Physical sciences

THE EFFECTS OF HALL CURRENT ON MHD BY NATURAL CONVECTION FLOW OVER AN INFINITE VERTICAL POROUS PLATE.

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Abstract:

The purpose of this paper is to analyze the influence of hall current on natural convection flow, in the presence of magnetic field. The present mathematical analysis consists of continuity equations, momentum equation and energy equations, which are simplified using the approximation of flow regime. The reduced coupled differential equations are solved analytically. The velocity distribution and local skin friction for secondary flow of Bismuth and lithium have been calculated. The impact of all the physical parameters of interest, such as Reynolds number, Hartmann number and Prandtl number are taken into account.

Keyword: Magnetohydrodynamics, Magnetic field, Reynolds number.

Introduction:

The phenomenon of Magnetohydrodynamics free convection flow with heat transfer from different geometrics bounded by a porous medium has several engineering and geophysical application, such as, in geothermal reservoirs, underground energy transport, drying of porous solids, thermal insulation etc. Convective flows also play an important role in chemical engineering, turbo machinery and aero space engineering which may arise either due to unsteady motion of boundary temperature.

Soundalgekan showed that the effect of free convection on steady MHD flow of an electrically conducting fluid past a vertical plate [1]. Mansutti etal have discussed the steady flow of a non-Newtonian fluid past a porous plate with suction and injection [2]. soundalgekar analyzed the transient free convection flow with mass transfer on an isothermal vertical flat plate employing finite difference scheme [3]. Raptis and kafousias investigated the flow and heat transfer in an electrically conducting fluid through a porous medium past an infinite vertical plate under action of transverse magnetic field [4]. Grubka and Bobba discussed the heat transfer characteristics of a continuously stretching surface with variable temperature [5]. Takhar and his associated discussed the transient free convection flow past a semi infinite vertical plate with variable surface temperature [6]. Das and co-workers analyzed the transient free convection flow past an infinite vertical plate under periodic variation of temperature [7]. Pathal etal estimated the unsteady mass momentum and heat transfer in MHD free convection flow along a vertical plate suddenly set in motion [8]. The unsteady free convection MHD flow and heat transfer of a second order fluid between two heated vertical plates through a porous medium was studied [9]. The effect of mass transfer on MHD flow and heat transfer past a vertical porous plate through a porous medium under oscillatory suction and heat source [10].

In recent years, the problem of free convection flow have been extensively studied due to its application in the physical and engineering problems such as nuclear waste repositors, influence of the magnetic field on natural convention flow in liquid metals, ionized gases etc, in view to these applications many researchers have studied MHD natural convection flow in a porous medium [11-12].

Geometrical Interpretation:

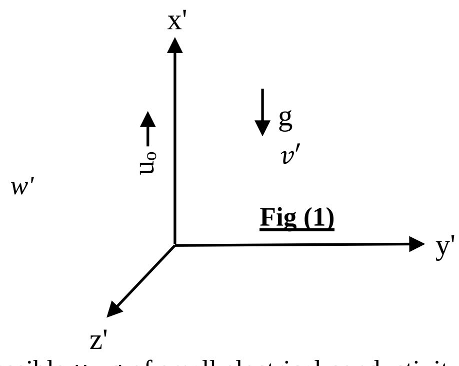

Fig (1)

We have consider a viscous incompressible fluid of small electrical conductivity on an infinite vertical porous plate, located at the plane $y' = 0$. The x'- axis is taken along the plate in upward direction and z'- axis is normal to the plane $x' - y'$. The plane is moving with a time dependent velocity. The magnetic field is applied in y'- direction. The joule heating terms have been neglected Hall current gives rise to the Lorentz force in z'- direction which induces a cross flow in that direction.

Assumptions:

It is assumed that the magnetic field Reynold number Rem <<1. Under these conditions we neglect the induced magnetic field in compression to the applied magnetic field. The plate being infinite in length all the physical variables depend on *y*' and *t*'

Formulation:

Applying the Boussineq -approximation the boundary layer energy and diffusion equations along with Maxwell's electromagnetic equations can be written as,

Continuity equation

$$\nabla \cdot \vec{\upsilon} = 0 \tag{1}$$

Momentum equation

$$\frac{\partial \vec{\upsilon}}{\partial t'} + (\vec{\upsilon}\cdot\nabla)\vec{\upsilon} = -\frac{1}{\rho}\nabla p + \nu\nabla^2\vec{\upsilon} + g\beta'(T - T_\infty) + g\beta'_2(C - C_\infty) + \frac{1}{\rho}(\vec{J}\times\vec{B}) \tag{2}$$

