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The Radiative Effect on Velocity, Magnetic and Temperature Fields of a Magneto Hydrodynamic Oscillatory Flow past a Limiting Surface with Variable Suction

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Abstract: This paper examines the effect of heat transfer through radiation on velocity, magnetic and temperature fields in the case of two dimensional hydromagnetic oscillatory flow of a viscous incompressible and electrically conducting fluid, past a porous, limiting surface, subjected to variable suction and moving impulsively with a constant velocity in the presence of transverse magnetic field. The non linear partial differential governing equations were non-dimensionalised and then solved using perturbation techniques. The resulting set of ordinary differential equations were solved. Numerical calculations were carried out for various values of the parameters. It was found that increase in the radiative parameter, leads to decrease in temperature, magnetic and velocity as presented on graphs.

Key words: Radiation · Hydromagnetic Oscillatory Flow · Viscous Incompressible · Heat Transfer · Magneto- Hydrodynamics

INTRODUCTION

Oscillatory flow is of great importance owing to its many practical applications. It plays significant roles, in (i) a fluttering airfoil, (ii) the aerodynamics of a helicopter rotor and (iii) many bio-engineering projects.

Several studies have been carried out in this area. Some of these previous works which are relevant to the problem studied in this paper are the work by light hill [1] that studied the time-dependent viscous flow problem with the effect of unsteady fluctuations of the free-stream velocity on the flow in the boundary layer of an incompressible fluid past two-dimensional bodies. The effects of free stream oscillations on the flow past an infinite porous limiting surface with constant suction was examined by Stuart [2]. The above problem of Stuart was extended by considering variable suction as opposed to constant suction carried out by messiah [3].

In [4], Soundalgeker, extended Messiha's problem by studying the effects of the oscillatory free-stream on the flow past an infinite porous limiting surface with variable suction and moving impulsively with a constant velocity. Cookey *et al*. [5] proposed a model for the study of magneto hydrodynamic (MHD) free convection flow past an infinite heated vertical plate in a porous medium in which they observed that increased cooling of the plate was accompanied with an increase in the velocity.

Taneja and Jain [6] looked at the unsteady MHD flow in a porous medium in the presence of radiative heat. Where they obtained expressions for velocity, temperature and rate of heat transfer. Ojulu and Prakash [7] considered the two dimensional oscillatory flow of an incompressible viscous, radiatory electrically conducting fluid past an infinite wall with constant heat embedded in a porous medium of variable permeability with velocity components (U', V') in the (X', Y') direction. Rajagopal *et al*. [8] studied the effect of an oscillatory motion of a viscous elastic fluid over an infinite stretching sheet through porous media in the presence of magnetic fluid with applied suction.

The subject of magneto hydrodynamic (MHD) in recent years, had attracted many authors for its applications to astrophysics, geophysics and engineering observed by Cramer and Pai [9].

In this paper, the effect of heat transfer through radiation on velocity, magnetic and temperature is considered. The study also investigate the radiative effect on velocity, magnetic and temperature fields of a magneto hydrodynamic oscillatory flow past a limiting surface with variable suction.

More – over, we investigate the effect of heat transfer through radiation on velocity, magnetic and temperature fields in the case of two-dimensional hydro magnetic oscillatory flow, past a limiting surface with a variable suction.

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Problem Formulation: The purpose of this paper is to examine the radiative effect on velocity, magnetic and temperature fields of a magneto hydrodynamic oscillatory flow past a limiting surface with variable suction.

The- two-dimensional hydro magnetic oscillatory flow of a viscous incompressible and electrically conducting fluid, past a porous, limiting surface (e.g. of a star) with variable suction is considered. The limiting surface is moved impulsively with a constant velocity either in the direction of flow or in the opposite direction in the presence of transverse magnetic field is not negligible so that in the region considered H = [Hx′, Hy′, 0]. The x′ –axis is chosen along the limiting surface.

Within the framework of the above assumptions in the problem definition, the hydro magnetic flow relevant to the problem is governed by the set of equations: Continuity equation, the momentum equation, the magnetic induced equation and Energy equation, we finally arrived at the governing equations for the problem of our consideration as follows:

$$\frac{\partial v'}{\partial y'} = 0 \tag{1}$$

$$\frac{\partial u'}{\partial t'} + \frac{v'\partial u'}{\partial y'} = -\frac{1}{\rho}\frac{\partial p'}{\partial x'} + \upsilon'\frac{\partial^2 u'}{\partial y'^2} + \mu/\rho \, H_{Y'}\frac{\partial Hx'}{\partial y'} \tag{2}$$

$$\frac{\partial Hx'}{\partial t'} + \frac{v'\partial x'}{\partial y'} = -\frac{1}{\sigma\mu^0}\frac{\partial^2 Hx'}{\partial y^{12}} + Hy'\frac{\partial u'}{\partial y'} \tag{3}$$

$$C_p\left(\frac{\partial T}{\partial t} + v\frac{\partial T'}{\partial y}\right) = \frac{k}{\rho}\frac{\partial^2 T}{\partial y^2} + v\left(\frac{\partial u}{\partial y}\right)^2 + \frac{1}{\sigma\rho}\left(\frac{\partial Hx}{\partial y}\right)^2 - 4\left(T'_{-}T'_{\infty}\right)\int_0 K_{\lambda w}\left(\frac{\partial \ell_{b\wedge}}{\partial T_w}\right)\partial k \tag{4}$$

Subject to the following corresponding boundary conditions:

$$y' = 0; \quad u' = U', \quad Hx' = 0, \quad \frac{\partial T'}{\partial y} = 0;$$
$$y' \to \infty; \quad u \to U'(t'), \qquad Hx' = 0, \quad T' \to T'_{\infty} \tag{5}$$

We shall now solve the non linear partial differential governing equations using perturbation techniques. First, the required equations to be solved were non-dimensionalised. We now introduce the following non-dimensional parameters.

