

The effect of Taylor number on Two Ionized Fluids in channels under transverse magnetic field

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ABSTRACT: The theoretical and experimental results for predicting design parameters of two-fluid/or two-phase flows are becoming increasingly important because of their widespread applications in industry relating to various energy conversion systems. In particular, the development of conceptual design of fusion reactors and liquid metal magnetohydrodynamic rotating power generators, demands an accurate and reliable knowledge of the heat transfer and thermohydraulic mechanisms of two-fluid flows in presence of an applied magnetic field. 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: Taylor number, MHD, Ionized Fluids, 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 $\bar{\Omega}$ about y-axis normal to the walls. K is the Taylor number (rotation parameter). The fluids in the upper and lower regions, that is, $0 \leq y \leq h_1$ and $-h_2 \leq y \leq 0$ are designated as Region -I and Region-II respectively. Region -I and Region -II are occupied by two immiscible electrically conducting incompressible fluids having different densities ρ_1, ρ_2 , viscosities μ_1, μ_2 and electrical conductivities σ_{01}, σ_{02} .

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:

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Region- I

$$-\left[1-s\left(1-\frac{\sigma_{11}}{\sigma_{01}}\right)\right]\frac{\partial p}{\partial x} + \rho_1 v_1 \frac{d^2 u_1}{dy^2} + B_0[-\sigma_{11}(E_z + u_1 B_0) + \sigma_{21}(E_x - w_1 B_0)] = 2\rho_1 \Omega w_1$$

$$\left(s \frac{\sigma_{21}}{\sigma_{01}}\right) \frac{\partial p}{\partial x} + \rho_1 v_1 \frac{d^2 w_1}{dy^2} + B_0[\sigma_{11}(E_x - w_1 B_0) + \sigma_{21}(E_z + u_1 B_0)] = -2\rho_1 \Omega u_1$$

$$J_x = \sigma_{11} E_x - B_0 \sigma_{11} w_1 + \sigma_{21} E_z + B_0 \sigma_{21} u_1 + \frac{s \sigma_{21}}{\sigma_{01} B_0} \left(\frac{\partial p}{\partial x}\right)$$

$$J_z = \sigma_{11} \left(\frac{E_z}{B_0} + u_1\right) - \sigma_{21} \left(\frac{E_x}{B_0} - w_1\right) - \frac{s}{B_0} \left(1 - \frac{\sigma_{11}}{\sigma_{01}}\right) \left(\frac{\partial p}{\partial x}\right)$$

Region- II

$$-\left[1-s\left(1-\frac{\sigma_{12}}{\sigma_{02}}\right)\right]\frac{\partial p}{\partial x} + \rho_2 v_2 \frac{d^2 u_2}{dy^2} + B_0[-\sigma_{12}(E_z + u_2 B_0) + \sigma_{22}(E_x - w_2 B_0)] = 2\rho_2 \Omega w_2$$

$$\left(s \frac{\sigma_{22}}{\sigma_{02}}\right) \frac{\partial p}{\partial x} + \rho_2 v_2 \frac{d^2 w_2}{dy^2} + B_0[\sigma_{12}(E_x - w_2 B_0) + \sigma_{22}(E_z + u_2 B_0)] = -2\rho_2 \Omega u_2$$

$$J_x = \sigma_{12} E_x - B_0 \sigma_{12} w_2 + \sigma_{22} E_z + B_0 \sigma_{22} u_2 + \frac{s \sigma_{22}}{\sigma_{02} B_0} \left(\frac{\partial p}{\partial x}\right)$$

$$J_z = \sigma_{12} E_z + \sigma_{12} B_0 u_2 - \sigma_{22} E_x + \sigma_{22} B_0 w_2 - \frac{s}{B_0} \left(1 - \frac{\sigma_{12}}{\sigma_{02}}\right) \left(\frac{\partial p}{\partial x}\right)$$

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, where $\vec{\Omega} = (0, \Omega, 0)$. 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, shear stress must be continuous across the interface $y=0$. So the boundary and interface conditions on u_1, w_1 and u_2, w_2 are:

$$u_1(h_1) = 0, w_1(h_1) = 0,$$

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$$u_2(-h_2) = 0, w_2(-h_2) = 0,$$

