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HYDROMAGNETIC VISCO-ELASTIC FLOW THROUGH A HORIZONTAL PARALLEL PLATES MOVING IN OPPOSITE DIRECTIONS IN PRESENCE OF SUCTION/INJECTION

Paban Dhar

Department of Mathematics, Karimganj College, Sribhumi, Assam

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ABSTRACT

In this chapter, a study of two dimensional unsteady visco-elastic fluid flow through a horizontal parallel plates moving in opposite directions has been carried out in presence of suction/injection. The transverse magnetic field of magnitude B0 is applied in the direction perpendicular to the plate. The plate suction is considered to be periodic in nature. The equations of fluid motion are solved numerically by using Matlab bvp4c inbuilt solver. The effects of various fluid parameters on fluid motion are analyzed graphically and discussed.

KEYWORDS: MHD, Matlab Bvp4c Solver, Visco-Elastic

1. INTRODUCTION

The topic of fluid flow phenomena along with MHD with heat and mass transfer continues to create much interest among the scientific community. This is because of their applications in many industrial aspects such as the compact heat exchangers, aerodynamics, cooling of nuclear reactor, chemical distillation and others. The process of mass and heat transmission through a channel in presence of suction and injection has attracted the attention of scientists in perspective of their industrial applicability.

In (1953), Berman has investigated the laminar flow in channels with porous walls. Alpher (1961) has examined the heat transfer in magneto-hydrodynamic flow between parallel plates. Verma and Bansal (1966) have studied the flow of an incompressible fluid between two parallel plates, one in uniform motion and the other at rest with uniform suction at the stationary plate. The velocity and temperature distributions of a viscous incompressible fluid flow between two parallel plates have been analyzed by Verma and Gaur (1972). Kaviany (1985), Sharma and Singh (1992), Sharma and Patidar (1994), Attia and Kotb (1996), Sharma and Mishra (2002) have analyzed the nature of steady viscous flow between two infinite parallel porous plates under the effects of various physical phenomenon. Sharma and Kumar (1998), Sharma *et al.* (2004), Sarangi and Sharma (2005) have studied the unsteady viscous fluid flow in presence of various physical properties like heat transfer or MHD or heat source/ sink etc. Bodosa and Borkakati (2003) have analyzed the problem of MHD Couette flow with heat transfer between two horizontal plates in presence of uniform transverse magnetic field. Umavathi *et al.* (2009) have examined the nature of unsteady oscillatory flow and heat transfer in a horizontal composite porous medium channel. The analytical solutions of unsteady oscillatory particulate visco-elastic fluid flow between two parallel walls have been given by Ajadi (2010). The behavior of unsteady MHD Couette flow of a visco-elastic fluid with heat transfer has been examined by Attia (2010). Choudhury *et al.* (2014) have investigated the visco-elastic MHD flow through a porous medium bounded by horizontal parallel plates moving in opposite direction in presence of heat and

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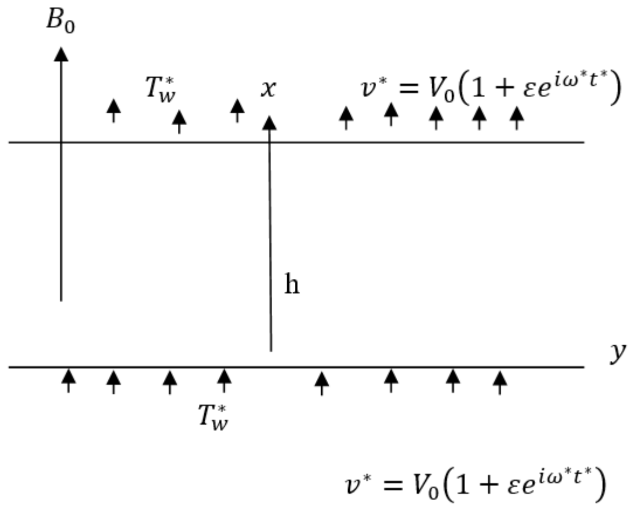
mass transfer.

The purpose of this study is to analyze the visco-elastic effect in an unsteady MHD viscous flow with heat and mass transfer through a horizontal parallel porous plates moving in opposite directions with periodic suction and injection.

