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MHD Viscous Flow of an Ionized gas through a Horizontal Channel Bounded by two Parallel walls in a Rotating Frame of Reference

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ABSTRACT

MHD viscous flow of an ionized gas through a horizontal channel bounded by two parallel walls in a rotating frame of reference, taking the effects of Hall currents into account. It is assumed that the magnetic Reynolds number is small. The fluids in the two regions are assumed to be incompressible, immiscible and electrically conducting with different viscosities; electrical and thermal conductivities. The transport properties of the two fluids are taken to be constant and the bounding walls are maintained at constant and equal temperature. The governing equations of energy for both fluids are solved using the prescribed conditions (that is, isothermal boundary and interface conditions).The governing differential equations are solved analytically, using the prescribed boundary conditions in both phases and obtained exact solutions for primary and secondary velocity distributions.

Numerical calculations of the resulting solutions are performed and by varying the various physical parameters Hartmann number, Hall parameter, viscosity ratio, height ratio and represented graphically to discuss interesting features of the solutions. We observed that an increase Hall parameter increases the primary and secondary velocity distributions for fixed values of the remaining governing parameters.

Keywords: Angular velocity, Ionized Fluids, MHD, Two Phases, Viscous.

I. INTRODUCTION

We consider a steady state two-dimensional two-fluid flow of an ionized gas bounded by two infinite horizontal parallel walls(y= h_1 and y= h_2) extending in x-and z-directions under the action of a uniform transverse magnetic field B_0 applied in the y-direction, that is, normal to the plane of flow. We assume that, both the fluid and walls are in a state of rigid rotation with uniform angular velocity about y-axis normal to the walls. K is the Taylor number (rotation parameter). The effect of flow parameters on the fluid's temperature and the heat transferred between the fluids and the walls is considered, using the fully developed two-fluid. Further, assuming that the thermal boundary conditions apply everywhere on the infinite channel walls and neglecting the thermal conduction in the flow direction, the governing energy equations in two-fluid regions.

II. FORMULATION OF THE PROBLEM

The fundamental equations of motion and current for the steady state two-fluid flow of neutral fully-ionized gas valid under above assumptions and in a rotating frame of reference, for both regions are simplified as:

Region– I

$$\frac{1}{P_r}\frac{d^2\theta_1}{dy^2} = -\left\{\left(\frac{du_1}{dy}\right)^2 + \left(\frac{dw_1}{dy}\right)^2 + H_a^2 I_1^{\,2}\right\}, \qquad I_1^{\,2} = I_{x_1}^{\,2} + I_{z_1}^{\,2},$$

Region– II

$$\frac{d^2\theta_2}{dy^2} = -\frac{\beta}{\alpha}\left[\left(\frac{du_2}{dy}\right)^2 + \left(\frac{dw_2}{dy^2}\right)\right] + h^2\sigma\beta H_a^2 I_2^{\,2}, \qquad I_2^{\,2} = I_{x_2}^{\,2} + I_{z_2}^{\,2},$$

In the above equations, the subscripts 1 and 2 refer to the quantities for Region-I and II respectively, such as u_1, u_2 and w_1, w_2 are the primary and secondary velocity distributions in the two regions respectively, Ω is the angular velocity, E_x and E_z , also J_x and J_z are x- and z- components of electric field, also current densities respectively. Here, $s = p_e/p$ is the ratio of the electron pressure to the total pressure. The value of s is 1/2 for neutral fully–ionized plasma and approximately zero for a weakly–ionized gas. σ_{11}, σ_{12} and σ_{21}, σ_{22} are the modified conductivities parallel and normal to the direction of electric field respectively.

The boundary condition on velocity requires the no slip condition. In addition, the fluid velocity, sheer stress must be continuous across the interface y=0. So the boundary and interface conditions on θ_1, θ_2, u_1, u_2, w_1, w_2, I_1, I_2, are:

The isothermal boundary and the interface conditions are

$$\theta_1(1) = 0,$$

$$\theta_2(-1) = 0,$$

$$\theta_1(0) = \theta_2(0),$$

$$\frac{d\theta_1}{dy} = \frac{1}{\beta h}\frac{d\theta_2}{dy}, \text{ at } y = 0.$$

III. SOLUTIONS OF THE PROBLEM

Exact solutions of the governing differential equations subject to the boundary and interface conditions for the temperatures θ_1, θ_2, regions are obtained as in the following two cases of study.

IV.EXPERIMENTAL RESULTS

The problem of MHD two immiscible fluids flow through a horizontal channel is investigated analytically in the presence of an applied magnetic field transverse to the flow direction. The two fluids are assumed to be incompressible and electrically conducting possessing different viscosities, thermal and electrical conductivities. The resulting partial differential equations are reduced to ordinary linear differential equations and solved analytically by means of the assumed solutions to obtain exact solutions for the velocity distributions, such as, u_1, u_2 respectively in the two regions. The graphs for the velocity distributions for steady state flow motions are shown in figures to discuss the important features of hydromagnetic state of the fluid.