$$u_1(0) = u_2(0), w_1(0) = w_2(0),$$

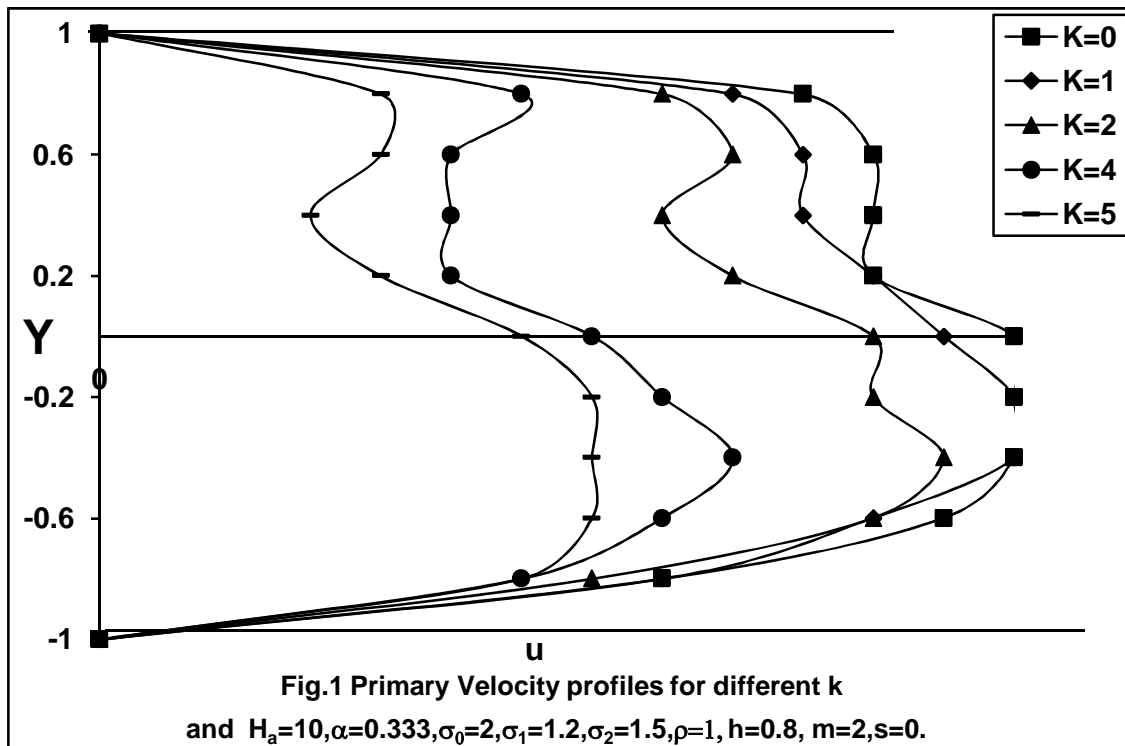
$$\text{and } \mu_1 \frac{dw_1}{dy} = \mu_2 \frac{dw_2}{dy} \text{ at } y = 0.$$

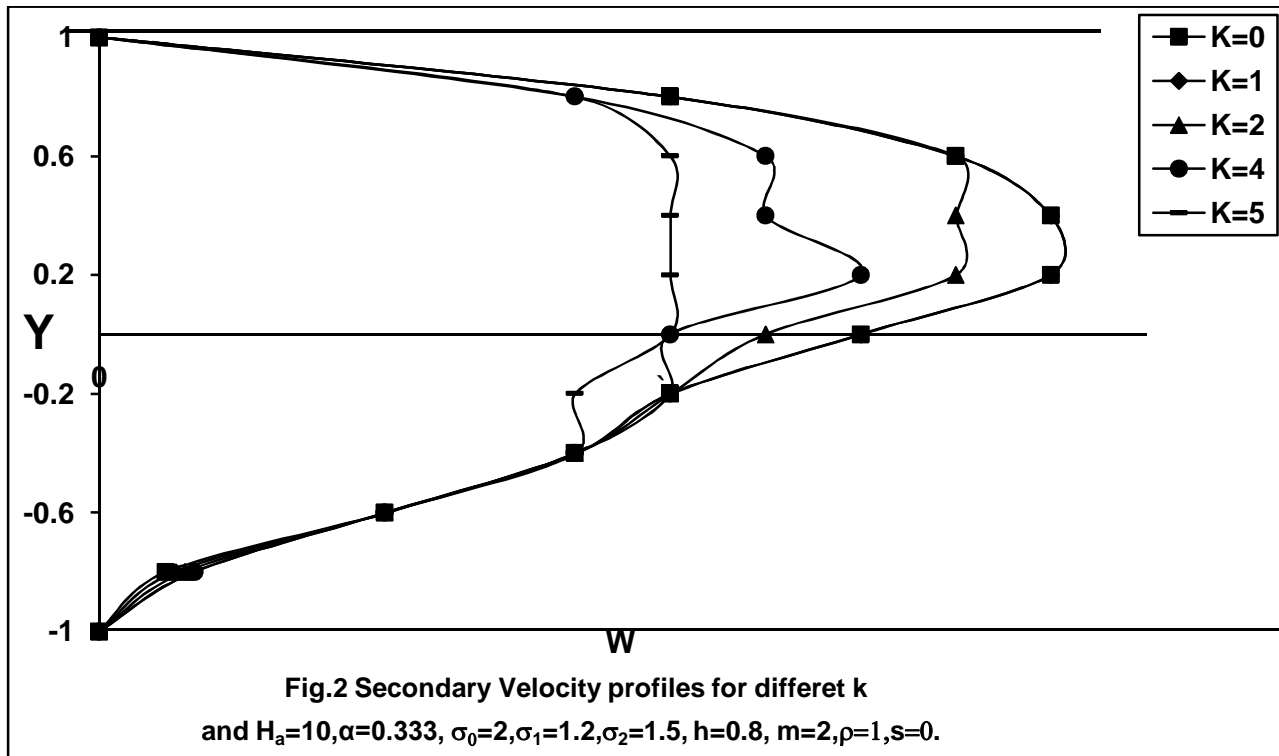
III. SOLUTIONS OF THE PROBLEM

Exact solutions of the governing differential equations subject to the boundary and interface conditions for the primary and secondary velocities u_1, u_2 and w_1, w_2 ; and 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.





V. CONCLUSION

The effect of Taylor number K in the case of $s=0$ is represented in figs.1 and 2. From these figures it is noticed that, an increase in Taylor number diminishes the primary and secondary velocity distributions in the two regions. Also it is observed that, the maximum velocity in the channel tends to move above the channel centerline towards region-I (fluid in the upper region) as the Taylor number increases in the case of primary and secondary velocity distributions.

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