MATHEMATICAL FORMULATION

Consider an unsteady MHD visco-elastic flow with heat and mass transfer through moving parallel plates in opposite direction with periodic suction and injection moving with same velocity U. A magnetic field of strength B_0 is applied in transverse direction to the plate. The distance between parallel plates is h and maintained at temperature T_w^*. Let x- axis be taken along the tangential direction of the plates and y- axis be taken in the perpendicular direction to the plates.



Physical model of the Problem

With these assumptions and usual boundary layer approximations, the governing equations of fluid motion are:

Equation of Continuity:

Equation of Continuity:

$$\frac{\partial v^*}{\partial y^*} = 0 \Rightarrow v^* = V_0\left(1+\varepsilon e^{i\omega^* t^*}\right) \tag{1}$$

Momentum equation:

$$\frac{\partial u^*}{\partial t^*} + v^*\frac{\partial u^*}{\partial y^*} + \frac{1}{\rho}\frac{\partial p^*}{\partial x^*} = \nu\frac{\partial^2 u^*}{\partial y^{*2}} - \frac{k_0}{\rho}\left(\frac{\partial^3 u^*}{\partial y^{*2}\partial t^*} + v^*\frac{\partial^3 u^*}{\partial y^{*3}}\right) - \frac{\nu}{K^*}u^* - \frac{\sigma B_0^2}{\rho}u^* \tag{2}$$

Energy equation:

$$\frac{\partial T^*}{\partial t^*} + v^*\frac{\partial T^*}{\partial y^*} - \frac{K_T}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}} = \frac{\nu}{C_p}\left(\frac{\partial u^*}{\partial y^*}\right)^2 - \frac{k_0}{\rho C_p}\left(\frac{\partial u^*}{\partial y^*}\frac{\partial^2 u^*}{\partial y^*\partial t^*} + v^*\frac{\partial u^*}{\partial y^*}\frac{\partial^2 u^*}{\partial y^{*2}}\right) \tag{3}$$

Concentration equation:

$$\frac{\partial C^*}{\partial t^*} + v^*\frac{\partial C^*}{\partial y^*} = D\frac{\partial^2 C^*}{\partial y^{*2}} \tag{4}$$

Boundary conditions are:

$$y^* = 0: \quad u^* = U^*, \quad T^* = T_w^*, \quad C^* = C_{w_1}^*$$

$$y^* = h: \quad u^* = -U^*, \quad T^* = T_w^*, \quad C^* = C_{w_2}^* > C_{w_1}^* \tag{5}$$

Introduce the following non-dimensional quantities:

$$x=\frac{x^*}{h}, y=\frac{y^*}{h}, u=\frac{u^*h}{\nu}, U=\frac{U^*h}{\nu}, \phi=\frac{C^*-C_s^*}{C_{w_1}^*-C_s^*}, \nu=\frac{\eta_0}{\rho}$$

$$K=\frac{K^*}{h^2}, M^2=\frac{\sigma B_0^2h^2}{\rho\nu}, Gr=\frac{h\beta g(C_{w_1}^*-C_\infty^*)}{v_0^2}, Pr=\frac{\eta_0 C_p}{K_T}, Sc=\frac{\nu}{D'}, p=\frac{p^*h^2}{\rho\nu^2}$$

$$Re=\frac{v_0 h}{\nu}, \theta=\frac{T^*-T_s^*}{T_w^*-T_s^*}, Ec=\frac{\nu^2}{h^2C_p(T_w'-T_s')}, \omega=\frac{\omega^*h^2}{\nu}, t=\frac{t^*\nu}{h^2}, k=\frac{k_0}{\rho h^2}$$