$$y = \frac{y'v'_0}{v}, u = \frac{u'}{U'_0}, t = \frac{v_0'^2 t'}{4v}, v = \frac{U'_1}{U'_0}, w = \frac{4v\omega'}{v_0^2}, H = \left(\mu_0/\rho\right)^{1/2}\frac{Hx'}{U'_0}$$
$$P_m = \sigma\mu_0 v, \qquad m = \left(\mu_0/\rho\right)^{1/2} H_0/V'_0, \; p = \frac{v}{k}, \theta = \frac{T' - T'_0}{T^i_{\infty}} \tag{6}$$
$$E = \frac{U'_0}{Cpt'_{\infty}}, K = \frac{k}{\rho cp}, C = \frac{4v}{v_0^{12}}Cp\int_0^w k_{\lambda w}\left(\frac{\partial \ell_{b\lambda}}{\partial T}\right)\partial h$$

Following [7], Equation (1) for variable velocity integrates to

$$V = -V_0\left[1 + \varepsilon A e^{i\omega t}\right] \tag{7}$$

Where V'_0 is the constant mean velocity, A and ε are small positive constants such that ε are small positive constants such that εA<<1 and ω′ is the frequency of free-stream oscillation.

Let $\cup'(t')$ be the free- stream velocity and by boundary conditions (4), equation (2), becomes

$$-\frac{1}{\rho}\frac{\partial p'}{\partial x'}=\frac{\partial \text{U}'}{\partial t} \tag{8}$$

Also, from Maxwell's Equations the components of the electric current density are given by

$$\xi x'=0 \qquad \xi y'=0 \quad \text{and} \qquad \xi z'=-\left(\frac{\partial Hx'}{\partial y'}\right) \tag{9}$$

and the divergence equation for the magnetic field gives.

$$\text{Hy}'=\text{H}_0=\text{constant} \tag{10}$$

Where H_0 is the externally applied transverse magnetic field.

Where H_0 is the mean free-stream velocity, P_m the magnetic Prandt number, M the Magnetic field parameter, H the induced magnetic field, θ is the non-dimensional temperature, P is the Prandth number and E is the Eckert number.

With the aid of equations (6), (7), (8) and (10), coupled with the non – dimensional quantities, Equations (2) and (3) reduce to

$$\frac{1}{4}\frac{\partial u}{\partial t}-\left[1+\varepsilon A\ell^{i\omega t}\right]\frac{\partial u}{\partial t}=\frac{1}{4}\frac{\partial u}{\partial t}+\frac{\partial^2 U}{\partial y^2}+M\frac{\partial H}{\partial y} \tag{11}$$

$$\frac{1}{4}\frac{\partial H}{\partial t}-\left[1+\varepsilon Ae^{iwt}\right]\frac{\partial H}{\partial y}=\frac{1}{P_m}\frac{\partial^2 H}{\partial y^2}+\frac{M\partial U}{\partial y} \tag{12}$$

$$\frac{1}{4}\frac{\partial \theta}{\partial t}-\left[1+\varepsilon Ae^{iwt}\right]\frac{\partial \theta}{\partial y}=\frac{1}{p}\frac{\partial^2 \theta}{\partial y^2}+E\left(\frac{\partial u}{\partial y}\right)+E\left(\frac{\partial H}{\partial y}\right)^2-C\theta \tag{13}$$

In view of equations (2) and (3) the boundary condition (5) in the non –dimensional form become

$$\text{Y}=0\,;\ \text{U}=\text{v}\,;\ \ \text{H}=0\,;\ \frac{\partial\theta}{\partial y}=0$$

$$\text{Y}\rightarrow\infty;\ \text{u}\rightarrow\text{U};\ \text{H}\rightarrow 0,\ \theta\rightarrow 0 \tag{14}$$

Analysis: We simplify equations (11), (12) and (13) under the boundary conditions in (14) by equating the harmonic and the non-harmonic terms and neglecting the coefficients of ϵ^2 when the magnetic Prandtl number $P_m = 1$ i.e., $V = \alpha$ and magnetic parameter M < 1. We finally get the expressions for the velocity and for the induced magnetic field as

$$U(y,t)=1+\frac{(v-1)}{2}\left(\ell^{-\alpha y}+\ell^{-\beta y}\right)+\varepsilon\,\ell^{-iwt}\left(1-ki(\ell^{-c_1 y}\ell^{-\alpha y})-\lambda i(\ell^{-dy}-\ell^{-\beta y})\right) \tag{15}$$

$$\text{H}(y,t)=\frac{v-1}{2}(\ell^{-\alpha y}-\ell^{-\beta y})+\varepsilon\,\ell^{iwt}(-ki(\ell^{-c_1 y}\ell^{-\alpha y})+\lambda i(\ell^{-dy}-\ell^{-\beta y})) \tag{16}$$

The real part of the velocity, from expression (15), can be written in terms of the fluctuating parts as

$$\text{Re (u)} = 1 + \frac{v-1}{2}(\ell^{-\alpha y} + \ell^{-\beta y}) + \varepsilon\,(u_1 \cos t + u_2 \sin \omega t) \tag{17}$$

$$\text{Or Re (u)} = 1 + \frac{v-1}{2}(\ell^{-\alpha y} + \ell^{-\beta y}) + \varepsilon \left| u_{12} \right| \cos + (\omega_t - \alpha_1) \tag{18}$$

Where

$$u_1 = 1 - \frac{2A(v-1)}{w}(\alpha \ell^{-c_{11} y} \sin c_{12} \left(y + \beta \ell^{-diy} \sin d_2 y \right) \tag{19}$$

$$u_2 = 1 - \frac{2A(v-1)}{\omega}(\alpha(\ell^{-c_{11} y} \cos c_{12}(y - \ell^{-\alpha y}) + \beta(\ell^{-diy} \cos d_2 y - \ell^{-\beta y})) \tag{20}$$

$$\left| u_{12} \right| = (u_1^2 + u_2^2)^{1/2}, \quad \tan \alpha_1 = u_2 / u_1$$

