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Two Phase Flow of Stratified Incompressible Viscous Fluid Between Two Semi-Infinite Parallel Plates Partially Filled With Porous Medium Under Transverse Magnetic Field Applied Only in the Porous Region

Dr. Shiva Shanker K[1], Dr.Venumadav.K[2]

[1]Associate Professor, [2]Assistant professor

[1,2] Dept of Mathematics,

[1,2] Kakatiya Institute of Technology & Science, Warangal, Telangana, India.

Abstract

The aim of the present paper is to investigate the flow of stratified incompressible viscous fluid between two semi-infinite parallel plates. The space between the parallel plates is partially filled with porous medium. The flow will be two phase flow one in clear region and other in porous region. Brinkman equation is applied to study flow in the porous region and Navier stokes equation is applied to study the flow in the clear region. Transverse magnetic field is applied in porous region perpendicular to the length of the plates.The expressions for fluid velocities in both regions are obtained sophisticatedly. The effects of the magnectic parameter and permeability parameter on the fluid velocities are investigated. The results are graphically represented.

Keywords : Porous medium, stratified incompressible viscous fluid,magnectic parameter ,permeability parameter.

1. INTRODUCTION

The study of flows through porous medium assumed importance because of the interesting applications in the diverse fields of science, Engineering and Technology. The practical applications are in the percolation of water through soil, extraction and filtration of oils from wells, the drainage of water, irrigation and sanitary engineering and also in the inter disciplinary fields such as biomedical engineering etc. The classical Darcy's law Musakat [1] states that the pressure gradient pushes the fluid against the body forces exerted by the medium which can be expressed as

$$\vec{V} = -\left(\frac{k}{\mu}\right)\nabla P \ .$$

The law gives good results in the situations when the flow is uni-directional or the flow is at low speed. In general, the specific discharge in the medium need not be always low. As the specific discharge increases, the convective forces get developed and the internal stress generates in the fluid due to its viscous nature and produces distortions in the velocity field. In the case of highly porous medium such as fiber glass, papus of dandelion the flow occurs even in the absence of the pressure gradient.

Modifications for the classical Darcy's law were considered by the Beavers and Joseph [2], Saffman [3] and others. A generalized Darcy's law propsed by Brinkmann [4] is given by

$$O = -\nabla P - \left(\frac{\mu}{K}\right)\vec{v} + \mu \nabla^2 \vec{v}$$

Where μ and K are coefficients of viscosity of the fluid and permeability of the porous medium.

The applications of flows through porous medium bears wide spread interest in Geophysics, biology and medicine. In many of these areas the flow consists of more than one phase, such type of flows find applications in the inter disciplinary fields such as bio-medical engineering etc., the flow of blood is one such application. The blood may be represented as Newtonian fluid and the flow of the blood is in two layered. Lightfoot [5], Shukla *et al.* [6] and Chaturani [7]. Bird *et al*. [8] found an exact solution for the laminar flow of two immiscible fluids between two parallel plates. Bhattacharya [9] discussed the flow of immiscible fluids between rigid plates with a time dependent pressure gradient. Vajravelu *et al*. [10] have discussed the effect of magnetic field on unsteady flow of two immiscible conducting fluids between two permeable beds. Transciet couette flow in a rotating non-Darcian porous medium parallel plate configuration is studied by Anwarbeg *et al*. [11] Kandryzakaria *et al*. [12] discussed magneto hydrodynamics instability of interfacial waves between two immiscible cylindrical fluids.

Earlier Narasimhacharyulu *et al*. [13] studied the problem of two phase fluid flow between parallel plates with porous lining and Narasimhacharyulu *et al*. [14] examined the flow of micropolar fluid between parallel plates coated with porous lining . Narasimhacharyulu *et al*. [16] studied the problem of two phase flow of an incompressible viscous fluid between two semi-infinite parallel plates under transverse magnetic field.

