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Heat Transfer Study for Unsteady Liquid Metal MHD Duct Flow

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Abstract: *A numerical study for unsteady MHD flow in a channel having insulating slip walls moving in opposite direction under the action of intense inclined external magnetic field has been carried out. The numerical solutions for velocity, induced magnetic field and temperature distribution profile have been obtained by using a central difference scheme and are presented graphically for various parametric conditions using MATLAB software.*

Keywords: *MHD flow, Couette flow, Hartmann number, slip wall, unsteady flow*

1. INTRODUCTION

During last few decades emphasis has been given by the research on the MHD coutte flow due to its application arises in the field of engineering and technology, chemical engineering and different branches of engineering. Takahasi et al.[1] made an experiment to investigate the pressure drop and heat transfer for single phase flow of lithium in a horizontal channel with uniformly heated bottom under the action of horizontal magnetic field. Umavathi and Malashetty [2] analytically studied the combined free and forced convective MHD flow in a vertical channel. By employing Mathematica, Singha and Deka [3] analytically studied the two phase MHD flow problem and heat transfer issue in a parallel plate channel. In subsequent period, Singha [4] , Joseph et al. [5] , Chutia and Deka [6] studied the unsteady flow of an electrically conducting fluid under different flow environment.

In this paper, by employing central difference scheme we numerically studied the unsteady MHD couette flow of an electrically conducting fluid between two horizontal and parallel insulated slip plates which are moving in opposite directions under the action of an uniform inclined transverse magnetic field. Under various parametric conditions, we have obtained numerical solutions for velocity, induced magnetic field and temperature distributions.

2. FORMULATION OF THE PROBLEM

In this problem, an unsteady motion of electrically conducting fluid is considered between two horizontal parallel insulated slip plates separated by a distance of $2a$ under the action of an uniform external magnetic field of strength B_0 which is inclined at an angle θ with the positive direction of horizontal (X axis). The walls of the channel are at $y=\pm a$ and are moving with same velocity U but in opposite direction. The upper and lower wall of the channel are kept at temperature T_1 and T_0, where $T_1 > T_0$.

Following assumptions are made in this study to solve the governing equations of the flow problem.

- Flow is fully developed and
- Viscous dissipation and Joule heat are neglected.

The fluid velocity and magnetic field distribution for the present channel flow problem are $\vec{V}=\left[V_x\left(y,t\right),0,0\right]$ and $\vec{B}=\left[B_x+B_0\lambda,\sqrt{1-\lambda^2}B_0,0\right]$, where $\lambda=\cos\theta$.

The governing equations for present channel flow study are

$$\rho\left[\frac{\partial\vec{V}}{\partial t}+\left(\vec{V}.\nabla\right)\vec{V}\right]+\nabla p=\vec{J}\times\vec{B}+\mu\nabla^2\vec{V}+\vec{Z} \tag{1.1}$$

$$\frac{\partial \vec{B}}{\partial t} = \nabla \times \left(\vec{V} \times \vec{B}\right) + \lambda_1 \nabla^2 \vec{B} \qquad (1.2)$$

and

$$\rho C_p \frac{\partial T}{\partial t} = \frac{d}{dy}\left(k \frac{dT}{dy}\right) \qquad (1.3)$$

Where $\vec{Z} = \rho\beta g\left(T - T_0\right)$ is the force due to buoyancy.

Using fluid velocity and magnetic field distribution as stated, Eqs. (1.1)-(1.3) becomes

$$\frac{\partial V_x}{\partial t} = \nu \frac{\partial^2 V_x}{\partial y^2} - \frac{\sigma B_0{}^2}{\rho}\left(1 - \lambda^2\right) V_x + \beta g\left(T - T_0\right) \qquad (1.4)$$

$$\frac{\partial \vec{B}}{\partial t} - \left(B_0 \sqrt{\frac{1}{\lambda^2} - 1}\right) \frac{\partial V_x}{\partial y} - \lambda_1 \frac{\partial^2 \vec{B}}{\partial y^2} = 0 \qquad (1.5)$$

$$\frac{\partial T}{\partial t} = \alpha_1 \frac{\partial^2 T}{\partial y^2} \qquad (1.6)$$

where, $\alpha_1 = k/\rho C_p$.

The boundary condition for the present channel flow problem are (when $t > 0$)

$$\left.\begin{aligned} &V = U, B = B_0, T = T_1 \ \text{ at } y = +h \\ &V = -U, B = B_0, T = T_0 \ \text{ at } y = -h \end{aligned}\right\} \qquad (1.7)$$

After introducing following non-dimensional quantities

$$V^* = \frac{V_x}{U}, y^* = \frac{y}{a}, t^* = \frac{tU}{a}$$
$$B^* = \frac{B}{B_0}, \theta = \frac{T - T_0}{T_1 - T_0}$$

and following non dimensional parameters

$$M = \frac{\sigma B_0{}^2 \nu}{\rho U^2},\ R_e = \frac{Ua}{\nu},\ P_r = \frac{\nu}{\alpha_1},\ G_r = \frac{\beta g h^3\left(T_1 - T_0\right)}{\nu^2}$$
$$P_e = P_r\ R_e,\ R_m = \frac{\beta g h^3 T_0}{\nu \alpha_1}$$

