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MHD vicous viscoelastic fluid through magnetic field

Mathematics

KEYWORDS:

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ABSTRACT Synthesis of coumarins by the reaction of phenols with ethyl acetoacetate (Pechmann reaction) in presence of different Heteropoly acids (HPA) modified Bentonite (STA-Ben, PTA-Ben) as catalysts with high yields, under mild reaction conditions in short reaction time have been reported. HPA-Ben have been synthesized and characterized by various analytical techniques. It has been found to be an efficient and reusable catalyst for the synthesis of coumarin derivatives in excellent yields. Other solid acid catalysts were tested for comparison reasons. The reaction conditions (time and amount of catalyst) have been optimized using various catalysts.

Introduction

The interest in MHD fluid flows stems from the fact the liquid metals that occur in nature and industry are electrically conducting. Naturally, studies of these systems are mathematically interesting and physically useful dynamical study of such flow problems is quite complicated, However, there problems are usually investigated under various simplifying assumptions. First order reactant in MHD turbulence before the final period of decay for the case of multipoint and multi-time has been given by M.A. Islam and Sarkar[8]. Alyub Khan and Bhatia[1] investigated stability of two superposed viscoelastic fluids in a horizontal magnetic field. Gupta and Bhatia[2] have studied the stability of the plane interface between two viscous superposed partially lonized plasma of uniform. Insities in a uniform two dimensional horizontal magnetic field Srivastava and Khare[3] have investigated the Rayleigh – Taylor instability of two viscous superposed conducting fluids on a vertical magnetic field. Daval Osorozco[7] has studied the Reyleigh Taylor instability of a two fluid layer under a general rotation field and horizontal magnetic field. Elgowainy and Ashgriz[4] have investigated the Rayleigh-Talor instability of viscous fluid layers more recently. Bhatia and Sharma[13] have studied the instability of the plane interface between two viscous fluids through porous medium under a uniform vertical magnetic field. P. Kumar and N.P. Singh[14] have investigated MHD Hele-shaw flow of an elastico viscous fluid through porous medium B. Yadav and Ray[5] studied unsteady flow of n-immiscible visco-elastic fluids through a porous medium between two parallel plates in the presence of a transverse magnetic field.

M.F. El Sayeed[9] has recently investigated the electro-hydrodynamics instability of two superpose viscous streaming fluid through porous media. G.D. Gupta and Joha[6] investigated MHD tree dimensional flow past a porous plate. N.D. Anglo and Song[11] & [12] have studied the Kelvin-Helmholtz instability problem in superposed dusty plasma.

Frguven has considered the dynamical Reissner-Sagocci problem for a radially non-homogeneous material. Pal and Kumar[15] have shown the effect of inhomogeneity on torsional impulsive motion over a circular region in a transversely isotropic elastic half-space. In another paper, Pal and Kumar16 have considered the generation and propagation of SH-waves due to stress discontinuity in a linear viscoelastic layered medium. Recently existence and propagation of torsional surface waves on viscoelastic medium have been discussed by Dey et al[17].

In this paper we have investigated MHD viscous viscelastic fluid through magnetic field.

NOMENCLATURE

B_0=Magnetic field component along y-axisPC=Specific heat of fluid at constant pressure

g = Acceleration due to gravity

k=Thermal conductivity of the fluid='KPermeability of the porous medium.

K= Permeability parameter

L=Half-wave length of the periodic suction velocity

M=Hartmann number='$p$pressure

P=Prandtl number

R=Reynolds number='TTemperature of the fluid='wTTemperature of the plate=∞'TTemperature of the fluid far away from the plate=''',,wvu

Velocity components in '",,zyxdirections
u,v,w=Dimensionless velocity components

U=Free stream velocity$systemcoordinatezyx$=",,,

y,z=Dimensionless coordinatesρ=Density of the fluid=νKinematic viscosity=μviscosity=αsuction parameter

Formulation of Problem

Consider three dimensional flow of viscous-incompressible fluid through a highly porous medium which is bounded by a vertical infinite porous plate.

