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EFFECT OF HALL CURRENTS ON UNSTEADY MIXED CONVECTIVE HEAT AND MASS TRANSFER FLOW OF A CHEMICALLY REACTING VISCOUS FLUID IN A HORIZONTAL CHANNEL WITH TRAVELING THERMAL WAVES

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ABSTRACT

This paper deals with the thermo-diffusion and chemical reaction effects on the unsteady convective Heat and Mass transfer flow of a viscous, incompressible electrically conducting fluid in a horizontal channel bounded by flat walls. The unsteadiness in the flow is due to the traveling thermal wave imported on y = L. The momentum, energy and diffusion equations are non linear coupled equations. By making use of perturbation technique the governing equations are solved to obtain the expressions for velocity, temperature and concentration.

Keywords: *Chemical Reaction, Hall Effects, Traveling Thermal Waves, Horizontal channel, Radiation effect.*

I. INTRODUCTION:

In recent years, energy and material saving considerations have prompted an expansion of the efforts at producing efficient heat exchanger equipment through augmentation of heat transfer. It has been established [2] that channels with diverging – converging geometries augment the transportation of heat transfer and momentum. As the fluid flows through a tortuous path viz., the dilated – constricted geometry, there will be more intimate contact between them. The flow takes place both axially (primary) and transversely (secondary) with the secondary velocity being towards the axis in the fluid bulk rather than confining within a thin layer as in straight channels. Hence it is advantageous to go for converging-diverging geometries for improving the design of heat transfer equipment. Vajravelu and Nayfeh [10] have investigated the influence of the wall waviness on skin friction and pressure drop of the generated coquette flow. Vajravelu and Sastry [8] have analyzed the free convection heat transfer in a viscous, incompressible fluid confined between long vertical wavy walls in the presence of constant heat source. Later Vajravelu and Debnath [9] have extended this study to convective flow in a vertical wavy channel in four different geometrical configurations. Several authors have analyzed that the flow and heat/mass transfer in a wavy duct with various corrugation angles in two dimensional flow regimes.

In all these investigations, the effects of Hall currents are not considered. However, in a partially ionized gas, there occurs a Hall current [1] when the strength of the impressed magnetic field is very strong. These Hall effects play a significant role in determining the flow features. Sato [6], Yamanishi [11], Sherman and Sutton [7] have discussed the Hall effects on the steady hydromagnetic flow between two parallel plates. Taking Hall effects in to account Krishna *et. al.*,[3,4] have investigated Hall effects on the unsteady hydromagnetic boundary layer flow. Rao *et. al.*, [5] have analyzed Hall effects on unsteady Hydromagnetic flow.
In this paper we investigate the convective heat and mass transfer flow of a viscous electrically conducting fluid in a horizontal channel bounded by flat walls under the influence of an inclined magnetic fluid with heat generating sources.

2. FORMULATION AND SOLUTION OF THE PROBLEM:

We consider the unsteady flow of an incompressible, viscous ,electrically conducting fluid confined in a horizontal channel bounded by two flat walls under the influence of an inclined magnetic field of intensity Ho lying in the plane (x-z).The magnetic field is inclined at an angle α_1 to the axial direction and hence its components are $(0, H_0 Sin(\alpha_1), H_0 Cos(\alpha_1))$ .In view of the traveling thermal wave imposed on the wall x=L the velocity field has components(u,0,w)The magnetic field in the presence of fluid flow induces the current($(J_x, 0, J_z)$ .We choose a rectangular Cartesian co-ordinate system O(x,y,z) with z-axis in the vertical direction and the walls at $x = \pm L$.

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When the strength of the magnetic field is very large we include the Hall current so that the generalized Ohm's law is modified to

$$\bar{J} + \omega_e \tau_e \bar{J} x \bar{H} = \sigma(\bar{E} + \mu_e \bar{q} x \bar{H}) \tag{2.1}$$

where q is the velocity vector. H is the magnetic field intensity vector. E is the electric field, J is the current density vector, ω_e is the cyclotron frequency, τ_e is the electron collision time,σ is the fluid conductivity and μ_e is the magnetic permeability. Neglecting the electron pressure gradient, ion-slip and thermo-electric effects and assuming the electric field E=0, equation (2.1) reduces

$$j_x - m H_0 J_z Sin(\alpha_1) = -\sigma\mu_e H_0 w Sin(\alpha_1) \tag{2.2}$$

$$J_z + m H_0 J_x Sin(\alpha_1) = \sigma\mu_e H_0 u\, Sin(\alpha_1) \tag{2.3}$$

where m= $\omega_e \tau_e$ is the Hall parameter.

