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Non Darcian Approach to Flow of an Electrically Conducting Incompressible Viscous Fluid through Highly Porous Medium between Two Semi-Infinite Parallel Plates

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ABSTRACT: The flow of an electrically conducting incompressible viscous fluid is examined between two semi-infinite parallel plates. The space between the parallel plates is filled with highly porous medium.. The flow of an electrically conducting incompressible viscous produces induced electric current and the induced current produces induce magnetic field. The expressions for velocity of the fluid , flow rate of the fluid, induced magnetic field and current density are obtained in elegant forms.

KEYWORDS: electrically conducting incompressible viscous fluid, porous medium, permeability parameter

I. INTRODUCTION

The study of flow 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 Muskat [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 proposed by Brinkmann [4] is given by

$$0 = -\nabla P - \left(\frac{\mu}{K}\right)\vec{v} + \mu \nabla^2 \vec{v}$$

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

II. RELATED WORK

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. Earlier Narasimhacharyulu *et al.* [9] studied Two phase flow of an Incompressible Viscous fluid between two semi-infinite parallel plates under transverse magnetic field.

In this present paper flow of an electrically conducting incompressible viscous fluid is examined between two semi-infinite parallel plates. The space between the parallel plates is filled with highly porous medium.. The expressions for velocity of the fluid , flow rate of the fluid, induced magnetic field and current density are obtained in elegant forms.



III. MATHEMATICAL FORMULATION OF THE PROBLEM

The flow of an electrically conducting incompressible viscous fluid considered between two semi infinite parallel plates given by $y = \pm h$. The space between the plates is filled with 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 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 quantity depends only on y. The equation of motion is given by

$$\frac{d^2u}{dy^2} - \frac{u}{k} = -\frac{G}{\nu} \quad -h < y < h \quad \dots (2.1)$$

Induced magnetic field is given by the equation

$$\frac{1}{\mu} \frac{d^2h_x}{dy^2} + H_0 \frac{du}{dy} = 0 \quad \dots (2.2)$$

Where $G = -\frac{\partial p}{\partial x}$ is a constant pressure gradient in the x direction, ν is coefficient of viscosity of the fluid, k is permeability of the porous medium h_x is induced magnetic field, μ_e magnetic permeability, σ electric conductivity, H_0 magnetic field strength component

Using the following Non dimensional quantities.

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

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

$$\frac{d^2u}{dy^2} - \frac{h^2}{k} u = -\frac{G}{\nu}; \quad -1 < y < 1 \quad \dots (2.4)$$

The boundary conditions are given by

$$\left. \begin{aligned} u &= 0 & \text{at} & \quad y = \pm 1 \\ h_x &= 0 & \text{at} & \quad y = \pm 1 \end{aligned} \right\} \dots (2.5)$$

IV. SOLUTION OF THE PROBLEM

Solving the equation (2.4) and (2.2) employing boundary conditions (2.5) fluid velocity and flow rate are given by

$$u = \frac{G}{2\nu} (1 - y^2) \quad \dots (2.6)$$

Flow rate is

$$Q = \int_{-1}^1 u dy$$

$$Q = \frac{2G}{3\nu} \quad \dots (2.7)$$

Induced magnetic field

$$h_x = \frac{\mu GH_0}{\nu} y(1 + y^2) \quad (2.8)$$

Current density

$$J = -\frac{dh_x}{dy} = -\frac{\mu GH_0}{\nu} (1 + 3y^2) \quad \dots (2.9)$$



V. CONCLUSION

The flow of an electrically conducting incompressible viscous fluid is considered between two semi infinite parallel plates. The space between the plates is filled with 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 under a constant pressure gradient.

From the obtained analytical solutions, it is observed that as the viscosity of the fluid is increasing the velocity of the fluid, flow rate and induced magnetic field are decreasing. Further it is also observed that as viscosity of the fluid is increasing, the current density is also decreasing.

The results of the problem have great importance to the petroleum engineer concerned with the movement of oil, gas and water through the reservoir of an oil or gas field. Beyond this, the results of present problem are widely applicable in soil mechanics, water purification, ceramic engineering and power metallurgy.

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