Continuity equation:-

$$\frac{\partial u'}{\partial x'}+\frac{\partial v'}{\partial y'}+\frac{\partial w'}{\partial z'}=0 \qquad (1)$$

Momentum Equation

$$u'\frac{\partial u'}{\partial x'}+v'\frac{\partial u'}{\partial y'}+w\frac{\partial u'}{\partial z'}=-\frac{1}{\rho}\frac{\partial p'}{\partial x'}+\nu\left(\frac{\partial^2 u'}{\partial x'^2}+\frac{\partial^2 v'}{\partial y'^2}+\frac{\partial^2 z'}{\partial z'^2}\right)-\frac{\sigma B_0^2 u'}{\rho} \qquad (2)$$

$$u'\frac{\partial v'}{\partial x'}+v'\frac{\partial v'}{\partial y'}+w\frac{\partial v'}{\partial z'}=-\frac{1}{\rho}\frac{\partial p'}{\partial y'}+\nu\left(\frac{\partial^2 v'}{\partial x'^2}+\frac{\partial^2 v'}{\partial y'^2}+\frac{\partial v'}{\partial z'^2}\right)-\frac{\sigma B_0^2 v'}{\rho} \qquad (3)$$

$$u'\frac{\partial w'}{\partial x'}+v'\frac{\partial w'}{\partial y'}+w\frac{\partial w'}{\partial z'}=-\frac{1}{\rho}\frac{\partial p'}{\partial z'}+\nu\left(\frac{\partial^2 w'}{\partial x'^2}+\frac{\partial^2 w'}{\partial y'^2}+\frac{\partial w'}{\partial z'^2}\right)-\frac{\sigma B_0^2 w'}{\rho} \qquad (4)$$

$$\rho Cp\left(u'\frac{\partial T'}{\partial x'}+v'\frac{\partial T}{\partial y'}+w'\frac{\partial T}{\partial z'}\right)=k\left(\frac{\partial^2 T'}{\partial x'^2}+\frac{\partial^2 T'}{\partial y'^2}+\frac{\partial^2 T'}{\partial z'^2}\right) \qquad (5)$$

We now introduce the following non-dimensional variables :

$$y=\frac{y'}{d}, z=\frac{z'}{d}, u=\frac{u'}{v}, v=\frac{v'}{v}, p=\frac{p'}{pv^2}$$

$$\theta=\left(\frac{T'-T_o}{T_1-T_o}\right)$$

Prandtl Number (P): $p=\frac{\mu C_p}{k}$

Reynold's Number (R) : $R=\frac{UL}{v}$

Harmann Number (M) : $M=\frac{\sigma B_o^2 vL}{U\mu}$

Permeability Parameter (k) : $K=\frac{K'U^2}{v^2}$

Suction Parameter (α) : $\alpha=\frac{V}{U}$

Kinematic coefficient viscosity (v): $v=\frac{\mu}{\rho}$

With the help of the above non-dimensional variables eq (1) to (5) become:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \quad (6)$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{\partial p}{\partial x}+\frac{1}{R}\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)-Mu \quad (7)$$

$$u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{\partial p}{\partial y}+\frac{1}{R}\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)-Mv \quad (8)$$

$$u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=-\frac{\partial p}{\partial z}+\frac{1}{R}\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)-Mw \quad (9)$$

$$u\frac{\partial \theta}{\partial x}+v\frac{\partial \theta}{\partial y}+w\frac{\partial \theta}{\partial z}=\frac{1}{PR}\left(\frac{\partial^2 \theta}{\partial x^2}+\frac{\partial^2 \theta}{\partial y^2}+\frac{\partial^2 \theta}{\partial z^2}\right) \quad (10)$$

Solution of the Problem and Results

In order to solve these differential equations, we assume that.