On solving equations (2.2) & (2.3) we obtain

$$j_x = \frac{\sigma\mu_e H_0 Sin(\alpha_1)}{1 + m^2 H_0^2 Sin^2(\alpha_1)} (m H_0 Sin(\alpha_1) - w) \tag{2.4}$$

$$j_z = \frac{\sigma\mu_e H_0 Sin(\alpha_1)}{1 + m^2 H_0^2 Sin^2(\alpha_1)} (u + m H_0 w\, Sin(\alpha_1)) \tag{2.5}$$

where u,w are the velocity components along x and z directions respectively,

The momentum equations are

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + w\frac{\partial u}{\partial z} = -\frac{\partial p}{\partial x} + \mu(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial z^2}) + \mu_e(-H_0 J_z Sin(\alpha_1)) \tag{2.6}$$

$$\frac{\partial w}{\partial t} u \frac{\partial W}{\partial x} + w\frac{\partial W}{\partial z} = -\frac{\partial p}{\partial z} + \mu(\frac{\partial^2 W}{\partial x^2} + \frac{\partial^2 W}{\partial z^2}) + \mu_e(H_0 J_x Sin(\alpha_1)) \tag{2.7}$$

Substituting J_x and J_z from equations (2.4) and (2.5) in equations (2.6) and (2.7) we obtain

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + w\frac{\partial u}{\partial z} = -\frac{\partial p}{\partial x} + \mu(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial z^2}) - \frac{\sigma\mu_e H_0^2 Sin^2(\alpha_1)}{1 + m^2 H_0^2 Sin^2(\alpha_1)}(u + m H_0 w Sin(\alpha_1))$$
(2.8)

$$\frac{\partial w}{\partial t} + u\frac{\partial W}{\partial x} + w\frac{\partial W}{\partial z} = -\frac{\partial p}{\partial z} + \mu(\frac{\partial^2 W}{\partial x^2} + \frac{\partial^2 W}{\partial z^2}) - \frac{\sigma\mu_e H_0^2 Sin^2(\alpha_1)}{1 + m^2 H_0^2 Sin^2(\alpha_1)}(w - m H_0 u Sin(\alpha_1)) - \rho g \tag{2.9}$$

The energy equation is

$$\rho C_p(\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + w\frac{\partial T}{\partial z} = k_f(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial z^2}) + Q - \frac{\partial(q_r)}{\partial x} \tag{2.10}$$

The diffusion equation is

$$(\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + w\frac{\partial C}{\partial z} = D_{1f}(\frac{\partial^2 C}{\partial x^2} + \frac{\partial^2 C}{\partial z^2}) - k'C + k_{11}(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial z^2}) \tag{2.11}$$

The equation of state is

$$\rho - \rho_0 = -\beta(T - T_o) - \beta^\bullet(C - C_0)) \tag{2.12}$$

Where T, C are the temperature and concentration in the fluid. k_f is the thermal conductivity, C_p is the specific heat at constant pressure, β is the coefficient of thermal expansion, $\beta^{\bullet}$ is the volume coefficient with mass fraction,$D_1$is the molecular diffusivity, Q is the strength of the heat source ,k_{11} is the cross diffusivity, q_r is the radiative heat flux..

Invoking Rosseland approximation for radiative heat flux we get

$$q_R = \frac{4\sigma^{\bullet}}{3\beta_R}\frac{\partial(T'^4)}{\partial x} \tag{2.12a}$$

and expanding T'^4 by Taylor's expansion neglecting higher order terms we get

$$T'^4 \cong 4T_e^3 T - 3T_{e4}^4 \tag{2.12b}$$

The flow is maintained by a constant volume flux for which a characteristic velocity is defined as

$$q = \frac{1}{L}\int_{-L}^{L} w dx \tag{2.13}$$

The boundary conditions are

$$u= 0 , w=0, T=T_1 ,C=C_1 \text{ on } x = -L \tag{2.14}$$

$$u=0, \quad w=0, T=T_{2} + ((T_1-T_2) \sin (m_1z+nt), C=C_2 \text{ on } x = +L \tag{2.15}$$

Eliminating the pressure from equations (2.8) and (2.9) and introducing the Stokes Stream function ψ as

$$u = -\frac{\partial\psi}{\partial z} \quad , w = \frac{\partial\psi}{\partial x} \tag{2.16}$$

the equations (2.8)&(2.9), (2.10) in terms of ψ is

$$\frac{\partial(\nabla^2\psi)}{\partial t} + \frac{\partial\psi}{\partial z}\frac{\partial(\nabla^2\psi)}{\partial x} - \frac{\partial\psi}{\partial x}\frac{\partial(\nabla^2\psi)}{\partial z} = \mu\nabla^4\psi + \beta g\frac{\partial(T-T_e)}{\partial z} + \beta^{\bullet} g\frac{\partial(C-C_e)}{\partial z} - \left(\frac{\sigma\mu_e^2 H_0^2 Sin^2(\alpha_1)}{1+m^2 H_0^2 Sin^2(\alpha_1)}\right)\nabla^2\psi \tag{2.17}$$