We get following non-dimensionalized system of equations

$$\frac{\partial \vec{V}}{\partial t} = \left(\frac{1}{R_e}\right) \frac{\partial^2 \vec{V}}{\partial y^2} - MR_e\left(1 - \lambda^2\right) V + \left(\frac{G_r}{R_e{}^2}\right)\theta \qquad (1.8)$$

$$\frac{\partial \vec{B}}{\partial t} = \left(\sqrt{\frac{1}{\lambda^2} - 1}\right) \frac{\partial \vec{V}}{\partial y} + \left(\frac{1}{R_e R_m P_r}\right) \frac{\partial^2 \vec{B}}{\partial y^2} \qquad (1.9)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{P_e} \frac{\partial^2 \theta}{\partial y^2} \qquad (1.10)$$

and the boundary condition (1.7) becomes

$$\begin{aligned} &V = +1, B = 1, \theta = 1 \ \text{ at } \ y = +1 \\ &V = -1, B = 1, \theta = 0 \ \text{ at } \ y = -1 \end{aligned} \qquad (1.11)$$

We use separation of variable technique to solve Eqs. (1.8)-(1.10) and finally employed central difference scheme to solve the system of equations.

3. RESULT AND DISCUSSIONS

In this study, a numerical investigation on the fully developed unsteady MHD couette flow of conducting fluid between two horizontal parallel slip wall which are moving with same velocity but in opposite direction is presented.

In our numerical investigations, computation is carried out for different angle of inclination of imposed external magnetic field to the flow direction and we have considered $M=7, \lambda=0.5, R_m=0.2, R_e=1.5, G_r=2.0, n=1.0$ [7] unless otherwise stated in computation.

In figure 1, velocity profile for different angle of inclination of imposed magnetic field to the flow direction is shown. It is observed that with the increasing value of θ , fluid velocity decreases. Again from figure 2, we can conclude that velocity increases whenever Grashof number is increases.

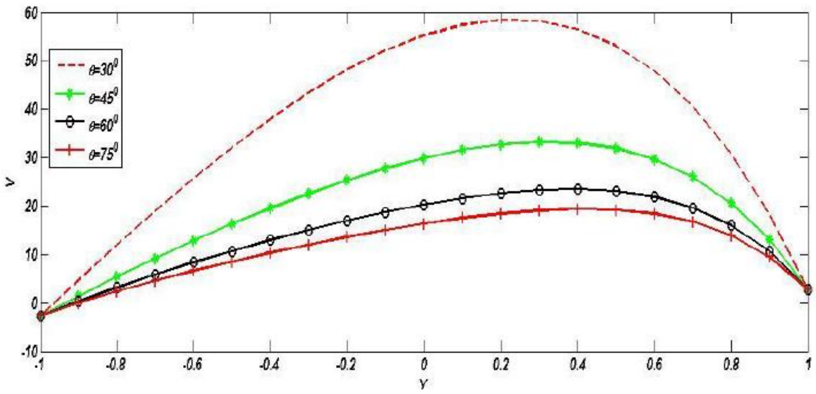

Fig1. *Variation of velocity profile for different values of* θ

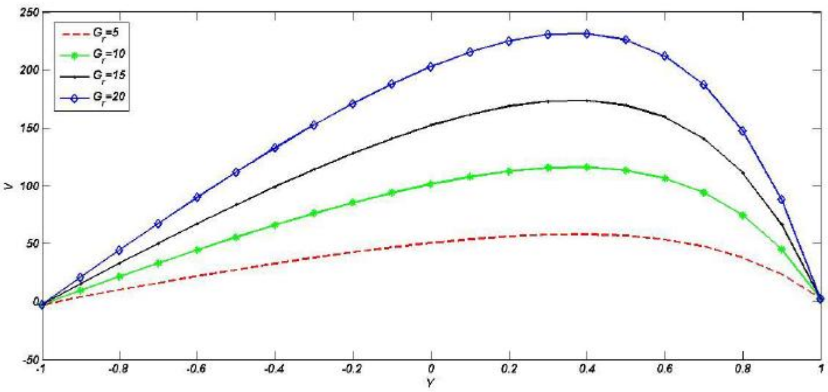

Fig2: *Variation of velocity profile for different values of* G_r

In figure 3, induced magnetic field profile for different values of θ is shown. It is observed that magnetic field increases whenever θ increases. Again from figure 4, we conclude that along with the increasing values of Grashof number magnetic field increases.