Case I

$$u(x,y,z)=u_o(x)+\varepsilon u_1(x,y,z), \quad (11)$$

$$v(x,y,z)=v_o(x)+\varepsilon v_1(x,y,z), \quad (12)$$

$$w(x,y,z)=w_o(x)+\varepsilon w_1(x,y,z), \quad (13)$$

$$p(x,y,z)=p_o(x)+\varepsilon p_1(x,y,z), \quad (14)$$

and

$$\theta(x,y,z)=\theta_o(x)+\varepsilon \theta_1(x,y,z), \quad (15)$$

partially diff. eq. (11) w. r. t. x

$$\frac{\partial u}{\partial x}=\frac{\partial u_o}{\partial x}+\varepsilon\frac{\partial u_1}{\partial x} \quad (16)$$

again p. diff. w. r. t. x

$$\frac{\partial^2 u}{\partial x^2}=\frac{\partial^2 u_o}{\partial x^2}+\varepsilon\frac{\partial^2 u_1}{\partial x^2} \quad (17)$$

p. diff. eq. (11) w. r. t. y

$$\frac{\partial u}{\partial y}=\varepsilon\frac{\partial u_1}{\partial y} \quad (18)$$

again diff. w. r. t. to y

$$\frac{\partial^2 u}{\partial y^2}=\varepsilon\frac{\partial^2 u_1}{\partial y^2} \quad (19)$$

p. diff. eq. (11) w. r. t. to z

$$\frac{\partial u}{\partial z}=\varepsilon\frac{\partial u_1}{\partial z} \quad (20)$$

Again diff. w. r. t. z

$$\frac{\partial^2 u}{\partial z^2}=\varepsilon\frac{\partial^2 u_1}{\partial z^2} \quad (21)$$

p. diff. eq (12) w. r. t. x

$$\frac{\partial v}{\partial x}=\frac{\partial v_o}{\partial x}+\varepsilon\frac{\partial v_1}{\partial x} \quad (22)$$

Again Diff. w. r. t. x

$$v_o\frac{\partial \theta_o}{\partial y}=\frac{1}{PR}\frac{\partial^2 \theta_o}{\partial y^2} \quad (23)$$

p. diff. Eq (12) w. r. to y

$$\frac{\partial v}{\partial y}=\varepsilon\frac{\partial v_1}{\partial y} \quad (24)$$

Again diff. w. r. t. y

$$\frac{\partial^2 v}{\partial y^2}=\varepsilon\frac{\partial^2 v_1}{\partial y^2} \quad (25)$$

diff. Eq. (12) w. r. t. z

$$\frac{\partial v}{\partial z}=\varepsilon\frac{\partial v_1}{\partial z} \quad (26)$$

Again diff. w. r. t. z

$$\frac{\partial^2 v}{\partial z^2}=\varepsilon\frac{\partial^2 v_1}{\partial z^2} \quad (27)$$

p. diff. eq . (13) w. r. t. x

$$\frac{\partial w}{\partial x}=\frac{\partial w_o}{\partial x}+\varepsilon\frac{\partial w_1}{\partial x} \quad (28)$$

Again diff. w. r. t. x

$$\frac{\partial^2 w}{\partial x^2}=\frac{\partial^2 w_o}{\partial x^2}+\varepsilon\frac{\partial^2 w_1}{\partial x^2} \quad (29)$$

p. diff. eq. (13) w. r. t. y

$$\frac{\partial w}{\partial y}=\varepsilon\frac{\partial w_1}{\partial y} \quad (30)$$

Again diff.

$$\frac{\partial^2 w}{\partial y^2} = \varepsilon \frac{\partial^2 w_1}{\partial y^2} \tag{31}$$

p. diff. eq. (13) w. r. t. z

$$\frac{\partial^2 w}{\partial z^2} = \varepsilon \frac{\partial^2 w_1}{\partial z^2} \tag{33}$$

Again diff.

$$\frac{\partial p}{\partial x} = \frac{\partial p_o}{\partial x} + \varepsilon \frac{\partial p_1}{\partial x} \tag{34}$$

p. diff. eq. (14) w. r. t. x

$$\frac{\partial p}{\partial y} = \frac{\partial p_o}{\partial y} + \varepsilon \frac{\partial p_1}{\partial y} \tag{35}$$

p. diff. eq. (14) w. r. t. z

$$\frac{\partial p}{\partial z} = \frac{\partial p_o}{\partial z} + \varepsilon \frac{\partial p_1}{\partial z} \tag{36}$$

put the values of $\frac{\partial u}{\partial x}, \frac{\partial v}{\partial y}, \frac{\partial w}{\partial z}$ in eq (6) from eq. no.s (16),(24) and (32) resp.

