_2+n_2)-\frac{iw}{4}Pr}$$

$$A_{29} = -A_{31}, A_{30} = -(A_{29}+A_{31}+A_{32}+A_{33}+A_{34}+A_{35}+A_{36}+A_{37}+A_{38})$$

$$\alpha_2 = \frac{-Sc-\sqrt{Sc^2+4KrSc}}{2}, z_2 = -Pr, q_1 = \frac{-1+\sqrt{1+4M}}{2}, q_2 = \frac{-1-\sqrt{1+4M}}{2}$$

$$g_1 = \frac{-1+\sqrt{1+4\left(\frac{iw}{4}+M\right)}}{2}, g_2 = \frac{-1-\sqrt{1+4\left(\frac{iw}{4}+M\right)}}{2}, d_1 = \frac{-Pr+\sqrt{Pr^2+iwPr}}{2}, d_2 = \frac{-Pr-\sqrt{Pr^2+iwPr}}{2}, n_1 = \frac{-1+\sqrt{1+iw+4M}}{2}$$

$$n_2 = \frac{-1-\sqrt{1+iw+4M}}{2}, j_2 = -Pr$$

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