Also, the real part of the induced magnetic field, from Equation (16) can be written as Re(H)

$$= \frac{V-1}{2}\left(e^{-xy} - e^{-\beta y} \right) + \varepsilon \left(H_1 \cos \omega t - H_2 \sin \omega t \right) \tag{21}$$

$$\text{Or Re(H)}\ \frac{v-1}{2}(\ell^{-\alpha y} - \ell^{-\beta y}) + \varepsilon \left| H_{12} \right| \cos(\omega t + \alpha_2) \tag{22}$$

Where

$$\text{H}_1 = \frac{2A(v-1)}{\omega}(\beta \ell^{-diy} \sin d_2 y - \alpha \ell^{c_{11} y} \sin C_{12} y)$$

$$\text{H}_2 = \frac{2A(v-1)}{\omega}(\beta(\ell^{-diy} \cos d_2 y - \ell^{-\beta y}) - (\ell^{-ciy} \cos C_2 y - \ell^{-\alpha y})) \tag{23}$$

$$\left| H_{!2} \right| = (H_1^2 + H_2^2)^{1/2,}, \tan \alpha_2 = H_2 / H_1$$

Hence we can now write expressing for the transient velocity and for the transient induced magnetic field, respectively, when $\omega t = \pi/_2$ as

$$R_e(u) = 1 + \frac{v-1}{2}(\ell^{-\alpha y} + \ell^{-\beta y}) + \varepsilon\, u_2 \tag{24}$$

$$and\ R_e(H) = 1 + \frac{v-1}{2}(\ell^{-\alpha y} - \ell^{-\beta y}) - \varepsilon\, H_2 \tag{25}$$

Knowing the velocity field, we can now calculate the skin friction as

$$\tau = \frac{\tau^1}{QU_0^1 V_0^1} = \frac{\partial u}{\partial y}\Big|_{v=0}$$

$$\begin{aligned} \tau &= \frac{\tau^1}{QU_0^1 V_0^1} = \frac{\partial u}{\partial y}\Big|_{v=0} \\ &= 1 - v + 2A\frac{(v-1)}{w} i(\alpha(c-\alpha) + \beta(d-\beta) \end{aligned} \tag{26}$$

In terms of the amplitude and phase of the skin friction, we have from (26)

$$\text{Re }(\tau) = 1 - v - \varepsilon(\tau_1 \cos_{wt} + \tau_2 \sin w_t) \tag{27}$$

Or

$$R_e(\tau) = 1 - v - \varepsilon|\tau_{12}\ |\cos(w_t - \alpha_2) \tag{28}$$

Where

$$\tau_1 = 2A\frac{(v-1)}{w}(\alpha C_{12} + \beta d_2)$$

$$\tau_2 = 2A\frac{(v-1)}{w}(\alpha C_{11} - \alpha) + \beta(d_2 - \beta)$$

$$|\tau_{12}| = (\tau_1^2 + \tau_1^2)^{1/2}, \tan\alpha_3 = \tau_2 / \tau_1 \tag{29}$$

Finally, we get, for the electric current density, the expression.

$$\frac{v5z_1}{U_0'V_0'}\left(\frac{\mu_0}{Q}\right)^{1/2} = \frac{\partial H}{\partial y}$$

$$= \frac{v-1}{2}(\alpha\ell^{-\alpha y} - \beta\ell^{-\beta y}) + \frac{2A(v-1)}{\omega}i\varepsilon\,\ell^{iwt}x(\beta(d\ell^{-\alpha y} - \beta\ell^{-\beta y}$$
$$-\alpha(c_1\ell^{-ciy} - \alpha\ell^{-\alpha y} \tag{30}$$

Hence,

$$R_e(z) = \frac{v-1}{2}(\alpha\ell^{-\alpha y} - \beta\ell^{-\beta y}) + 2A\frac{(v-1)}{\omega}\varepsilon(Z_1\cos w_t - Z_2\sin w_t) \tag{31}$$

$$or R_e(z) = \frac{v-1}{2}(\alpha\ell^{-\alpha y} - \beta\ell^{-\beta y}) - 2A\frac{(v-1)}{w}\varepsilon(Z_{12}\cos(\omega_t + \alpha_1)$$

Where

$$Z_1 = \beta\ell^{-diy}(d_1\sin d_2 - d_2\cos d_{2y}) - \alpha\ell^{-c_{11}y}(c_{11}\sin c_{12}y - c_{12}\cos c_{12}y) \tag{33}$$

$$Z_2 = \beta\ell^{-diy}(d_1\cos d_2 y + d_2\sin d_2 y) - \alpha\ell^{-c_{11}y}(c_{11}\cos c_{12}y + c_{12}\sin c_{12}y) + \alpha^2\ell^{\alpha y} - \beta^2\ell^{-\beta y} \tag{34}$$

$$|Z_{12}| = (Z_1^2 + Z_1^2)^{1/2}, \tan\alpha_4 = z_2 / z_1$$

The values of f_1, f_2, g_1, g_2, θ_0, θ_1, θ_2, u(y, t), H(y, t) and θ(y, t) were determined using a computer programme pascal see Appendix and the table of results that gave the graphs in chapter four are also affected in the appendix.

RESULTS AND DISCUSSION

This paper examines the effect of heat transfer through radiation on velocity, magnetic and temperature fields in the case of two-dimensional hydro magnetic oscillatory flow of a viscous incompressible and electrically conducting fluid, past a porous, limiting surface subjected to variable suction and moving impulsively with a constant velocity in the presence of a transverse magnetic field.

In order to point out the radiation effect on magnetic, velocity, temperature and on all the other quantities, the following discussion is set out. Numerical calculations are carried out for different values of the magnetic parameter M, the limiting surface velocity V, of the free-stream oscillation frequency ω, of the radiative fluid C and of the suction parameter A. The velocity V of the limiting surface can take positive or negative values. The positive value indicate that the impulsive velocity of the limiting surface is in a direction opposite to that of the flow.