$$\frac{\partial u_o}{\partial x} + \varepsilon \frac{\partial u_1}{\partial x} + \varepsilon \frac{\partial v_1}{\partial y} + \varepsilon \frac{\partial w_1}{\partial z} = 0 \tag{37}$$

equating the terms of free from ε

$$\frac{\partial u_o}{\partial x} = 0 \text{ i. e. } u_0' = 0 \tag{38}$$

Put the values of $\frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}, \frac{\partial u}{\partial z}, \frac{\partial^2 u}{\partial x^2}, \frac{\partial^2 u}{\partial y^2}, \frac{\partial^2 u}{\partial z^2}$ and $\frac{\partial p}{\partial x}, u, v, w,$ in eq (7) from eq no.

$$(u_o + \varepsilon u_1)\left(\frac{\partial u_o}{\partial x} + \varepsilon \frac{\partial u_1}{\partial x}\right) + (v_o + \varepsilon v_1)\left(\varepsilon \frac{\partial u_1}{\partial y}\right) + (w_o + \varepsilon w_1)\left(\varepsilon \frac{\partial u_1}{\partial z}\right)$$
$$= -\frac{\partial p_o}{\partial x} - \varepsilon \frac{\partial p_1}{\partial x} + \frac{1}{R}\left(\frac{\partial^2 u_o}{\partial x^2} + \varepsilon \frac{\partial^2 u_1}{\partial x^2} + \varepsilon \frac{\partial^2 u_1}{\partial y^2} + \varepsilon \frac{\partial^2 u_1}{\partial z^2}\right) - M(u_0 + \varepsilon u_1) \tag{39}$$

equating the terms free from ε

$$u_o \frac{\partial u_o}{\partial x} = -\frac{\partial p_o}{\partial x} + \frac{1}{R}\left(\frac{\partial^2 u_o}{\partial x^2}\right) - M u_o$$

$$u_o u_o' R = -p_o' R + u_o'' \_ MR u_o$$
$$-u_o'' + u_o R u_o' + R p_o' + MR u_o = 0$$
$$u_o'' - u_o R u_o' - R p_o' - MR u_o = 0 \tag{40}$$

Put the values of $\frac{\partial v}{\partial x}, \frac{\partial v}{\partial y}, \frac{\partial v}{\partial z}, \frac{\partial^2 v}{\partial x^2}, \frac{\partial^2 v}{\partial y^2}, \frac{\partial^2 v}{\partial z^2}$ and $\frac{\partial p}{\partial x}, u, v, w$ in eq (8) from eq no.-

$$(u_o + \varepsilon u_1)\left(\frac{\partial v_o}{\partial x} + \varepsilon \frac{\partial v_1}{\partial x}\right) + (v_o + \varepsilon v_1)\left(\varepsilon \frac{\partial v_1}{\partial y}\right) + (w_o + \varepsilon w_1)\left(\varepsilon \frac{\partial v_1}{\partial z}\right)$$

$$= -\frac{\partial p_o}{\partial x} + \frac{1}{R}\left(\frac{\partial^2 v_o}{\partial x^2} + \varepsilon \frac{\partial^2 v_1}{\partial x^2} + \varepsilon \frac{\partial^2 v_1}{\partial y^2} + \varepsilon \frac{\partial^2 v_1}{\partial z^2}\right) - M(v_o + \varepsilon v_1) \tag{41}$$

equating the terms free from e from eq. (41)

$$u_o \frac{\partial v_o}{\partial x} = \frac{1}{R}\left(\frac{\partial^2 v_o}{\partial x^2}\right) - M u_o$$
$$u_o v_o' R = v_o'' - MR v_o$$
$$-v_o'' + u_o R v_o' + MR v_o = 0$$
$$v_o'' - u_o R v_o' - MR v_o = 0 \tag{42}$$