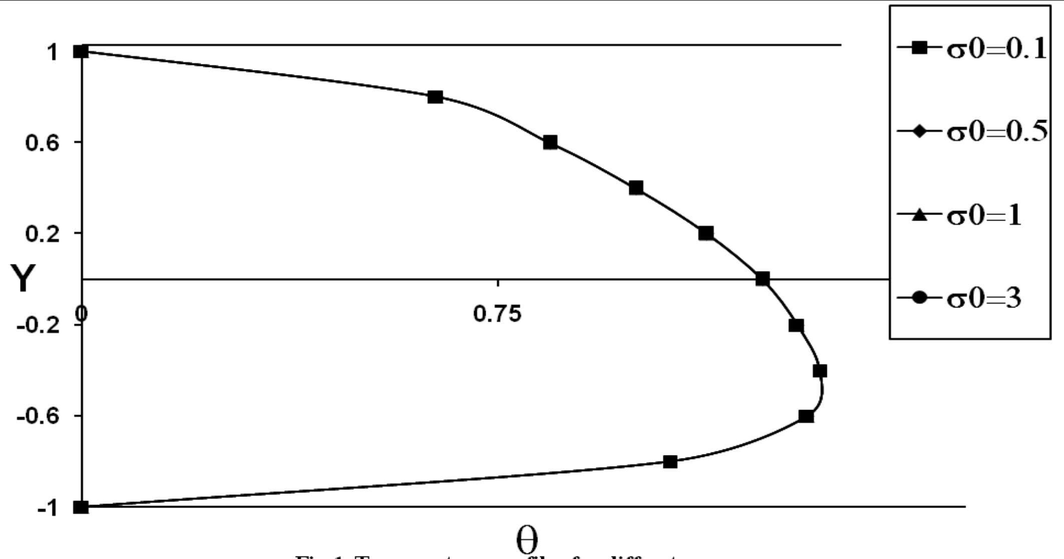

Fig.1 Temperature profiles for differet s_0 and α=0.333, s_0=2, s_1=1.2, s_2=1.5, h=0.8, m=2, r=1, b=1.

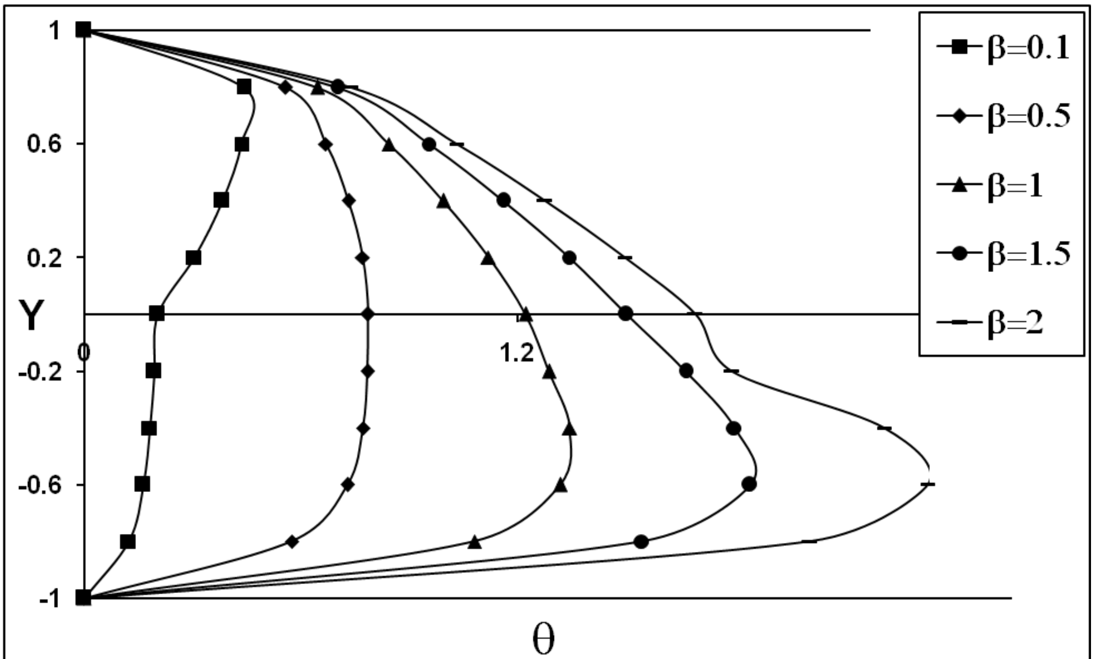

Fig.2 Temperature profiles for different b and H_a=10, a=0.333, s_0=2, s_1=1.2, s_2=1.5, r=1, h=0.8, m=2,k=2.

V. CONCLUSION

The effect of the ratio of electrical conductivity σ is shown in fig.1. It is found that, there is no much significant variation on temperature as σ_0 increases.

Fig.2 depicts the effect of the thermal conductivity ratio on temperature distribution. It is found that the temperature increases as β increases. Also, the maximum temperature distribution in the channel tends to move below the channel centerline towards region-II (fluid in the lower region) for thermal conductivity ratio (for β=1.5, 2), and the maximum temperature in the channel tends to move above the channel centerline towards region-I (fluid in the upper region) for height ratio (for β= 0.1).

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