The mean velocity profiles f_1 shown in figure 1 for different values of the magnetic parameter M and of the limiting surface velocity V, we observe that when the magnetic parameter M increases, the mean velocity decreases; here also the magnetic field is limited to only retardation as normal. Also from this figure we see that the mean velocity increases when the limiting surface moves in the positive direction of the flow, whereas it decreases when it moves in the opposite direction. The variations of the transient velocity profiles are shown in figure 2 for different values of the suction parameter A, the magnetic parameter M, the limiting surface velocity V and the free- stream oscillation frequency ω, when $\varepsilon = 0.2$ and $\omega t = \pi/2$. We see that for all values of A there is a reverse type of flow when the limiting surface moves in direction opposite to that of the flow and as ω increases, the transient velocity decreases near to the limiting surface. The variations of the ransient velocity with M and V are the same with those of the mean velocity. From figures 1 and 2 we observe that there is a reversed type of flow when the limiting surface moves in the direction opposite – the velocity being positive – the reverse type of flow does not occur. The variations of the fluctuating parts of the velocity profiles $u_1$and u_2 are shown in figures 3 and 4, respectively. From these we see that as M increases u_1 and u_2 decreases and an increase in ω leads to an increase in $u_1$and u_2. For positive values of V we observe that $u_1$and u_2 decrease with increasing V whereas an increase in V in the reverse direction leads to an increase in $u_1$and u_2. The amplitude $|u_{12}|$ and the phase tan $\alpha_1$of the velocity profiles are shown in figures 5 and 6, in which we see that the suction parameter A increases, $|u_{12}|$ and tan α_1 increase, while as the magnetic parameter M and frequency ω increase, the amplitude and the phase decrease.

The mean induced magnetic field, g and the transient induced magnetic field, H, are shown in figures 7 and 8. from these we see that as M increases and for positive values of V, g and H decrease with increasing V, whereas an increase in V in the reverse direction leads to an increase in g_1 and H. Also from figure 8 we observe that as A or ω increase, the transient induced magnetic field also increases. The variations of the fluctuating parts H_1 and H_2 of the induced magnetic field are shown in figures 9 and 10.

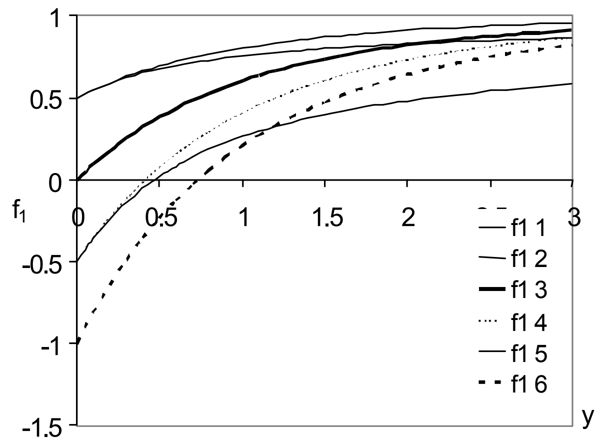

Fig. 1: Mean velocity profiles (f_1)

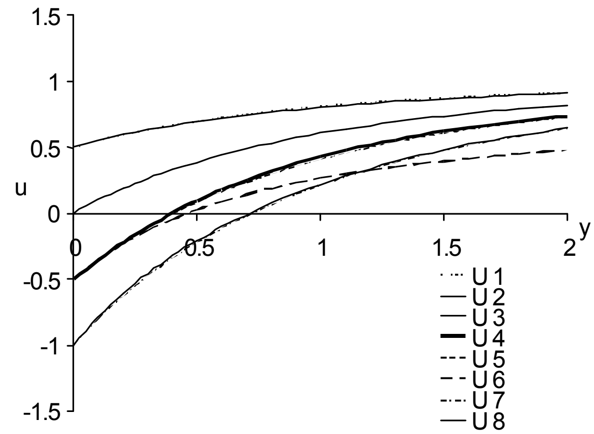

Fig. 2: Transient velocity profiles (u)

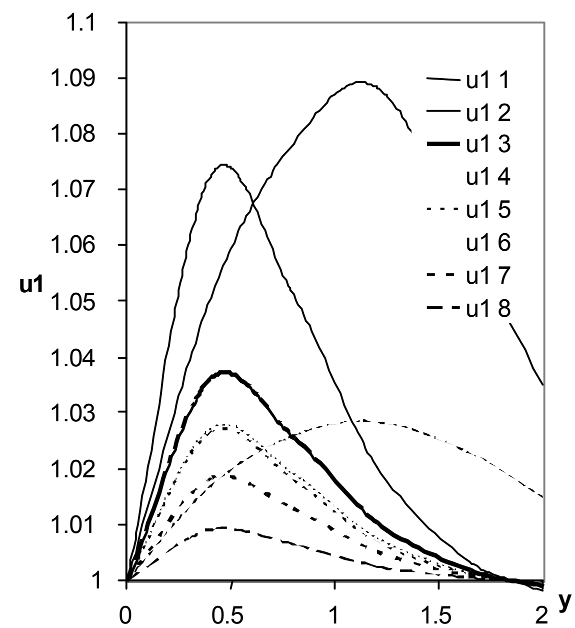

Fig. 3: Fluctuating part of velocity profiles (u_1)

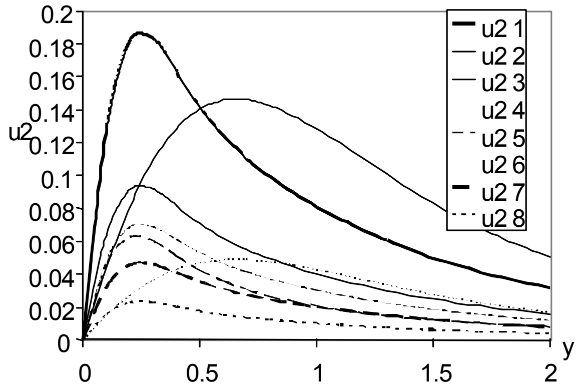

Fig. 4: Fluctuating part of velocity profiles (u_2)