Put the values of $\frac{\partial w}{\partial x}, \frac{\partial w}{\partial y}, \frac{\partial w}{\partial z}, \frac{\partial^2 w}{\partial x^2}, \frac{\partial^2 w}{\partial y^2}, \frac{\partial^2 w}{\partial z^2}$ and u, v, w in eq (9) from eq no.-

$$(u_o + \varepsilon u_1)\left(\frac{\partial w_o}{\partial x} + \varepsilon \frac{\partial w_1}{\partial x}\right) + (v_o + \phi v_1)\left(\varepsilon \frac{\partial w_1}{\partial y}\right) + (w_o + \varepsilon w_1)\left(\varepsilon \frac{\partial w_1}{\partial z}\right)$$
$$= -\frac{\partial p_1}{\partial x} + \frac{1}{R}\left(\frac{\partial^2 w_o}{\partial x^2} + \varepsilon \frac{\partial^2 w_1}{\partial x^2} + \varepsilon \frac{\partial^2 w_1}{\partial y^2} + \varepsilon \frac{\partial^2 w_1}{\partial z^2}\right) - M(w_0 + \varepsilon w_1) \tag{43}$$

equating the terms free from ε from eq. (43)

$$u_o \frac{\partial w_o}{\partial x} = \frac{1}{R}\left(\frac{\partial^2 w_o}{\partial x^2}\right) - M w_o$$
$$-w_o'' + u_o R w_o' + MR w_o = 0$$
$$w_o'' - u_o R w_o' - MR w_o = 0 \tag{44}$$

$$u \frac{\partial \theta}{\partial x} + v \frac{\partial \theta}{\partial y} + w \frac{\partial \theta}{\partial z} = \frac{1}{PR}\left(\frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2} + \frac{\partial^2 \theta}{\partial z^2}\right)$$

partially diff. eq (15) w. r. t. x

$$\frac{\partial \theta}{\partial x} = \frac{\partial \theta_o}{\partial x} + \varepsilon \frac{\partial \theta_1}{\partial x} \tag{45}$$

Again diff. eq w.r. t. x

$$\frac{\partial^2 \theta}{\partial x^2} = \frac{\partial^2 \theta_o}{\partial x^2} + \varepsilon \frac{\partial^2 \theta_1}{\partial x^2} \tag{46}$$

Partially diff. eq (15) w. r. t. y

$$\frac{\partial \theta}{\partial y} = \varepsilon \frac{\partial \theta_1}{\partial y} \tag{47}$$

Again diff. eq w.r. t. y

$$\frac{\partial^2 \theta}{\partial y^2} = \varepsilon \frac{\partial^2 \theta_1}{\partial y^2} \tag{48}$$

Partially diff. eq (15) w. r. t. z

$$\frac{\partial \theta}{\partial z} = \varepsilon \frac{\partial \theta_1}{\partial z} \tag{49}$$

Again diff. eq w.r. t. z

$$\frac{\partial^2 \theta}{\partial z^2} = \varepsilon \frac{\partial^2 \theta_1}{\partial z^2} \tag{50}$$

Put the values of $\frac{\partial \theta}{\partial x}, \frac{\partial \theta}{\partial y}, \frac{\partial \theta}{\partial z}, \frac{\partial^2 \theta}{\partial x^2}, \frac{\partial^2 \theta}{\partial y^2}, \frac{\partial^2 \theta}{\partial z^2}$ and u, v, w in eq (9) from eq no.-

$$(u_o + \varepsilon u_1)\left(\frac{\partial \theta_o}{\partial x} + \varepsilon \frac{\partial \theta_1}{\partial x}\right) + (v_o + \varepsilon v_1)\left(\varepsilon \frac{\partial \theta_1}{\partial y}\right) + (w_o + \varepsilon w_1)\left(\varepsilon \frac{\partial \theta_1}{\partial z}\right)$$
$$= -\frac{1}{RP}\left(\frac{\partial^2 \theta_o}{\partial x^2} + \varepsilon \frac{\partial^2 \theta_1}{\partial x^2} + \varepsilon \frac{\partial^2 \theta_1}{\partial y^2} + \varepsilon \frac{\partial^2 \theta_1}{\partial z^2}\right) \tag{51}$$

equating the terms free from e from eq. (51)

$$u_o \frac{\partial \theta_o}{\partial x} = -\frac{1}{RP} \frac{\partial^2 \theta_o}{\partial x^2} \tag{52}$$