$$\rho C_p\left(\frac{\partial T}{\partial t} + \frac{\partial\psi}{\partial x}\frac{\partial T}{\partial z} - \frac{\partial\psi}{\partial z}\frac{\partial T}{\partial x}\right) = k_f\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial z^2}\right) + Q + \frac{16\sigma^{\bullet} T_e^3}{3\beta_r}\frac{\partial^2 T}{\partial x^2} \tag{2.18}$$

$$\left(\frac{\partial C}{\partial t} + \frac{\partial\psi}{\partial x}\frac{\partial c}{\partial z} - \frac{\partial\psi}{\partial z}\frac{\partial C}{\partial x}\right) = D_1\left(\frac{\partial^2 C}{\partial x^2} + \frac{\partial^2 C}{\partial z^2}\right) - k'C + k_{11}\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial z^2}\right) \tag{2.19}$$

On introducing the following non-dimensional variables

$$(x', z') = (x/L, m_1 z)\ , \psi' = \frac{\psi}{qL},\ \theta = \frac{T-T_2}{T_1-T_2}, C' = \frac{C-C_2}{C_1-C_2}$$

the equation of momentum and energy in the non-dimensional form are

$$\nabla^4\psi - M_1^2\nabla^2\psi + \frac{G}{R}\left(\frac{\partial\theta}{\partial z} + N\frac{\partial C}{\partial z}\right) = \delta R\left(\delta\frac{\partial}{\partial t}(\nabla^2\psi) + \left(\frac{\partial\psi}{\partial z}\frac{\partial(\nabla^2\psi)}{\partial x} - \frac{\partial\psi}{\partial x}\frac{\partial(\nabla^2\psi)}{\partial z}\right)\right) \tag{2.20}$$

$$\delta P\left(\delta\frac{\partial\theta}{\partial t} + \frac{\partial\psi}{\partial x}\frac{\partial\theta}{\partial z} - \frac{\partial\psi}{\partial z}\frac{\partial\theta}{\partial x}\right) = \left(\frac{\partial^2\theta}{\partial x^2} + \frac{\partial^2\theta}{\partial z^2}\right) + \alpha + \frac{4}{3N_1}\frac{\partial^2\theta}{\partial x^2} \tag{2.21}$$

$$\delta Sc\left(\delta\frac{\partial C}{\partial t} + \frac{\partial\psi}{\partial x}\frac{\partial C}{\partial z} - \frac{\partial\psi}{\partial z}\frac{\partial C}{\partial x}\right) = \left(\frac{\partial^2 C}{\partial x^2} + \frac{\partial^2 C}{\partial z^2}\right) - kC + \frac{ScSo}{N}\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial z^2}\right) \tag{2.22}$$

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \delta^2 \frac{\partial^2}{\partial z^2}$$

where $G = \frac{\beta g \, \Delta T_e L^3}{\nu^2}$ (Grashof Number) $\quad \delta = m_1 L$ (Aspect ratio)

$M^2 = \frac{\sigma \mu_e^2 H_o^2 L^2}{\nu^2}$ (Hartman Number) $\quad M_1^2 = \frac{M^2 Sin^2(\alpha_1)}{1+m^2}$

$R = \frac{qL}{\nu}$ (Reynolds Number) $\quad P = \frac{\mu C_p}{K_f}$ (Prandtl Number)

$\alpha = \frac{QL^2}{K_f (T_1 - T_2) C_p}$ (Heat Source Parameter) $\quad Sc = \frac{\nu}{D_1}$ (Schmidt Number)

$So = \frac{k_{11}\beta^\bullet}{\beta\nu}$ (Soret parameter) $\quad N = \frac{\beta^\bullet (C_1 - C_2)}{\beta (T_1 - T_2)}$ (Buoyancy ratio)

$N_1 = \frac{\beta_R k_f}{4\sigma^\bullet T_e^3}$ (Radiation parameter) $\quad k = \frac{k' L^2}{D_1}$ (Chemical reaction parameter)

$$N_2 = \frac{3N_1}{3N_1 + 4} \quad P_1 = PN_2 \quad \alpha_1 = \alpha N_2$$

The corresponding boundary conditions are

$$\psi(+1) - \psi(-1) = 1$$
(2.23)

$$\frac{\partial \psi}{\partial z} = 0, \frac{\partial \psi}{\partial x} = 0, \theta = 1 \,, C = 1 \quad at \;\; x = -1$$

$$\frac{\partial \psi}{\partial z} = 0, \frac{\partial \psi}{\partial x} = 0, \theta = Sin(z + \gamma t), C = 0 \quad at \;\; x = +1$$