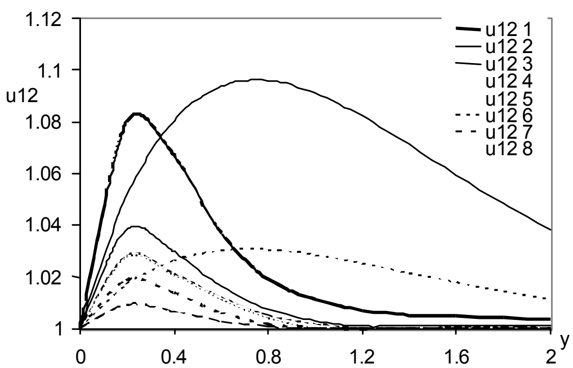

Fig. 5: Amplitude of velocity profiles ($|u_{12}|$)

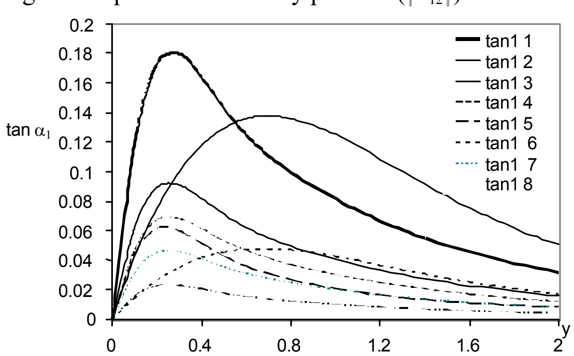

Fig. 6: Phase of velocity profiles ($\tan \alpha_1$)

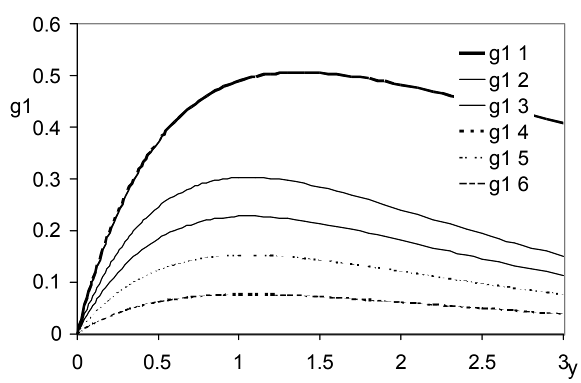

Fig 7: Mean induced magnetic field (g_1)

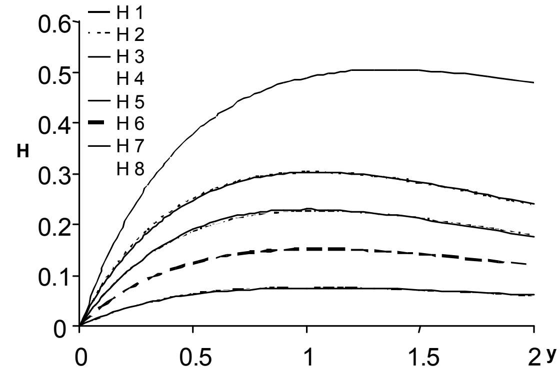

Fig. 8: Transient induced magnetic field (H)

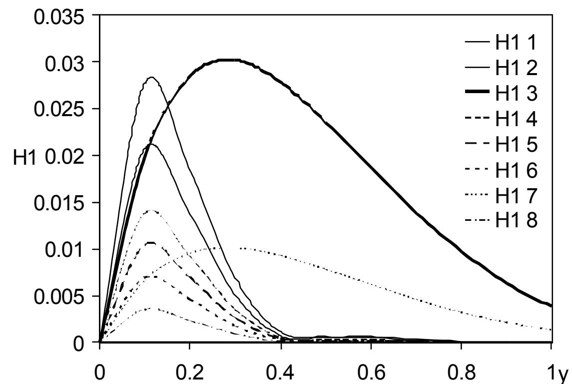

Fig. 9: Fluctuating part of induced magnetic field (H_1)

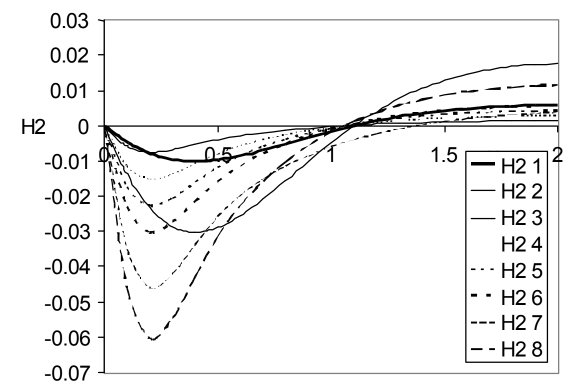

Fig. 10: Fluctuating part of induced magnetic field (H_2)

From figure 9 we see that as A or M increases, H_1 also increases, while as ω increases, the fluctuating part H_1 decreases. Also from this figure we observe that the variations of H_1 are the same as those of the transient induced magnetic field H and from figure 10 we see that the variations of the fluctuating part H_2 with A, M and V are opposite to those of H_1. The amplitude $|H_{12}|$ of the induced magnetic field is shown in figure II. From this figure we derive similar conclusions to those for H_1. The phase $\tan \alpha_2$ of the induced magnetic field is shown in figure 12 and we see that as the magnetic parameter M or