We get the following set of governing equations of motion which are dimensionless

$$\frac{\partial u}{\partial t}+Re\left(1+\varepsilon e^{i\omega t}\right)\frac{\partial u}{\partial y}=-\frac{\partial p}{\partial x}+\frac{\partial^2 u}{\partial y^2}-k\left\{\frac{\partial^3 u}{\partial y^2\partial t}+Re\left(1+\varepsilon e^{i\omega t}\right)\frac{\partial^3 u}{\partial y^3}-\frac{u}{K}-M^2u\right\} \tag{6}$$

$$\frac{\partial\theta}{\partial t}+Re\left(1+\varepsilon e^{i\omega t}\right)\frac{\partial\theta}{\partial y}=\frac{1}{Pr}\frac{\partial^2\theta}{\partial y^2}+Ec\left(\frac{\partial u}{\partial y}\right)^2-kEc\left\{\frac{\partial u}{\partial y}\frac{\partial^2 u}{\partial y\partial t}+Re\left(1+\varepsilon e^{i\omega t}\right)\frac{\partial u}{\partial y}\frac{\partial^2 u}{\partial y^2}\right\} \tag{7}$$

$$\frac{\partial\phi}{\partial t}+Re\left(1+\varepsilon e^{i\omega t}\right)\frac{\partial\phi}{\partial y}=\frac{1}{Sc}\frac{\partial^2 u}{\partial y^2} \tag{8}$$

where Pr is the Prandtl number, Gr is the Grashof number, M is the magnetic parameter, Ec is the Eckert number, K is the permeability parameter, k is the visco-elastic parameter, Sc is the Schmidt number, Re is the cross flow Reynolds number, T_w^* is the wall temperature, $C_{w_1}^*$ and $C_{w_2}^*$is the concentration of the fluid at the walls.

The transformed boundary conditions are

$$y=0: \quad u=U, \theta=1, \phi=1;$$

$$y=1: u=-U,\ \theta=1,\ \phi=\frac{C^*_{w_2}-C_s^*}{C_{w_1}^*-C_s^*}=m(say) \tag{9}$$

where m is a constant

METHOD OF SOLUTION

Numerical technique has been employed to solve the equations (6) to (8) under boundary conditions (9). MATLAB's built in solver bvp4c is used in this problem.

RESULTS AND DISCUSSIONS

The main purpose of this paper is to study the visco-elastic effects on fluid flow through a horizontal parallel plates moving in opposite directions in presence of periodic suction/injection. Figures (1) and figure (2) represents the velocity field against the displacement variable y for various values of fluid parameters involved in the solution. The visco-elasticity is represented through the non-zero value of dimensionless parameter k. It is seen in the figures that a growth in visco-elasticity enhances the fluid motion. Also, it can be said that the visco-elastic effect is prominent in the middle of the channel.

Generally, transverse magnetic field creates Lorentz force and it has some retarding effect in the vicinity of the lower plate which is moving in the positive direction. An accelerating nature of fluid flow is noticed from the midway of the channel as the upper plate is moving in the opposite direction of the lower plate (Figure 1). The retarding effect of Lorentz force is more prominent in the neighborhood of the lower plate. Since Reynolds number signifies the effect of inertia force and viscous force together in the fluid flow regime and so it is seen that as Reynolds number increases, speed of both Newtonian and visco-elastic fluid flows increases throughout the channel (Figure 2).

The effect of various flow parameters on the fluid temperature are depicted in figures 3 and figure 4. Figure 3 tells that the increasing values of visco-elastic parameter from k=0 to k=0.1, decrease the fluid temperature and the visco-elastic effect is maximum in the centre of the flow channel. In addition to that the effect of intensity of magnetic field on the temperature field is seen on figure 3. It is noticed from figure 3 that the magnetic field affects the Newtonian fluid temperature a little bit but it affects non-Newtonian fluid temperature vigorously. The magnitude of the fluid temperature slightly rises for Newtonian fluid but the non-Newtonian fluid temperature decreases rapidly due to increase of intensity of the magnetic field. This magnitude is higher in Newtonian fluid than visco-elastic fluid.

The effects of Reynolds number on temperature distribution is illustrated in figure 4. It is seen that with the modification of visco-elastic parameter, temperature field of visco-elastic fluid gradually decreases but the increasing effect of Reynolds number Re, modifies the magnitude of visco-elastic fluid temperature field.

The rate of heat transfer in terms of Nusselt number and the rate of mass transfer in terms of Sherwood number are not significantly affected by the visco-elastic parameter.

CONCLUSION

The present investigation noted the following conclusions:

- The rising value of visco-elastic parameter accelerates the speed of visco-elastic fluid.
- The fluid temperature decreases with the modification of visco-elastic parameter.
- The rate of heat transfer and the rate of mass transfer are not significantly affected by the visco-elastic parameter.