$$u_o \theta_o' = -\frac{1}{RP} \theta_o''$$

$$\theta_o'' + RP u_o \theta_o' = 0 \tag{53}$$

$$\theta_o'' + RPu_o\theta_o' = 0 \tag{53}$$

equating the coefficient of ε from eq's (39)

$$u_o\frac{\partial u_1}{\partial x} + v_o\frac{\partial u_1}{\partial y} + w_o\frac{\partial u_1}{\partial z} = -\frac{\partial p}{\partial x} + \frac{1}{R}\left(\frac{\partial^2 u_1}{\partial x^2} + \frac{\partial^2 u_1}{\partial y^2} + \frac{\partial u_1}{\partial z^2}\right) - Mu_1 \tag{54}$$

equating the coefficient of ε from eq. (37)

$$\frac{\partial u_1}{\partial x} + \frac{\partial v_1}{\partial y} + \frac{\partial w_1}{\partial z} = 0 \tag{55}$$

equating the coffrcient of ε from equation(431)

$$u_0\frac{\partial v_1}{\partial x} + u_1\frac{\partial v_0}{\partial x} + v_0\frac{\partial v_1}{\partial y} + w_0\frac{\partial v_1}{\partial z}$$
$$= -\frac{\partial p}{\partial y} + \frac{1}{R}\left(\frac{\partial^2 v_1}{\partial x^2} + \frac{\partial^2 v_1}{\partial y^2} + \frac{\partial^2 v_1}{\partial z^2}\right) - Mv_1 \tag{56}$$

equating the coefficient of ε from equation (46)

$$u_0\frac{\partial w_1}{\partial x} + u_1\frac{\partial w_0}{\partial x} + v_0\frac{\partial w_1}{\partial y} + w_0\frac{\partial w_1}{\partial z}$$
$$= -\frac{\partial p_1}{\partial z} + \frac{1}{R}\left(\frac{\partial^2 w_1}{\partial x^2} + \frac{\partial^2 w_1}{\partial y^2} + \frac{\partial^2 w_1}{\partial z^2}\right) - Mw_1 \tag{57}$$

equating the coefficient of ε from equation (51)

$$u_0\frac{\partial \theta_1}{\partial x} + u_1\frac{\partial \theta_0}{\partial x} + v_0\frac{\partial \theta_1}{\partial y} + w_0\frac{\partial \theta_1}{\partial z} = -\frac{1}{RP}\left(\frac{\partial^2 \theta_1}{\partial x^2} + \frac{\partial^2 \theta_1}{\partial y^2} + \frac{\partial^2 \theta_1}{\partial z^2}\right) \tag{58}$$

Case II

$$u(x,y,z) = u_o(y) + \varepsilon u_1(x,y,z) \tag{59}$$
$$v(x,y,z) = v_o(y) + \varepsilon v_1(x,y,z) \tag{60}$$
$$w(x,y,z) = w_o(y) + \varepsilon w_1(x,y,z) \tag{61}$$
$$p(x,y,z) = p_o(y) + \varepsilon p_1(x,y,z) \tag{62}$$
$$\theta(x,y,z) = \theta_o(y) + \varepsilon \theta_1(x,y,z) \tag{63}$$
$$\varepsilon\frac{\partial u}{\partial x} + \varepsilon\frac{\partial v_o}{\partial y} + \varepsilon\frac{\partial v_1}{\partial y} + \varepsilon\frac{\partial w}{\partial z} = 0 \tag{64}$$

$$(u_0 + \varepsilon u_1)\varepsilon\frac{\partial u_1}{\partial x} + (v_o + \varepsilon v_1)\left(\frac{\partial u_o}{\partial y} + \varepsilon\frac{\partial u_1}{\partial y}\right) + (w_o + \varepsilon w_1)\left(\varepsilon\frac{\partial u_1}{\partial z}\right)$$
$$= -\left(\varepsilon\frac{\partial p_1}{\partial x}\right) + \frac{1}{R}\left(\varepsilon\frac{\partial^2 u_1}{\partial x^2} + \frac{\partial^2 u_0}{\partial y^2} + \varepsilon\frac{\partial^2 u_1}{\partial y^2} + \varepsilon\frac{\partial^2 w_1}{\partial z^2}\right) - M(u_o + \varepsilon u_1) \tag{65}$$

