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THE EFFECT OF THE RATIO α OF VISCOSITIES ON TWO IONIZED FLUIDS THROUGH A HORIZONTAL CHANNEL BETWEEN TWO PARALLEL WALLS

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ABSTRACT

The two-fluid/or two-phase flows are of great practical concern in a large number of engineering disciplines, including the chemical, petroleum and various power generating industries. For instance, questions concerning nuclear-reactor safety have led to a demand for an understanding of the detailed phase-distribution mechanisms involved two-phase flows. 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.

INTRODUCTION

The more interesting and potentially useful phenomena associated with the simultaneous, horizontal pipeline flow of two incompressible fluids is the fact that the pressure gradient and power requirement necessary for the flow of the more viscous phase at a given rate may be substantially reduced by the presence of the less viscous phase. The most common practical example in which this effect is evident is the pipeline flow of petroleum and water. 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 given below and simplified as:

(i) The ionization is in equilibrium which is not affected by the applied electric and magnetic fields.
(ii) The effect of space charge is neglected.
(iii) The flow is fully developed and stationary, that is $\partial/\partial t = 0$
And $\partial/\partial x = 0$ except $\partial p/\partial x \neq 0$.
(iv) The magnetic Reynolds number is small [so that the externally applied magnetic field is undisturbed by the fluid, namely the induced magnetic field is small compared with the applied field [Shercliff (1965)]. Therefore components in the conductivity tensor are expressed in terms of B_0.
(v) The flow is two-dimensional, namely $\partial/\partial z = 0$.
With these assumptions, the governing equations of motion and current can be formulated as follows for the two-dimensional steady state problem of study in two regions.

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Region– I

$$k_1+\frac{d^2u_1}{dy^2}-\left(\frac{1}{1+m^2}\right)H_a{}^2(mz+u_1)+\left(\frac{m}{1+m^2}\right)H_a{}^2(mx-w_1)=0\,,$$

$$k_2+\frac{d^2w_1}{dy^2}+\left(\frac{1}{1+m^2}\right)H_a{}^2(mx-w_1)+\left(\frac{m}{1+m^2}\right)H_a{}^2(mz+u_1)=0\,,$$

$$I_x=\left(\frac{1}{1+m^2}\right)\left(m_x-w_1\right)+\left(\frac{m}{1+m^2}\right)\left(m_z+u_1\right)-\frac{s}{H_a^2}\left(\frac{m}{1+m^2}\right),$$

$$I_z=\left(\frac{1}{1+m^2}\right)\left(m_z+u_1\right)-\left(\frac{m}{1+m^2}\right)\left(m_x-w_1\right)+\frac{s}{H_a^2}\left(1-\frac{m}{1+m^2}\right),$$

Region –II

$$\beta_1\alpha h^2+\frac{d^2u_2}{dy^2}-\left(\frac{1}{1+m^2}\right)\alpha\sigma_1 h^2H_a{}^2(mz+u_2)+\left(\frac{m}{1+m^2}\right)\alpha\sigma_2 h^2H_a{}^2(mx-w_2)=0,$$

$$\beta_2\alpha h^2+\frac{d^2w_2}{dy^2}-\left(\frac{1}{1+m^2}\right)\alpha\sigma_1 h^2H_a{}^2(mx-w_2)+\left(\frac{m}{1+m^2}\right)\alpha\sigma_2 h^2H_a{}^2(mz+u_2)=0,$$

$$I_x=\left(\frac{\sigma_0\sigma_1}{1+m^2}\right)\left(m_x-w_2\right)+\left(\frac{m\sigma_2\sigma_0}{1+m^2}\right)\left(m_z+u_2\right)-\frac{s\sigma^2{}_0\sigma_2}{H_a^2}\left(\frac{m}{1+m^2}\right),$$

$$I_z=\left(\frac{\sigma_1\sigma_0}{1+m^2}\right)\left(m_z+u_2\right)-\left(\frac{m\sigma_2\sigma_0}{1+m^2}\right)\left(m_x-w_2\right)+\frac{s\sigma_0}{H_a^2}\left(1-\frac{\sigma_1\sigma_0}{1+m^2}\right),$$

where, $k_1=1-s\left(\frac{m^2}{1+m^2}\right);\ k_2=\frac{-sm}{1+m^2}\ ,\ \beta_1=1-s\left(1-\frac{\sigma_0\sigma_1}{1+m^2}\right);\ \beta_2=\left(\frac{-s\sigma_0\sigma_2 m}{1+m^2}\right),$

$I_x + iI_z = \frac{J_x+iJ_z}{\sigma_{0i}B_0u_p}$. (i=1,2)

The non-dimensional forms of the velocity, temperature and interface boundary conditions become:

$$u_1(+1)=0, w_1(+1)=0, \tag{1}$$

$$u_2(-1)=0, w_2(-1)=0, \tag{2}$$

$$u_1(0)=u_2(0), w_1(0)=w_2(0), \tag{3}$$

$$\frac{du_1}{dy}=\frac{1}{\alpha h}\frac{du_2}{dy} \text{ and } \frac{dw_1}{dy}=\frac{1}{\alpha h}\frac{dw_2}{dy} \text{ at } y = 0. \tag{4}$$

The conditions (1) and (2) represent the no-slip conditions at the walls. The conditions (3) and (4) represent the continuity of velocity and shear stress at the interface y=0.