3. ANALYSIS OF THE FLOW:

Assuming the aspect ratio δ to be small we take

$$\begin{aligned} \psi(x,z,t) &= \psi_0(x,z,t) + \delta\psi_1(x,z,t) + \delta^2\psi_2(x,z,t) + \ldots\ldots\ldots\ldots\ldots \\ \theta(x,z,t) &= \theta_o(x,z,t) + \delta\theta_1(x,z,t) + \delta^2\theta_2(x,z,t) + \ldots\ldots\ldots\ldots\ldots\ldots \\ C(x,z,t) &= C_o(x,z,t) + \delta C_1(x,z,t) + \delta^2 C_2(x,z,t) + \ldots\ldots\ldots \end{aligned} \tag{3.1}$$

Substituting (3.1) in equations (2.20)-(2.22) and equating the like powers of δ the equations and the respective boundary conditions to the zeroth order are

$$\frac{\partial^2 \theta_0}{\partial x^2} - \alpha_1 = 0 \tag{3.2}$$

$$\frac{\partial^2 C_0}{\partial x^2} - kC_0 = -\frac{ScSo}{N}\frac{\partial^2 \theta_0}{\partial x^2} \tag{3.3}$$

$$\frac{\partial^4 \psi_0}{\partial x^4} - (M_1^2)\frac{\partial^2 \psi_0}{\partial x^2} = -\frac{G}{R}\left(\frac{\partial \theta_0}{\partial z} + N\frac{\partial C_0}{\partial z}\right) \tag{3.4}$$

with

$$\psi_0(+1)-\psi_0(-1)=1$$

$$\frac{\partial\psi_0}{\partial x}=0,\ \frac{\partial\psi_0}{\partial z}=0,\quad \theta_0=1, C_0=1\quad at\quad x=-1 \tag{3.5}$$

$$\frac{\partial\psi_0}{\partial x}=0,\ \frac{\partial\psi_0}{\partial z}=0,\quad \theta_0=Sin(z+\gamma t), C_0=0\quad at\quad x=+1$$

and to the first order are

$$\frac{\partial^2\theta_1}{\partial x^2}=P_1R\left(\frac{\partial\psi_0}{\partial x}\frac{\partial\theta_0}{\partial z}-\frac{\partial\psi_0}{\partial z}\frac{\partial\theta_0}{\partial x}\right) \tag{3.6}$$

$$\frac{\partial^2 C_1}{\partial x^2}-kC_1=ScR\left(\frac{\partial\psi_0}{\partial x}\frac{\partial C_0}{\partial z}-\frac{\partial\psi_0}{\partial z}\frac{\partial C_0}{\partial x}\right)-\frac{ScSo}{N}\frac{\partial^2\theta_1}{\partial x^2} \tag{3.7}$$

$$\frac{\partial^4\psi_1}{\partial x^4}-(M_1^2)\frac{\partial^2\psi_1}{\partial x^2}=-\frac{G}{R}\left(\frac{\partial\theta_1}{\partial z}+N\frac{\partial C_1}{\partial z}\right)+R\left(\frac{\partial\psi_0}{\partial x}\frac{\partial^3\psi_0}{\partial z^3}-\frac{\partial\psi_0}{\partial z}\frac{\partial^3\psi_0}{\partial x\partial z^2}\right) \tag{3.8}$$

with

$$\psi_1(+1)-\psi_1(-1)=0$$

$$\frac{\partial\psi_1}{\partial x}=0,\ \frac{\partial\psi_1}{\partial z}=0,\quad \theta_1=0, C_1=0\quad at\quad x=-1 \tag{3.9}$$

$$\frac{\partial\psi_1}{\partial x}=0,\ \frac{\partial\psi_1}{\partial z}=0,\quad \theta_1=0, C_1=0\quad at\quad x=+1$$

4. SOLUTIONS OF THE PROBLEM:

Solving the equations (3.2)-(3.8) subject to the boundary conditions we obtain

$$\theta_0 = 0.5\alpha_1(x^2-1)+0.5Sin(z+\gamma t)(1+x)+0.5(1-x)$$

$$C_0=0.5\left(\frac{Ch(\beta_1 x)}{Ch(\beta_1)}-\frac{sh(\beta_1 x)}{sh(\beta_1)}\right)+a_3\left(\frac{Ch(\beta_1 x)}{Ch(\beta_1)}-1\right)$$

$$\psi_0=a_9 Cosh(M_1x)+a_{10}Sinh(M_1x)+a_{11}x+a_{12}+\phi_1(x)$$

$$\phi_1(x)=-a_6x+a_7x^2-a_8x^3$$

Similarly the solutions to the first order are

$$\begin{aligned}\theta_1 &= a_{36}(x^2-1)+a_{37}(x^3-x)+a_{38}(x^4-1)+a_{39}(x^5-x)+a_{40}(x^6-1)+\\ &+(a_{41}+xa_{43})(Ch(M\ x)-Ch(M_1)+a_{42}(Sh(M_1x)-xSh(M_1))++a_{44}(xSh(M_1x)-Sh(M_1))\end{aligned}$$