Fig. 1: Velocity u against y for Pr=1, K=1, ω=2,ωt=π/4 , Ec= 0.02, Re=0.5, A=0.1, U=1 ,ε=0.01

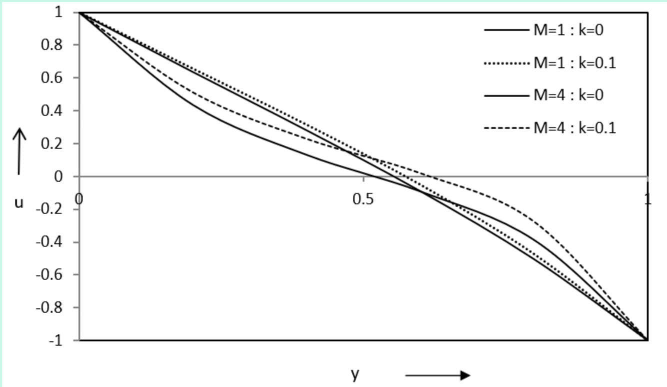


Fig. 2: Velocity u against y for M= 2, Pr=1, K=1,ω=2,ωt=π/4 , Ec= 0.02, A=0.1, U=1 ,ε=0.01

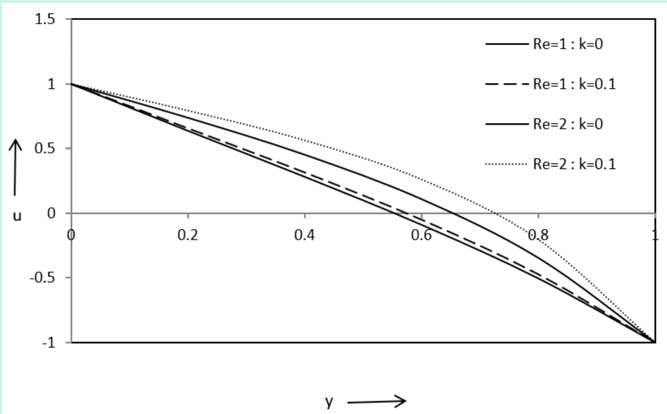


Fig. 3: Temperature θ versus y for Re= 1, Pr=1, K=1,ω=2,ωt=π/4 , Ec= 0.02, A=0.1, U=1 ,ε=0.01

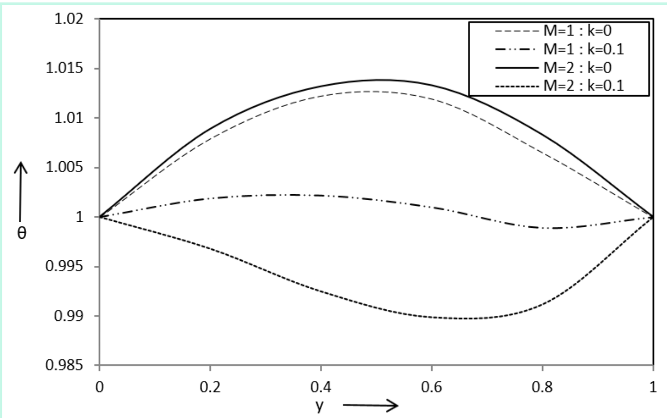
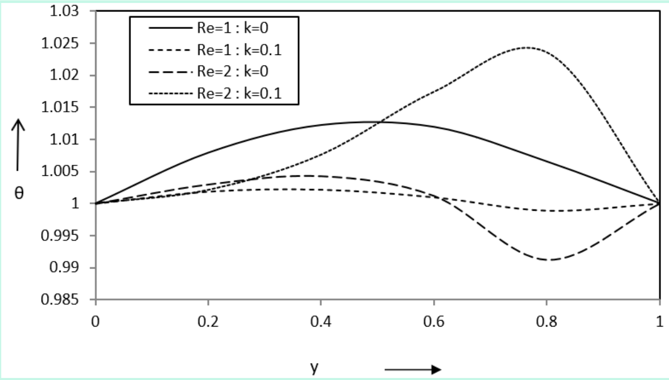


Fig. 4: Temperature θ versus y for Pr=1, K=1, ω=2,ωt=π/4 , Ec= 0.02, M=1, A=0.1, U=1 ,ε=0.01



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