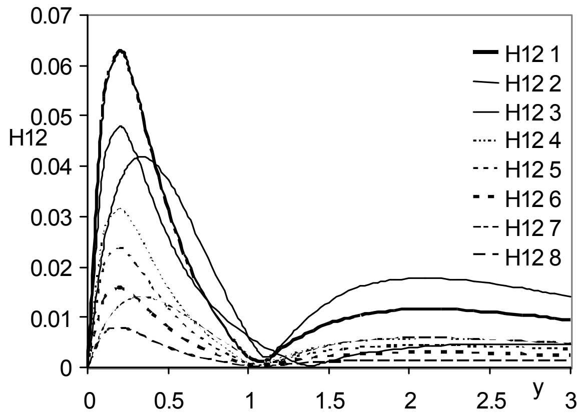

Fig. 11: Fluctuating part of induced magnetic field (H_2)

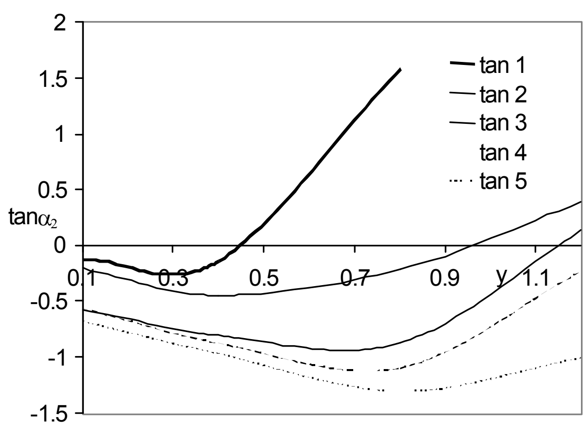

Fig. 12: Phase of induced magnetic field (tan α_2)

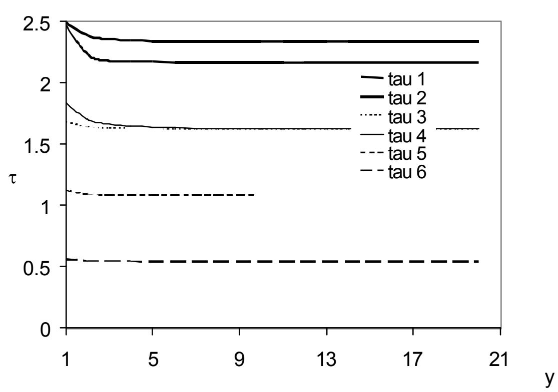

Fig. 13: The variation of skin friction (τ)

frequency ω increases, the phase of the induced magnetic field decreases. From this figure we also observe that the phase tan α_2 is independent of suction parameter A and limiting surface velocity V.

The skin friction τ is plotted against ω in figure 13. It is observed that τ increases as the suction parameter A increases, whereas it decrease as the magnetic parameter increases. Also an increase in the positive values of V

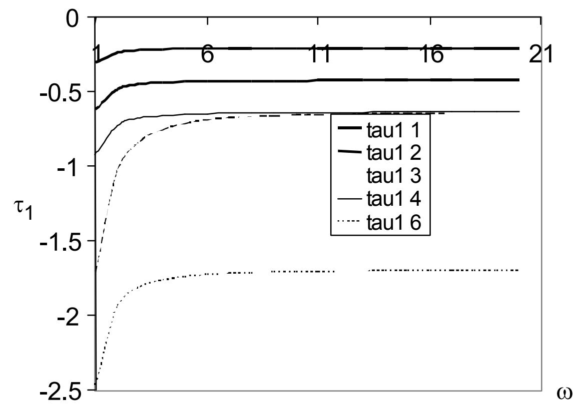

Fig. 14: Fluctuating part of skin friction (τ_1)

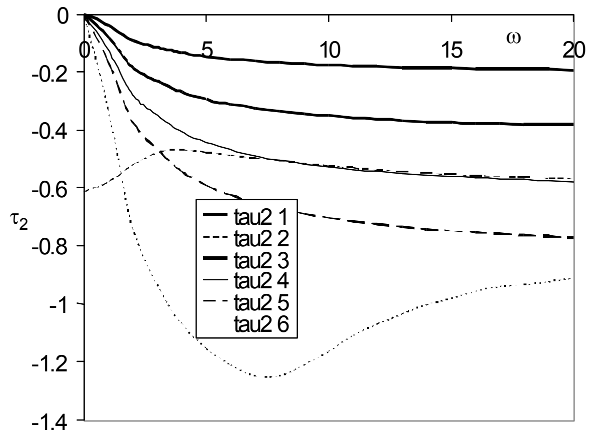

Fig. 15: Fluctuating part of skin friction (τ_2)

leads to a decrease in the skin friction, whereas an increase in the negative values of v leads to an increase in the friction, whereas an increase in the negative values of V leads to an increase in the skin friction. The fluctuating parts τ_1 and τ_2 of the skin friction are shown in figures 14 and 15, respectively. We see that as A increases τ_1 and τ_2 decreases, whereas they increase as M increases. Also we see that for positive values of V, τ_1 and τ_2 increase with increasing v, whereas an increase in V in the reverse direction leads to a decrease in τ_1 and τ_2. The amplitude $|\tau_{12}|$ of the skin friction is shown in figure 16. we see the amplitude increases with increasing value of M. the amplitude of the skin friction is also more when the plate moves in the opposite direction of the flow as compared to the amplitude in the case of a plate moving in he same direction of the flow. The phase of the skin friction is shown in figure 17. From this figure we observe that as M or ω increase, the phase of the skin friction decreases. Also, we see that the phase of the skin friction is independent of the suction parameter A and of the limiting surface velocity v and is always positive.