$$\begin{aligned}C_1 &= a_{47}\left(1-\frac{Ch(\beta_1x)}{Ch(\beta_1)}\right)+a_{48}\left(x-\frac{Sh(\beta_1x)}{Sh(\beta_1)}\right)+a_{49}\left(x^2-\frac{Ch(\beta_1x)}{Ch(\beta_1)}\right)\\ &+a_{50}\left(x^3-\frac{Sh(\beta_1x)}{Sh(\beta_1)}\right)+a_{51}\left(x^4-\frac{Ch(\beta_1x)}{Ch(\beta_1)}\right)+a_{52}\left(Ch(M_1x)-Ch(M_1)\frac{Ch(\beta_1x)}{Ch(\beta_1)}\right)\\ &+a_{53}\left(Sh(M_1x)-Sh(M_1)\frac{Sh(\beta_1x)}{Sh(\beta_1)}\right)+a_{54}\left(xCh(M_1x)-Ch(M_1)\frac{Sh(\beta_1x)}{Sh(\beta_1)}\right)\end{aligned}$$

$$+a_{55}(xSh(M_1x)-Sh(M_1)\frac{Ch(\beta_1x)}{Ch(\beta_1)})+b_3(Sh(\beta_2x)-Sh(\beta_2)\frac{Sh(\beta_1x)}{Sh(\beta_1)})$$
$$+b_4(Sh(\beta_3x)-Sh(\beta_3)\frac{Sh(\beta_1x)}{Sh(\beta_1)})+b_5(Ch(\beta_2x)-Ch(\beta_2)\frac{Ch(\beta_1x)}{Ch(\beta_1)})$$
$$+b_6(Ch(\beta_3x)-Ch(\beta_2)\frac{Ch(\beta_1x)}{Ch(\beta_1)})+b_7(xSh(\beta_1x)-Sh(\beta_1)\frac{Ch(\beta_1x)}{Ch(\beta_1)})$$
$$+b_8(x^2Sh(\beta_1x)-Sh(\beta_1)\frac{Ch(\beta_1x)}{Ch(\beta_1)})+b_9(x^3Sh(\beta_1x)-Sh(\beta_1)\frac{Ch(\beta_1x)}{Ch(\beta_1)})$$
$$+b_{11}(xCh(\beta_1x)-Ch(\beta_1)\frac{Sh(\beta_1x)}{Sh(\beta_1)})+b_{12}(x^2Ch(\beta_1x)-Ch(\beta_1))$$
$$+b_{13}(x^3Ch(\beta_1x)-Ch(\beta_1)\frac{Sh(\beta_1x)}{Sh(\beta_1)})$$

$$\psi_1=b_{49}Cosh(M_1x)+b_{50}Sinh(M_1x)+b_{51}x+b_{52}+\phi_2(x)$$

$$\varphi_2(x)=b_{21}+b_{22}x+b_{23}x^2+b_{24}x^3+b_{25}x^4+b_{26}x^5+b_{27}x^6+b_{28}x^7+(b_{29}+b_{30}x+$$
$$+b_{31}x^2+b_{32}x^3+b_{33}x^4+b_{34}x^5+b_{35}x^6)Cosh(\beta_1x)+(b_{36}+b_{37}x+b_{38}x^2+b_{39}x^3$$
$$+b_{40}x^4+b_{41}x^5+b_{42}x^6)Sinh(\beta_1x)+b_{43}Cosh(2\beta_1x)+b_{44}Sinh(2\beta_{1x}x)$$

where $a_1,a_2,\ldots\ldots\ldots,a_{90},b_1,b_2,\ldots\ldots\ldots,b_{52}$ are constants not mentioned due to space constraints.

where Ch=Cosh, Sh= Sinh

5. SHEAR STRESS AND NUSSELT NUMBER:

The rate of heat transfer (Nusselt Number) on the walls has been calculated using the formula

$$Nu=\frac{1}{(\theta_m-\theta_w)}(\frac{\partial\theta}{\partial x})_{x=\pm1}$$

where $\theta_m=0.5\int_{-1}^{1}\theta\,dx$

$$(Nu)_{x=+1}=\frac{1}{\theta_m-Sin(z+\gamma t)}(b_{24}+\delta b_{22})\quad(Nu)_{x=-1}=\frac{1}{(\theta_m-1)}(b_{25}+\delta b_{23})$$

$$\theta_m=a_{80}+\delta\,a_{81}$$

The rate of mass transfer (Sherwood Number) on the walls has been calculated using the formula