$$(u_0 + \varepsilon u_1)\varepsilon\frac{\partial v_1}{\partial x} + (v_o + \varepsilon v_1)\left(\frac{\partial v_o}{\partial y} + \varepsilon\frac{\partial v_1}{\partial y}\right) + (w_o + \varepsilon w_1)\left(\varepsilon\frac{\partial v_1}{\partial z}\right)$$
$$= -\left(\frac{\partial p_o}{\partial y} + \varepsilon\frac{\partial p_1}{\partial x}\right) + \frac{1}{R}\left(\varepsilon\frac{\partial^2 v_1}{\partial x^2} + \frac{\partial^2 v_0}{\partial y^2} + \varepsilon\frac{\partial^2 v_1}{\partial y^2} + \varepsilon\frac{\partial^2 v_1}{\partial z^2}\right) - M(v_o + \varepsilon v_1) \tag{66}$$

$$(u_0 + \varepsilon u_1)\varepsilon\frac{\partial w_1}{\partial x} + (v_o + \varepsilon v_1)\left(\frac{\partial w_o}{\partial y} + \varepsilon\frac{\partial w_1}{\partial y}\right) + (w_o + \varepsilon w_1)\left(\varepsilon\frac{\partial w_1}{\partial z}\right)$$
$$= -\left(\varepsilon\frac{\partial p_1}{\partial x}\right) + \frac{1}{R}\left(\varepsilon\frac{\partial^2 w_1}{\partial x^2} + \frac{\partial^2 w_0}{\partial y^2} + \varepsilon\frac{\partial^2 w_1}{\partial y^2} + \varepsilon\frac{\partial^2 w_1}{\partial z^2}\right) - M(w_o + \varepsilon w_1) \tag{67}$$

$$(u_0 + \varepsilon u_1)\varepsilon\frac{\partial \theta_1}{\partial x} + (v_o + \varepsilon v_1)\left(\frac{\partial \theta_o}{\partial y} + \varepsilon\frac{\partial \theta_1}{\partial y}\right) + (w_o + \varepsilon w_1)\left(\varepsilon\frac{\partial \theta_1}{\partial z}\right)$$
$$= -\frac{1}{PR}\left(\varepsilon\frac{\partial^2 \theta_1}{\partial x^2} + \frac{\partial^2 \theta_0}{\partial y^2} + \varepsilon\frac{\partial \theta_1}{\partial y^2} + \varepsilon\frac{\partial \theta_1}{\partial z^2}\right) \tag{68}$$

Equating the terms free from ε

$$\frac{\partial v_o}{\partial y} = 0$$
$$v_o' = 0 \tag{69}$$

$$v_o\frac{\partial u_o}{\partial y} = \frac{1}{R}\frac{\partial^2 u_o}{\partial y^2} - Mu_o$$
$$v_oRu_o' - u_o'' = -MRu_o$$
$$u_o'' - v_oRu_o' + MRu_o = 0 \tag{70}$$

$$v_o\frac{\partial v_o}{\partial y} = -\frac{\partial p_o}{\partial y} + \frac{1}{R}\frac{\partial^2 v_o}{\partial y^2} - Mv_o$$
$$Rv_ov_o' = -Rp_o' + v_o'' - MRv_o \tag{71}$$

$$v_o\frac{\partial w_o}{\partial y} = \frac{1}{R}\frac{\partial^2 w_o}{\partial y^2} - Mw_o$$
$$v_oRw_o' - w_o'' = -MRw_o$$
$$w_o'' - v_oRw_o' + MRw_o = 0 \tag{72}$$

$$v_o\frac{\partial \theta_o}{\partial y} = \frac{1}{PR}\frac{\partial^2 \theta_o}{\partial y^2}$$
$$PRv_o\theta_o' - \theta_o'' = 0$$

$$\theta'' - PRv_o\theta_o' = 0 \tag{73}$$

Result

MHD vicous viscoelastic fluid past an infinite, porous plate with constant suction under the action of time dependent plate temperature has been studied, when the plate temperature oscillates about a constant mean in magnitude but not in direction. In the absence of the magnetic field, it is observed that the flow is similar about y-axis where as this phenomenon disappears for non zero values of M.

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