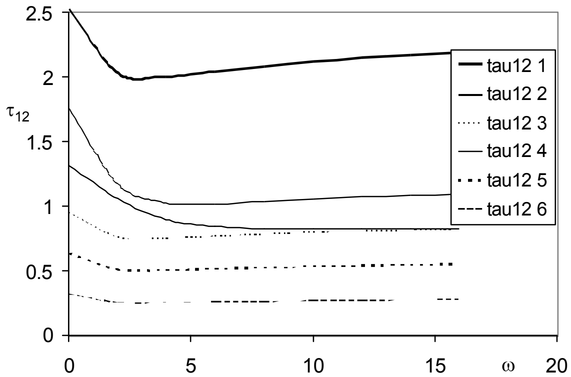

Fig. 16: Amplitude of the skin friction ($|\tau_{12}|$)

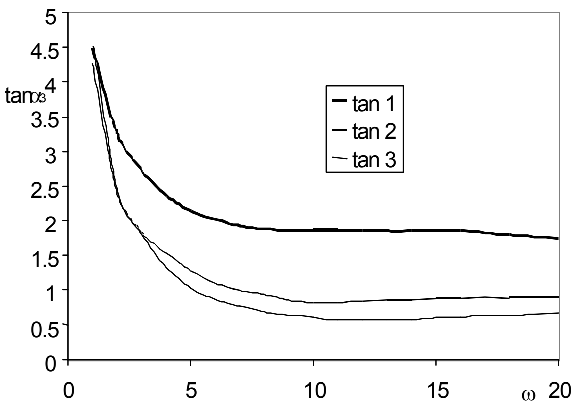

Fig. 17: Phase of the skin friction (tan α_3)

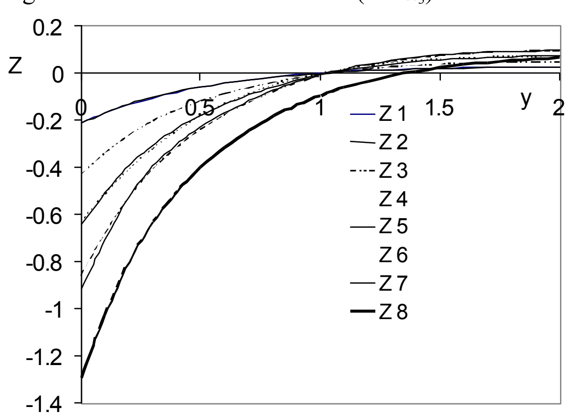

Fig. 18: Electric current density (Z)

The variations the electric current density Z, the fluctuating parts, Z_1, Z_z and the amplitude of the electric current density $|Z_{12}|$ are plotted in figure 18. From this figure we see that as A or M increase, all the above quantities also increase. We observe that when the limiting surface moves in the positive direction of the flow, the above quantities increase as v increase, whereas they decrease when it moves in the opposite direction. From figure 18 we see that the electric current density z

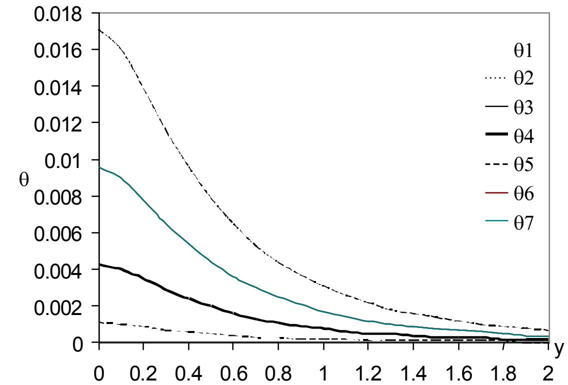

Fig. 19: Fluid Temperature at c = 1

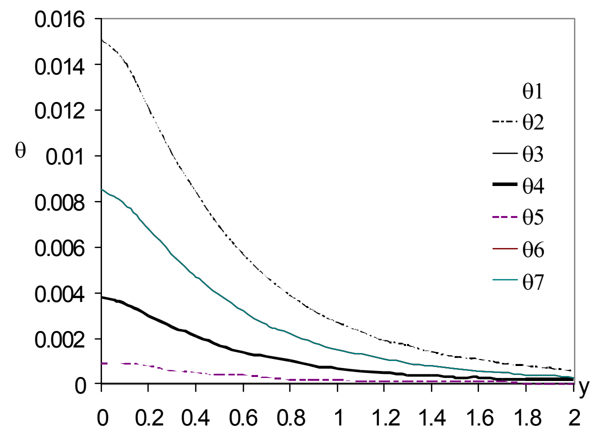

Fig. 20: Fluid Temperature at c = 2

flows in the negative z - direction $y < y^c$ and in the positive z – direction in $y > y^c$. The total electric current across the OY′ direction is certainly.

Zero. Also from this figure we note that for large values of M the point y_c is going away from the limiting surface.

The variation of fluid temperature θ inside the thermal boundary layer for different values of the dimensionless parameters entering into the problem is shown in figures 19-21. it is observed that the dimensionless fluid temperature θ increase with the frequency ω when than when the limiting surface moves in the direction opposite to that of the flow. Also, it is greater when the limiting surface moves in the direction opposite to that of the flow ($v < 0$) than when it is stationary ($v = 0$) or moves in the direction of the fluid flow ($v > 0$), the fluid temperature, is not significantly affected by the suction parameter A. Finally, for different values of radiative magneto hydrodynamic fluid C, we observe that the temperature parameter θ is significantly affected by the large values of C. In figures 22 we observed that when C varies θ decreases.