Energy equation

$$\frac{\partial T}{\partial t'} + (\vec{\upsilon}\cdot\nabla)T = \left(\frac{\nu}{P_r}\right)\nabla^2 T \tag{3}$$

Generalized ohm's law

$$\vec{J} = \sigma\left(\vec{E} + \vec{\upsilon}\times\vec{B}\right) - \frac{\sigma}{en_e}\left(\vec{J}\times\vec{B} - \nabla\rho_e\right) \tag{4}$$

The generalized ohm's law in absence of electric field can be written as

$$\vec{J} + \left(\frac{\omega_e l_e}{B_o}\right)\left(\vec{J}\times\vec{B}\right) = \sigma\left\{\vec{\upsilon}\times\vec{B}\left(\frac{\nabla\rho_e}{en_e}\right)\right\} \tag{5}$$

For weakly ionized gas the electron pressure gradient and ion slip effects which arise due to the imperfect coupling between ions and neutral particles can be neglected so equation (5) can be expressed as

$$J_{x'} = \sigma B_o\left(\frac{1}{1+H^2}\right)(Hu' - W')$$
$$J_{z'} = \left(\frac{\sigma B_o}{1+H^2}\right)(u' + HW') \tag{6}$$

Under the above conditions equations (1) to (5) for unsteady natural convection flow with magnetic field,

Continuity equation

$$\frac{\partial \upsilon'}{\partial t'} = 0 \tag{7}$$

Momentum equation in *z*' direction is

$$\frac{\partial w'}{\partial t'} + \upsilon'\frac{\partial w'}{\partial y'} = \nu\frac{\partial^2 w'}{\partial y'^2} - \frac{\sigma B_o^2}{\rho}\left(\frac{w' + Hu'}{1+H^2}\right) \tag{8}$$

Energy equation

$$\frac{\partial T'}{\partial t'} + \upsilon'\frac{\partial T}{\partial y'} = \left(\frac{\nu}{P_r}\right)\frac{\partial^2 T}{\partial y'^2} \tag{9}$$

Which approximate boundary condition (7) to (9) becomes

$$\upsilon' = \upsilon'_o(t') \tag{10}$$

Then equation is

$$\upsilon'_o \frac{\partial w}{\partial y} = \frac{\partial^2 w}{\partial y^2} - \frac{M}{1+H^2}\left(w - Hu\right) \tag{11}$$

$$\upsilon'_o \frac{\partial \theta}{\partial y} = \frac{1}{P_r}\frac{\partial^2 \theta}{\partial y^2} \tag{12}$$

Where υ' and w' are velocity components along *y*' and *z*' direction. B_o is magnetic induction, *E* is electric field vector, β is Grashof ratio number τ_s is skin friction coefficient in secondary flow. P_r is Prandtl number

Under the conditions at,

$$y = 0, \qquad w(0,t) = \theta(0,t) = 0$$

and at,

$$y = \infty, \qquad w(\infty,t) = \theta(\infty,t) = 0 \tag{13}$$

So the velocity components in *z*'-direction is given by

$$w(y) = e^{-\frac{s_o(1+a_r)y}{2}}\left[-\lambda\left(a_8+\beta a_{10}\right)\cos\frac{s_o b_i y}{2} + \left\{1+\lambda\left(a_7+\beta a_9\right)\right\}\sin\frac{s_o b_i y}{2}\right] + \lambda\left\{a_8 e^{-P_r s_o y} + \beta e^{-s_c s_o y} a_{10}\right\} \tag{14}$$

The velocity gradient at the surface in *z*'-direction is given by

$$\left(\frac{\partial w}{\partial y}\right)_{y=0} = \frac{\lambda s_o\left(1+a_i\right)}{2}\left(a_8+\beta a_{10}\right) + \left\{1+\lambda\left(a_7+\beta a_9\right)\right\}\frac{s_o b_i}{2} - \lambda s_o\left[P_r a_8 + \beta a_{10} s_c\right] \tag{15}$$

The skin friction coefficient in the *z*'-direction (secondary flow) is given by

$$\tau_s = -\left[\lambda\left\{\frac{s_o\left(1+a_i\right)}{2}\left(a_8+\beta a_{10}\right) + \left(a_7+\beta a_9\right)\frac{s_o b_i}{2} - \delta_o\left(a_8 P_r + \delta_c \beta a_{10}\right)\right\} + \frac{s_o b_i}{2}\right]$$

When $a_r, b_i, c, d, e, a_5, a_6, a_7, a_8, a_9, a_{10}$ are constants.