$$Sh=\frac{1}{(C_m-C_w)}(\frac{\partial C}{\partial x})_{x=\pm1}$$

where $C_m=0.5\int_{-1}^{1}C\,dx$

$$(Sh)_{x=+1}=\frac{1}{C_m}(b_{18}+\delta\,b_{16})\quad(Sh)_{x=-1}=\frac{1}{(C_m-1)}(b_{19}+\delta\,b_{17})$$

$$\theta_m=b_{26}+\delta\,b_7$$
$$C_m=b_{20}+\delta\,b_{21}$$

6. NUMERICAL RESULTS AND DISCUSSION:

The variation of w with Grashof number G shows that w exhibits a reversal flow for G<0 and the region of reversal flow enlarges with increase in G<0.|w| enhances with increase in |G| with maximum occurring at x = 0(fig. 1). The variation of w with the Hall parameter m and the radiation parameter N1 shows that the magnitude of w enhances with increase in m and N1 (fig.2). From fig. 3 we find that |w| depreciates with increase in the chemical reaction parameter k. Fig. 4 represent the variation of θ with G. It is found that the actual temperature depreciates with increase in |G|. The actual temperature experiences with increase in the Hall parameter m and radiation parameter N1 in the entire flow region (fig.5). The actual temperature with increase in the chemical reaction parameter k (fig. 6). Fig. 7 represents C with G. It is shown that the concentration reduces with increase in G>0 and enhances with |G| with maximum at x = +1. An increase in the Hall parameter m enhances the actual concentration and reduces with radiation parameter N1 (fig.8) From fig. 9 we find that the actual concentration experiences depreciation with increase in the chemical reaction parameter k.

