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Unsteady MHD Flow of a Viscous Fluid through Porous Medium

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Abstract: ***This paper analyzed the exact solution of the unsteady motion of an electrically conducting; incompressible viscous fluid through porous medium under the action of transverse of magnetic field is obtained. The velocity and temperature profiles are obtained analytically and used to compute the wall shear stress and rate of heat Transfer at the channel walls. On the basis of certain simplifying assumption, and the fluid equations of continuity momentum and energy are obtained.***

Key Words: Porous Medium, Magnetic Field, Oscillatory Flow.

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INTRODUCTION

The study of flow of an electrically conducting fluid has many applications in engineering problems such as MHD generator plasma studies, nuclear reactor, geothermal energy extraction, and boundary layer control in the field of aerodynamic. The study of the motion of Newtonian fluids in the presence of a magnetic field has applications in many areas, including the handling of biological fluids and the flow of nuclear fuel slurries, liquid metals and alloys, plasma, mercury amalgams, and blood.

This happens because the inertial effects become important. Recently, Ahamadi and manvi (1971) derived a general equation of motion and applied the results obtained to some basic flow problems. Raptis (1983) studied the free convective flow through porous medium bounded by an infinite vertical plate with oscillating plate temperature and constant suction. Attia (1999) discussed the Transient MHD flow and heat transfer between two parallel plates with temperature dependent viscosity. Kunugi et al (2005) gave MHD effect on flow structures and heat transfer characteristics of liquid metal–gas annular flow in a vertical pipe. Abbas et al (2008) studied the Hydromegnatic flow in a viscoelastic fluid due to the oscillatory stretching surface. Samadi et al (2009) discussed the Analytic solution for heat transfer of a third grade viscoelastic fluid in non-Darcy porous media with thermo physical effects. In the present paper, we investigate the combined effects of a transverse magnetic field on unsteady flow of a conducting optically thin fluid through a channel filled with saturated porous medium and non-uniform walls temperature. In the following sections, the problem is formulated, solved and the pertinent results are discussed.

MATHEMATICAL FORMULATION

We consider the unsteady of an electrically conducting, incompressible and viscous fluid through a porous medium in the present of transverse magnetic field. Take a Cartesian coordinate system (x, y) where ox lies along the centre of channel, y is the distance measured in the normal suction. The governing equations of motion are

$$\rho\frac{\partial u}{\partial t}=-\frac{\partial p}{\partial x}+\mu\frac{\partial^2 u}{\partial y^2}-\mu\frac{u}{K}-\sigma B_0^2 u+g\rho\beta\left(T-T_0\right)$$
…. (1)

$$-\frac{1}{\rho}\frac{\partial p}{\partial y}=0$$
…. (2)

$$\frac{\partial u}{\partial x}=0$$
…. (3)

With the initial boundary conditions

$u=0, \quad t\le 0$

$u=0, \; y=\pm d, \; t>0$

…. (4)

Where u is the axial velocity, t the time, T the fluid temperature, g the gravitational force, q the radiative heat flux, β the coefficient of volume expansion, K the permeability of porous medium, $B_0=(\mu_e H_0)$

the electromagnetic induction, μ_e is the magnetic permeability, H_0 the intensity of magnetic field, σ_e the conductivity of the fluid, ρ is the fluid density, υ is the kinematics viscosity coefficient, T_0 and T_w is the wall temperature.

Let us introduce the following non-dimensional variable

$$\mathrm{Re}=\frac{Ua}{\upsilon},\quad x^*=\frac{x}{d},\quad y^*=\frac{y}{d},\quad u^*=\frac{u}{U},\quad \theta=\frac{T-T_0}{T_w-T_0},$$

$$H^2=\frac{d^2\sigma_e B_0^2}{\rho\upsilon},\ P^*=\frac{dP}{\rho\upsilon U},\ Da=\frac{K}{a^2},\ Gr=\frac{g\beta\left(T_w-T_0\right)d^2}{\upsilon U}$$

Where *Gr* the grashoff number, U is the flow mean velocity, *H* the Hartmann number, *Re* the Reynolds number, *Da* is the Darcy number and *s =1/Da* is the porous medium shape factor parameter.

Using the non-dimensional variable the equations (1), (2) and (3) becomes

$$\mathrm{Re}\frac{\partial u^*}{\partial t^*}=-\frac{\partial p^*}{\partial x^*}+\frac{\partial^2 u^*}{\partial y^{*2}}-\mu\frac{u}{K}-\left(s^2+H^2\right)u^*+Gr\theta$$

…. (5)

$$\frac{\partial p^*}{\partial y^*}=0$$

…. (6)

$$\frac{\partial u^*}{\partial x^*}=0$$

…. (7)

With the initial boundary conditions

$$u=0,\ \theta=0,\quad y=1,$$
$$u=0,\ \theta=0,\quad y=0,$$

…. (8)

From equation (6) it is clear that P^* is independent of y^*, solving the equation (5) for purely oscillatory flow.

Let

$$-\frac{\partial p}{\partial x}=\delta e^{i\omega t},\quad u\left(y,t\right)=u_0\left(y\right)e^{i\omega t}$$

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…. (9)

Where δ is a constant and ω is the frequency of the oscillation, substituting the equation (9) in (5) we obtain the following form

$$\frac{d^2u_0}{dy^2}-m^2u_0=\delta-Gr\theta_0$$

…. (10)

With the boundary conditions