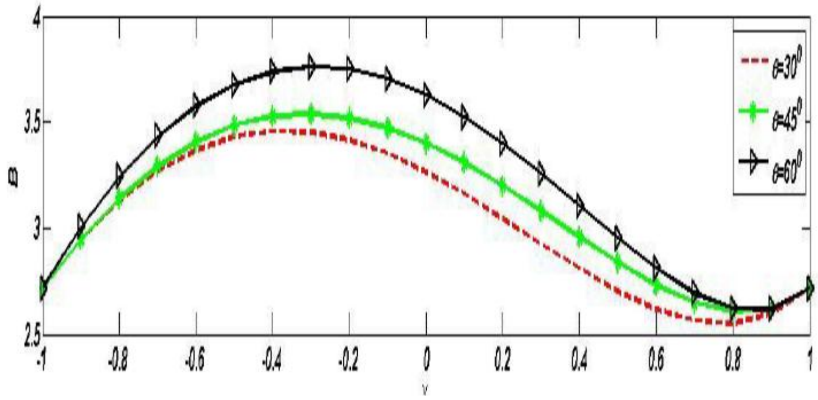

Fig3. *Variation of magnetic induced magnetic field profile for different values of* θ

In figure 5, temperature distribution is plotted against P_r , where it is observed that temperature distribution between the walls gradually increases along with the increasing values of P_r .

The results reflected from these plots are in good agreement with the earlier analytical results obtained by Singha [7] for the channel flow study with lower wall at rest and upper wall is moving.

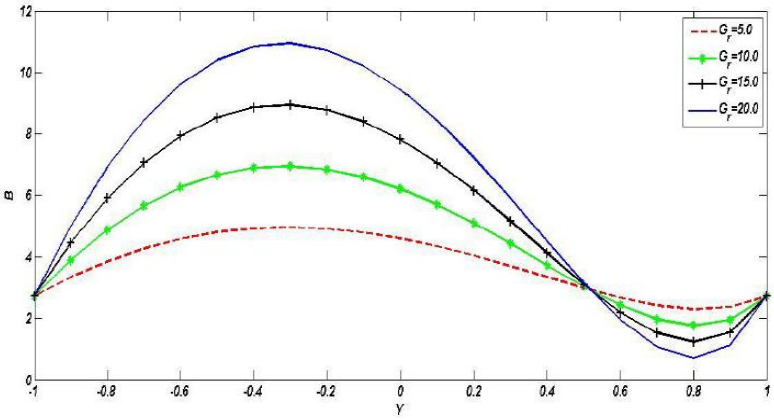

Fig4. *Variation of magnetic induced magnetic field profile for different values of* G_r

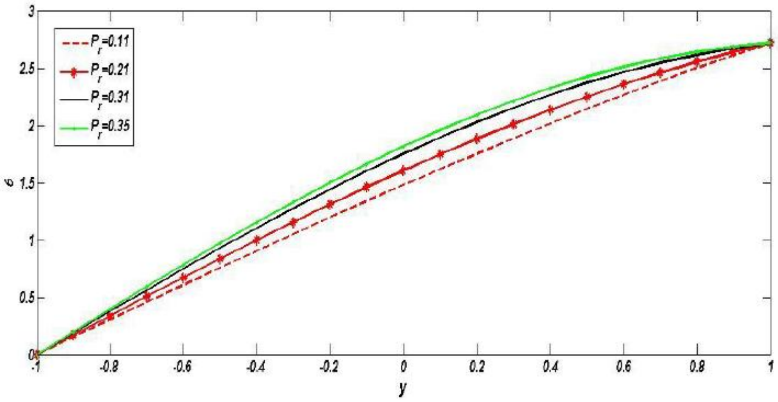

Fig5. *Variation of temperature field profile for different values of* P_r

REFERENCES

[1] Takahashi, M., Aritomi, M., Inoue, A., and Matsuzaki, M., MHD pressure drop and heat transfer of lithium single phase flow in a rectangular channel under transverse magnetic field, Fusion Engineering and Design, 42(1-4) ,pp. 365-372 (1998).

[2] Umavathi, J.C., and Malashetty, M.S., Magnetohydrodynamic mixed convection in a vertical channel, International Journal of Non-linear Mechanics, 40(1), pp. 91-101(2005).

[3] Singha, K.G., and Deka, P.N., MHD flow and heat transfer between two vertical parallel plates in presence of uniform inclined magnetic field, Mathematical Forum, XVI, pp. 25-37 (2003).

[4] Singha, K.G., Analytical solution to the problem of MHD free convective flow of an electrically conducting fluid between two heated parallel plates in the presence of an induced magnetic field, International Journal of Applied Mathematics and Computation, 1(4), pp. 183-193 (2009).

[5] Joseph, K.M., Daniel, S., and Joseph, G.M., Unsteady MHD Couette flow between two infinite parallel porous plates in an inclined magnetic field with heat transfer, International Journal of Mathematics and Statistics Invention, 2(3), pp. 103-110 (2014).

[6] Chutia, M. and Deka,P.N., Numerical study on steady Magnetohydrodynamics (MHD) flow and heat transfer in a heated rectangular electrically insulated duct under the action of strong oblique transverse magnetic field, International Journal of Computer Application, 86(15), pp.27-34 (2014).

[7] Singha, K.G., Ph.D. Thesis, Dibrugarh University, (2007).