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MHD two fluid channel flow in two parallel Non conducting walls.

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It is assumed that the fluids in the two regions are incompressible, immiscible and electrically conducting, having different viscosities, electrical conductivities. With these assumptions and considering that the magnetic Reynolds number is small the basic equations of motion, current, the no-slip boundary conditions at the walls and interface conditions between the two-fluid regions have been formulated. The resulting governing linear differential equations are solved analytically, using the prescribed boundary and interface conditions to obtain the exact solutions for velocity distributions such as primary and secondary distributions in both regions. Also, their corresponding numerical results for various sets of values of the governing parameters are obtained to represent them graphically and are discussed in detail.

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Introduction:

The purpose of the present study is to gain a detailed understanding of the flow pattern in the theoretical description of MHD two-fluid flow driven by a constant pressure gradient through a horizontal channel consisting of two parallel walls under the influence of a transversely applied uniform strong magnetic field, in presence of Hall currents. This study has been carried out when the walls are made up of non-conducting material.

Basic governing equations with boundary and interface conditions and mathematical analysis of the problem:

The fundamental equations to be solved are the equations of motion and current for the steady state two-fluid flow of neutral fully–ionized gas valid under assumptions above and simplified as:

Region – I

$$-\left[1-s\left(1-\frac{\sigma_{11}}{\sigma_{01}}\right)\right]\frac{\partial p}{\partial x}+\rho_1\nu_1\frac{d^2u_1}{dy^2}+B_0[-\sigma_{11}(E_z+u_1B_0)+\sigma_{21}(E_x-w_1B_0)]=0$$

$$\left(s\,\frac{\sigma_{21}}{\sigma_{01}}\right)\frac{\partial p}{\partial x}+\rho_1\nu_1\frac{d^2w_1}{dy^2}+B_0[\sigma_{11}(E_x-w_1B_0)+\sigma_{21}(E_z+u_1B_0)]=0$$

Region – II

$$-\left[1-s\left(1-\frac{\sigma_{12}}{\sigma_{02}}\right)\right]\frac{\partial p}{\partial x}+\rho_2\nu_2\frac{d^2u_2}{dy^2}+B_0[-\sigma_{12}(E_z+u_2B_0)+\sigma_{22}(E_x-w_2B_0)]=0$$

$$\left(s\,\frac{\sigma_{22}}{\sigma_{02}}\right)\frac{\partial p}{\partial x}+\rho_2\nu_2\frac{d^2w_2}{dy^2}+B_0[\sigma_{12}(E_x-w_2B_0)+\sigma_{22}(E_z+u_2B_0)]=0$$

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 known as primary and secondary velocity distributions in the two regions respectively. E_x and E_z are x- and z- components of electric fields. While, 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 and sheer stress must be continuous across the interface y=0.

The boundary and interface conditions for u_1, w_1 and u_2, w_2 are:

$$u_1(h_1) = 0 \quad w_1(h_1) = 0, w_2(-h_2) = 0$$
$$u_1(0) = u_2(0), w_1(0) = w_2(0),$$

$$\mu_1 \frac{du_1}{dy} = \mu_2 \frac{du_2}{dy} \quad \text{and}$$
$$\mu_1 \frac{dw_1}{dy} = \mu_2 \frac{dw_2}{dy} \quad at \quad y = 0$$

To make equations dimensionless, we use the following non-dimensional variables: $u^{\bullet}{}_1 = \frac{u_1}{u_p}$, $u^{\bullet}{}_2 = \frac{u_2}{u_p}$, $y^{\bullet}{}_i = \left(\frac{y_i}{h_i}\right)(i = 1,2)$, $w^{\bullet}{}_1 = \frac{w_1}{u_p}$, $w^{\bullet}{}_2 = \frac{w_2}{u_p}$, $u_p = \left(-\frac{\partial p}{\partial x}\right)\frac{h_1^2}{\rho_1 \nu_1}$, $k_1 = 1 - s(1 - \frac{\sigma_{11}}{\sigma_{01}})$, $k_2 = -s\frac{\sigma_{21}}{\sigma_{01}}$,

$$m_x = \frac{E_x}{B_0 u_p}, \qquad m_z = \frac{E_z}{B_0 u_p}, \qquad I_x = \frac{J_x}{\sigma_{0i} B_0 u_p},$$

$I_z = \frac{J_z}{\sigma_{0i} B_0 u_p}(i = 1,2)$, H_a^2 (Hartmann number) $= B_0^2 h_1^2 \left(\frac{\sigma_{01}}{\rho_1 \upsilon_1}\right)$, α (ratio of the viscosities) = $\frac{\mu_1}{\mu_2}$, h(ratio of the heights)= $\frac{h_2}{h_1}$, σ_0 (Ratio of the electrical conductivities) $= \frac{\sigma_{01}}{\sigma_{02}}$, $\sigma_1 = \left(\frac{\sigma_{12}}{\sigma_{11}}\right)$, $\sigma_2 = \left(\frac{\sigma_{22}}{\sigma_{21}}\right)$;

$$\frac{1}{1+m^2} = \frac{\sigma_{11}}{\sigma_{01}}, \quad \frac{m}{1+m^2} = \frac{\sigma_{21}}{\sigma_{01}},$$

(Hall parameter) $= \left(\frac{w_e}{\frac{1}{\tau} + \frac{1}{\tau_e}}\right)$

Solutions of the problem:

Exact solutions of the governing differential equations with the help of boundary and interface conditions for the primary and secondary velocities u_1, u_2 and w_1, w_2 respectively. The numerical values of the expressions given at equations and computed for different sets of values of the governing parameters involved in the study and these results are presented graphically from figures 1and 2, also discussed in detail.

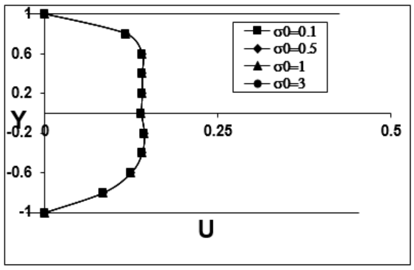

Fig. 1: Primary Velocity profiles for different σ_0 and H_a=10, α=0.333, s1=1.2, s2=1.5, h=0.8.

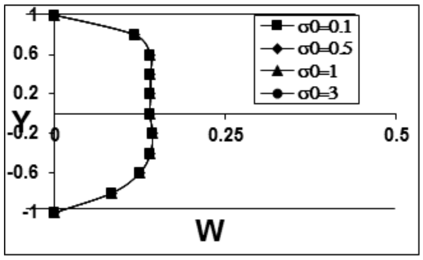

Fig. 2: Secondary Velocity profiles for different σ_0 and H_a=10, α=0.333, s1=1.2, s2=1.5, h=0.8.

Results and discussion:

The effect of the ratio of electrical conductivity σ_0 is shown in figs.1 and 2. It is found that, there is no much significant variation on both primary velocity and secondary velocity distributions as σ_0 increases.

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