Results and Discussion:-

In order to investigate the physical significance of the problem, the numerical values of Schmidt number, Nusselt number, Reynolds number, Buoyancy parameter, Hall Parameter, Suction parameter, Magnetic field strength vector, magnetic induction, Skin friction co-effcient in secondary flow have been computed for different values of various parameters. To obtain the steady state solution, the computation have been carried out up to dimensionless time t = 0 to

t = ∞. It is seen that, the numerical values of w(y) show little changers after y = 35, as shown in fig (2).

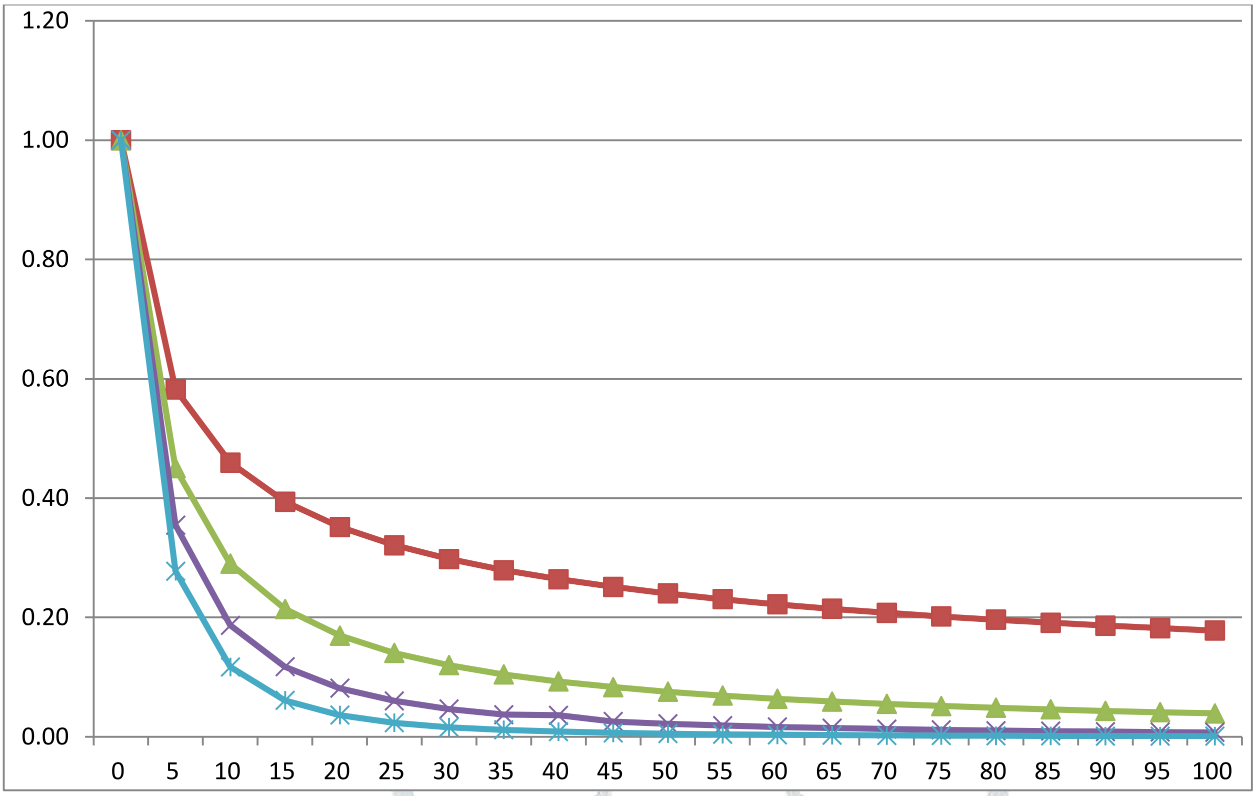

Fig (2)

The values of *w(y)* against *y* for different values of magnetic parameter (0.6, 0.8, 2, 3) when $\beta = S_o = \lambda = 1$ and Sc = 0.94 for Pr = 0.0083

Conclusion:

The unsteady flow of a viscous incompressible electrically conduction fluid past an infinite hot vertical porous plate, in the presence of constant suction and a transverse magnetic field has been formulated and solved employing multi parameters.
At the fixed prandlt number P_r (0.0083 for Bismuth at 760° and 0.0443 for Lithium at 315.6° C) and schmdt number S_c. The expression for secondary velocity $\omega(y)$ skin friction τ_s in secondary flow are numerically calculated for different values of magnetic parameters.
The effects of significant physical parameters show that as magnetic parameter increases, the boundary layer thickness decreases.

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