In this present paper we are considering stratified incompressible viscous fluid flow between two parallel plates, the space between the plates is partially filled with porous medium. There exists two regions one flow in clear region and other flow in porous region. Transverse magnetic field is applied in porous region. The results are graphically represented

2. MATHEMATICAL FORMULATION OF THE PROBLEM

The flow of stratified incompressible viscous fluid is considered between two semi infinite parallel plates given by $y = \pm h$. The space between the plates is filled with porous region of thickness '2δ'. The space between the two plates represents flow of fluid in two phases, one in clear region and other in porous region. The Coordinate system is taken such that x-axis lies parallel to the length of the plates and y-axis perpendicular to the length of the plates. The fluid flows in the two regions under a constant pressure gradient.

$$G = -\frac{\partial p}{\partial x}$$

The velocity of the fluid $\vec{V} = (u, 0, 0)$ satisfies the equation of continuity, the physical quantities depends on y only.

The equation of motion in the two regions is given by

$$\frac{d^2up}{dy^2} - \frac{u_p}{k} - \frac{\sigma\beta_0^2}{\mu}u_p = -\frac{G}{\nu}e^{\beta y} \quad \ldots \quad (2.1)$$

$$-\delta < y < \delta$$

$$\frac{d^2uc}{dy^2} = -\frac{G}{\nu}e^{\beta y} \quad \ldots \quad (2.2)$$

$$-h < y < -\delta \quad \text{and} \quad \delta < y < h$$

Where $G = -\frac{\partial p}{\partial x}$ is a constant pressure gradient, in the x direction, ν is coefficient of viscosity of the fluid, β stratification parameter , k is permeability of the porous medium. u_p and u_c are velocity of the fluid in the porous and clear region respectively.

Using the following non-dimensional quantities.

$$u^* = \frac{uh}{\nu}, y^* = \frac{y}{h}, G^* = \frac{Gh^3}{\nu}, \alpha^2 = \frac{h^2}{K} \quad \ldots \quad (2.3)$$

After removing *, the non-dimensional form of equation of motion is

$$\frac{d^2up}{dy^2} - \alpha^2 up = -\frac{G}{\nu}e^{\beta y}; \quad -\frac{\delta}{h} < y < \frac{\delta}{h} \quad (2.4)$$

$$\frac{d^2uc}{dy^2} = -\frac{G}{\nu}e^{\beta y}; \quad -1 < y < -\frac{\delta}{h} \text{ and } \frac{\delta}{h} < y < 1 \qquad (2.5)$$

Where $\alpha^2 = \beta_1^{\,2} + M^2, \quad \beta_1^{\,2} = \frac{h^2}{K}, \quad M^2 = \frac{\sigma \beta_0^2 h^{\ 2}}{\mu}$

The boundary conditions are given by

$$\left.\begin{array}{lll} u_c = u_p & \text{at} & y = \pm\frac{\delta}{h} \\ u_c = 0 & \text{at} & y = \pm 1 \end{array}\right\} \quad \ldots \qquad (2.6)$$

3. SOLUTION OF THE PROBLEM

Solving the equations (2.4) and (2.5) employing boundary conditions (2.6) we get

Fluid velocity in clear region is given by

$$u = \frac{G}{\nu\beta^2}\left(y\sinh\beta + \cosh\beta - e^{\beta y)}\right) \qquad \ldots.\ (2.7)$$

Fluid velocity in porous region is given by

$$u_p = \frac{G}{\nu\left(\beta^2 - \alpha^2\right)}\left[\frac{\cosh(\beta\frac{\delta}{h})}{\cosh(\alpha\frac{\delta}{h})}\cosh(\alpha y) + \frac{\sinh(\beta\frac{\delta}{h})}{\sinh(\alpha\frac{\delta}{h})}\sinh(\alpha y) \quad - e^{\beta\, y}\right] + \frac{G(1-\frac{\delta^2}{h^2})}{2\nu\cosh\alpha(\frac{\delta}{h})}\cosh(\alpha y) \qquad (2.8)$$

$$\alpha^2\Big)\left[\frac{\cosh(\beta\frac{\delta}{h})}{\cosh(\alpha\frac{\delta}{h})}\cosh(\alpha y) + \frac{\sinh(\beta\frac{\delta}{h})}{\sinh(\alpha\frac{\delta}{h})}\sinh(\alpha y) \quad - e^{\beta\, y}\right] + \frac{G(1-\frac{\delta^2}{h^2})}{2\nu\cosh\alpha(\frac{\delta}{h})}\cosh(\alpha y)$$