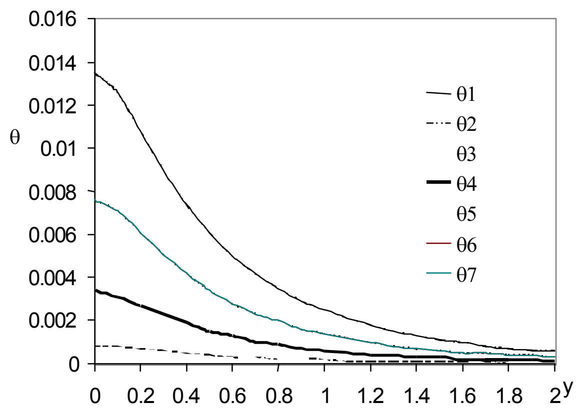

Fig. 21: Fluid Temperature at c = 3

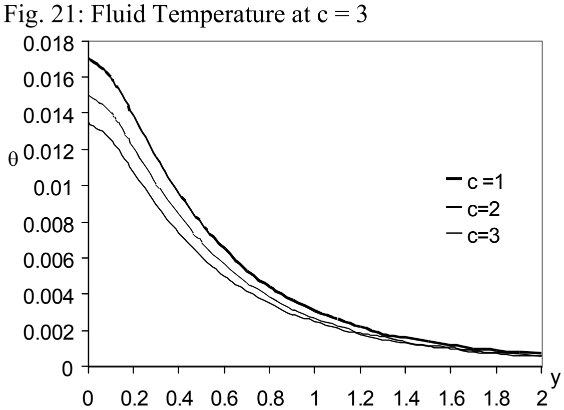

Fig. 22: Fluid Temperature for different c

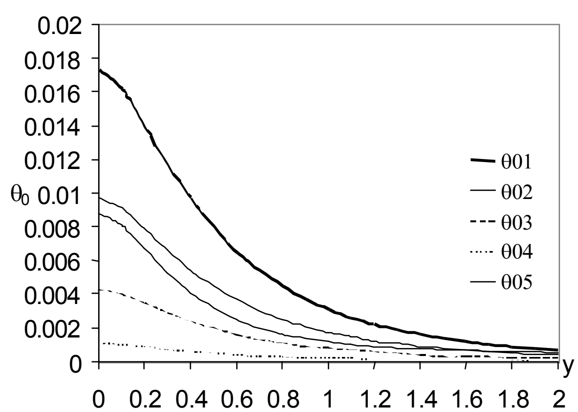

Fig. 23: Mean steady temperature at c = 1

The temperature of the limiting surface is shown in figures 23 – 25. from this figure we conclude that when the magnetic parameter M increases the temperature of the limiting surface decreases. The influence of the suction parameter A on θ (0) is insignificant, but θ (0) is influenced considerably by the Eckert number E, Also the limiting surface temperature is not significantly affected by large values of ω, when V > 0 but significantly affected by large value of C.

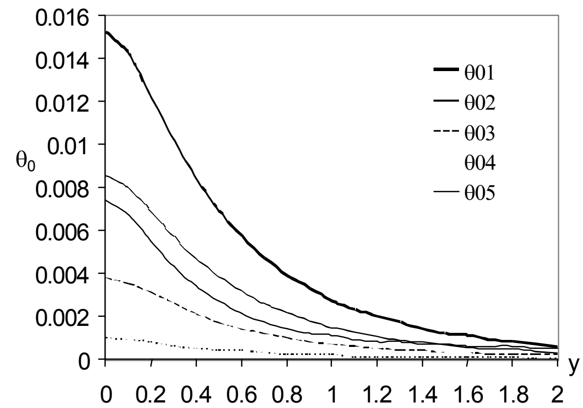

Fig. 24: Mean steady temperature at c = 2

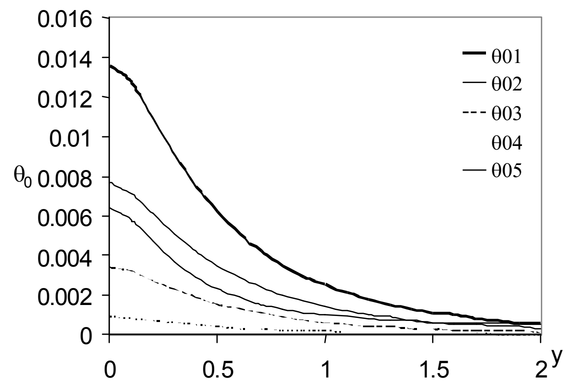

Fig. 25: Mean steady temperature at c = 3

The variations of the mean steady temperature θ_0 are shown in figures 27-30. An increase in the magnetic parameter M leads to a decrease in the mean steady temperature θ_0. Also, as in the other cases (figures 19 – 25) the mean steady temperature inside the thermal boundary layer is greater when the limiting surface moves in the direction opposite to that of the flow with velocity equal to that of the free-stream (v = 1) but decreases when the radiative fluid C increases.

CONCLUSION

This dissertation examines the effect of heat transfer through radiation on velocity, magnetic and temperature fields in the case of two- dimensional hydro magnetic oscillatory flow of a viscous incompressible and electrically conducting fluid, past a porous, limiting surface subjected to variable suction and moving impulsively with a constant velocity in the presence of transverse magnetic field.

The non linear partial differential governing equations were non- dimensionalised and then solved using perturbation techniques. The results set of ordinary differential equations was solved. Numerical calculations were carried out for various values of the parameters.

In the radiative effect on velocity, magnetic and temperature fields of a magneto hydrodynamic oscillatory flow past a limiting surface with variable suction.

Our findings are:

- When radiative fluid C, is zero we got what he observed.
- Other results followed the same trend as the (author).
- When C varies θ decreases as well as all other parameters, which show that velocity, magnetic and temperature fields are significantly affected by the values of C.

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Nomenclature:

U'_1 = Velocity of the limiting surface.
$U'(t')$ = Free- stream velocity.
U' = Velocity components in the x'- direction.
V' = Velocity components in the y'- direction.
t' = Time.
σ' = Electrical Conductivity of the fluid.
μ_0 = Magnetic permeability.
ρ = Density.
υ = Coefficient of kinematics viscosity.
P' = Pressure.
V'_0 = Constant mean velocity.
ω = Frequency of free-stream oscillation.
εA = Small positive constant <<1.
U'_0 = Mean free-stream velocity.
P_m = Magnetic Prandtl number.
M = Magnetic field parameter.
H = Induced magnetic field.
H_0 = Externally applied transverse Magnetic field.
C = Radiative magneto hydrodynamic fluid.
θ = Non- dimensional temperature.
E = Ecker number.
Cp = Specific heat at constant pressure.
T = Temperature in the boundary layer.
K = Thermal conductivity.

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