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.

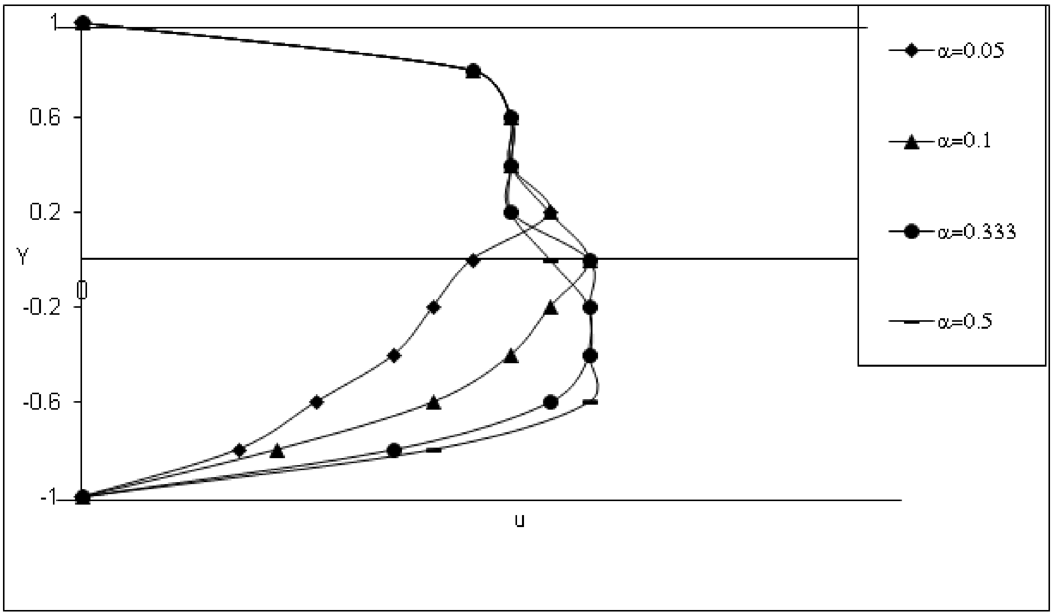

Figure-1: Primary Velocity profiles for different a and H_a=10,s_0=2,s_1=1.2,s_2=1.5, h=0.8, m=2,s=0.5.

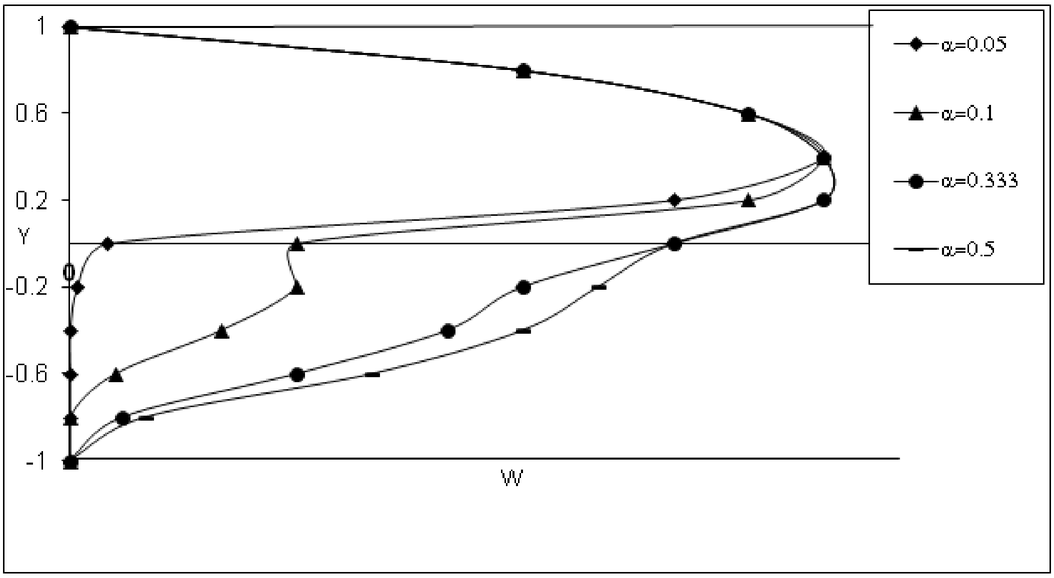

Figure-2: Secondary Velocity profiles for different a and H_a=10, s_0=2, s_1=1.2, s_2=1.5, h=0.8, m=2, s=0.5.

RESULTS AND DISCUSSION

The effect of the ratio α of viscosities of the two fluids in the case when $s = \frac{1}{2}$ is shown in figs 1and 2. It is noticed that as α increases, both the primary and secondary velocity distributions increase in the two regions. Also, the maximum velocity in the channel tends to move below the channel centerline towards region-II in the case of primary velocity distribution. While in the secondary velocity; 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 viscosity ratio increases.

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