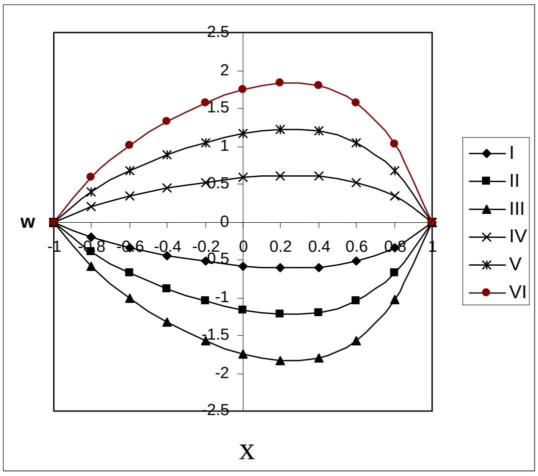

Fig. 1: Variation of w with G

	I	II	III	IV	V	VI
G	10^3	$2x10^3$	$3 x10^3$	-10^3	$-2 x10^3$	$-3 x10^3$

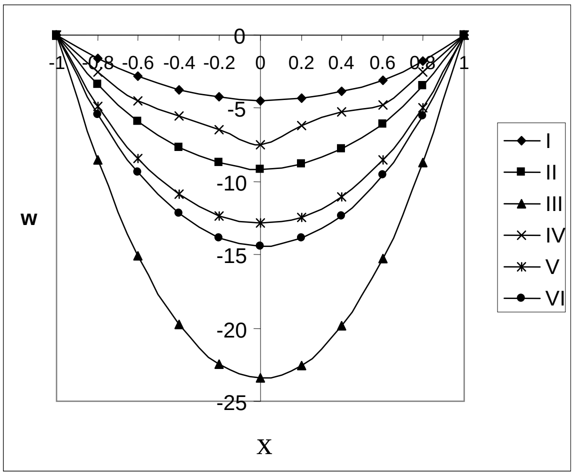

Fig. 2: Variation of w with m & N_1

	I	II	III	IV	V	VI
m	0.5	1.5	2.5	0.5	0.5	0.5
N_1	0.5	0.5	0.5	1.5	5	10

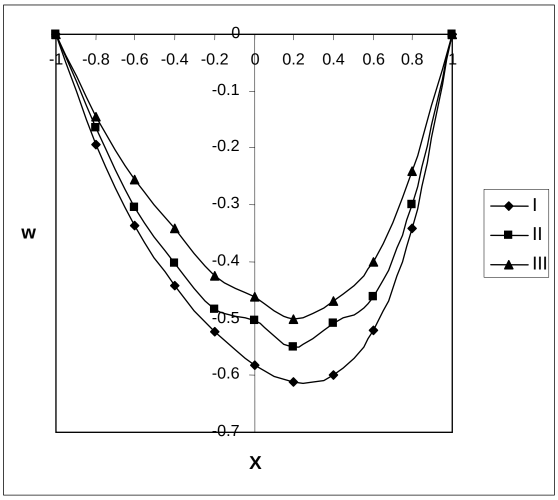

Fig.3: Variation of w with K

	I	II	III
K	1	1.5	2.5

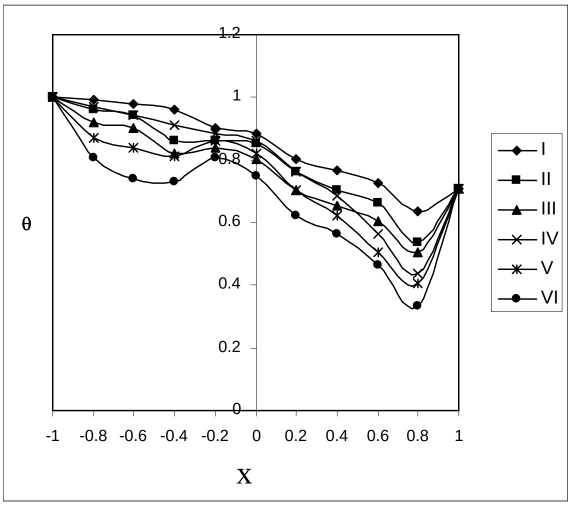

Fig. 4: Variation of θ with G

	I	II	III	IV	V	VI
G	10^3	$2x10^3$	$3 x10^3$	-10^3	$-2 x10^3$	$-3 x10^3$

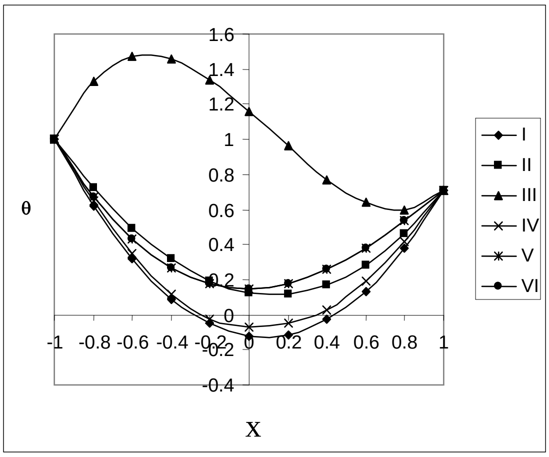

Fig. 5: Variation of θ with m & N_1

	I	II	III	IV	V	VI
m	0.5	1.5	2.5	0.5	0.5	0.5
N_1	0.5	0.5	0.5	1.5	5	10

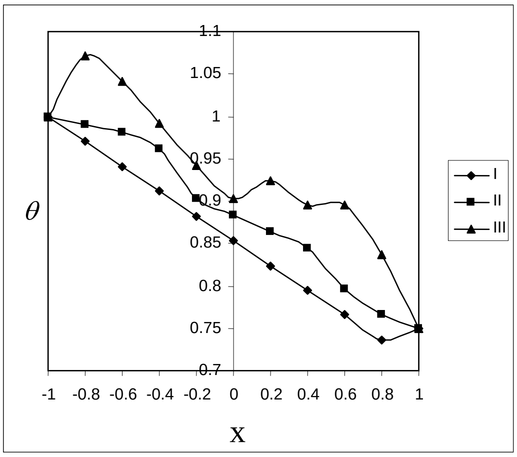

Fig.6: Variation of θ with K

	I	II	III
K	1	1.5	2.5

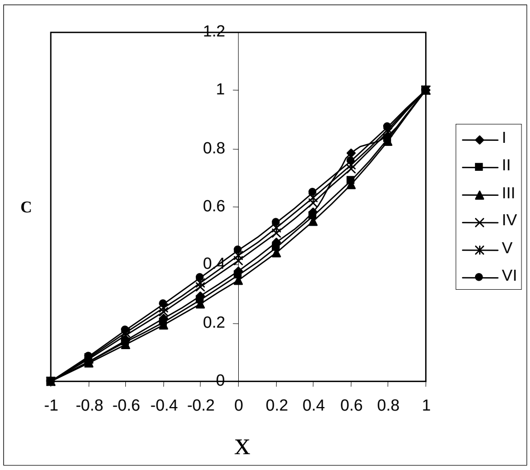

Fig. 7: Variation of C with G

	I	II	III	IV	V	VI
G	10^3	$2x10^3$	$3 x10^3$	-10^3	$-2 x10^3$	$-3 x10^3$

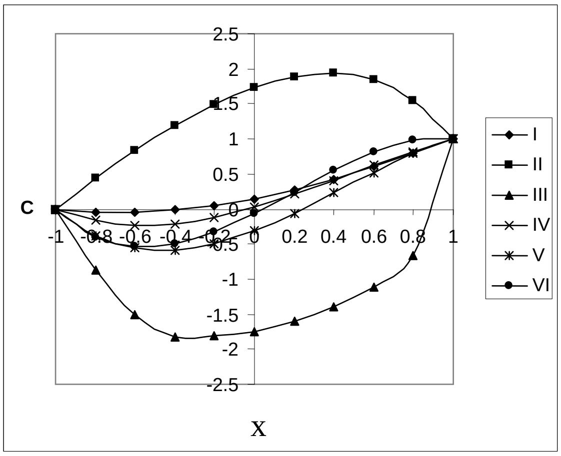

Fig. 8: Variation of C with m & N_1

	I	II	III	IV	V	VI
m	0.5	1.5	2.5	0.5	0.5	0.5
N_1	0.5	0.5	0.5	1.5	5	10

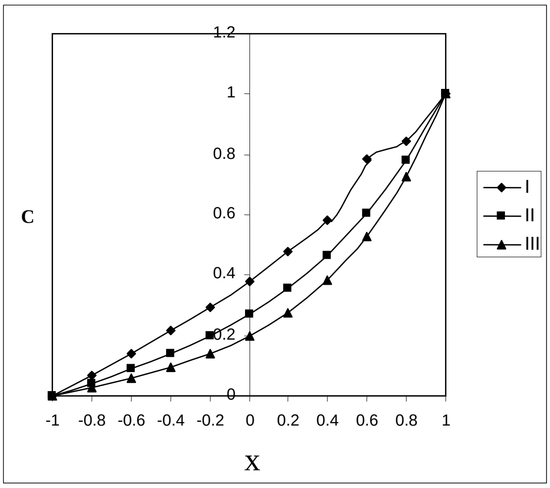

Fig.9: Variation of C with K

	I	II	III
K	1	1.5	2.5

7. TABLES:

The variation of Nu with Hall parameter m and N1 shows that the rate of heat transfer reduces at x=±1 with increase with m. An increase in the radiation parameter N1 enhances at x=±1 for all G (table.1and 2). The variation of sh with m&N1 shows that the rate of mass transfer at x=1 reduces with m≤1.5 and enhances with higher m≥2.5 for G>0 and for G<0, it depreciates with m for all G at x=-1 it enhances with m≤1.5 and reduces with m≥2.5 for all G. An increase in the radiation parameter N1 enhances Sh at x=±1 for all G (tables 3 and 4).