Where $\alpha^2 = \beta_1^{\,2} + M^2, \quad \beta_1^{\,2} = \frac{h^2}{K}, \quad M^2 = \frac{\sigma \beta_0^2 h^{\ 2}}{\mu}$

DEDUCTIONS:

Flow of an incompressible viscous fluid between two semi-infinite parallel plates partially with porous medium under transverse magnetic field is applied in porous region.(β=0)

Fluid velocity in clear region is given by

$$u_c = \frac{G}{2\nu}\left(1 - y^2\right) \quad \ldots \qquad (2.9)$$

Fluid velocity in porous region is given by

$$u_p = \frac{G}{2\nu}\left\{\left(1-\frac{2}{\alpha^2}-\left(\frac{\delta}{h}\right)^2\right)\frac{\cosh \alpha y}{\cosh(\alpha\,\delta/h)}+\frac{2}{\alpha^2}\right\} \qquad \ldots \qquad (3.0)$$

4. RESULTS AND DISCUSSIONS

Flow of stratified incompressible viscous fluid flow between two parallel plates is examined., The space between the plates is partially filled with h porous medium. There exists two regions one flow in clear region and other flow in porous region. Transverse magnetic field is applied in porous region. .

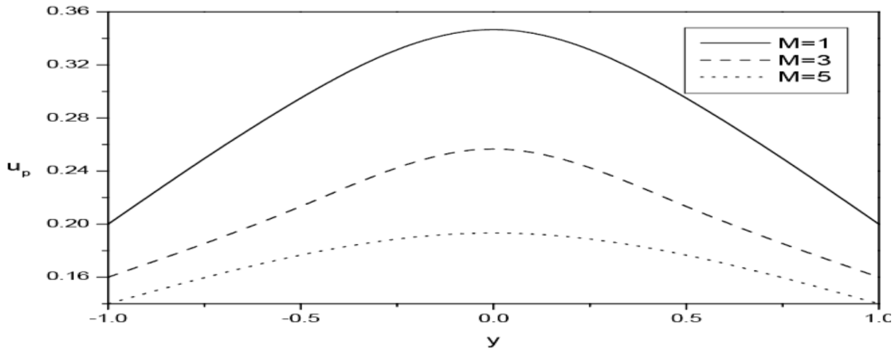

Fig.1: Variation of u_p with Magnatic parameter M

Fig.1, shows the variation of velocity of the fluid in porous region with increasing magnetic field. As magnetic field increases the velocity in porous region is decreasing

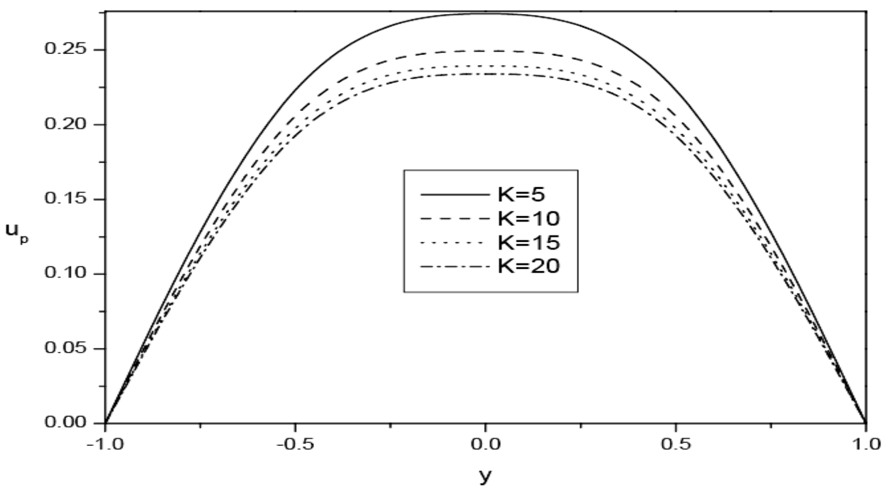

Fig.2: Variation of u_p with permeability parameter K

In Fig.2, the effect of the permeability of the porous medium on the fluid velocity in porous region is observed. As permeability of the porous medium is increasing the velocity of the fluid in porous region is decreasing.

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