TABLE 1: Average Nusselt Number (Nu) at x = 1

G	I	II	III	IV	V	VI
1 X 10^3	0.3118	0.44940	-0.55832	0.56015	0.72006	0.76513
3 X 10^3	0.36812	1.18875	-1.00631	0.60320	0.76106	0.80494
- 1 X 10^3	0.27969	0.23752	0.14657	0.51465	0.67341	0.71803
-3 X 10^3	0.27608	0.29839	0.39473	0.48398	0.62096	0.65890
m	0.5	1.5	2.5	0.5	0.5	0.5
N_1	0.5	0.5	0.5	1.5	5	10

TABLE 2: Average Nusselt Number (Nu) at x = - 1

G	I	II	III	IV	V	VI
1 X 10^3	-0.63966	-0.67671	-0.38325	-0.80884	-0.95995	-0.99190
3 X 10^3	-0.58929	-0.12304	-1.02076	-0.81426	-0.90226	-0.93490
- 1 X 10^3	-0.64021	-0.53254	-0.1529	-0.84894	-0.98056	-1.01561
-3 X 10^3	-0.64021	-0.53254	-0.15829	-0.78984	-0.91417	-0.94682
m	0.5	1.5	2.5	0.5	0.5	0.5
N_1	0.5	0.5	0.5	1.5	5	10

TABLE 3: Average Sherwood Number (Sh) at x = 1

G	I	II	III	IV	V	VI
1 X 10^3	64.51674	0.26586	-2.16926	-2.36394	-0.89761	-0.79138
3 X 10^3	-20.02291	-1.91591	-2.09263	-3.15743	-0.45452	-0.36595
- 1 X 10^3	11.84572	-10.01369	-1.30981	-0.98404	-1.40617	-1.26835
-3 X 10^3	6.96089	-6.22597	-1.29710	-0.40797	-2.05927	-1.86622
m	0.5	1.5	2.5	0.5	0.5	0.5
N_1	0.5	0.5	0.5	1.5	5	10

TABLE 4: Average Sherwood Number (Sh) at x = -1

G	I	II	III	IV	V	VI
1 X 10^3	0.01924	0.45019	-0.22548	-0.24268	0.32342	0.34282
3 X 10^3	0.16761	37.0769	-0.27360	-0.38725	0.54139	0.56542
- 1 X 10^3	-0.15074	-0.34165	-0.29781	-0.12048	0.09884	-0.11382
-3 X 10^3	-0.35547	-0.66986	-0.21319	-0.01005	-0.13271	-0.11997
m	0.5	1.5	2.5	0.5	0.5	0.5
N_1	0.5	0.5	0.5	1.5	5	10

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