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Unsteady Hydro magnetic Couette Flow in Presence of Variable inclined Magnetic Field

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***Abstract*— Unsteady MHD Couette flow of an incompressible electrically conducting fluid between two parallel infinite plates in the presence of an inclined variable magnetic field fixed relative to the moving porous plate with suction has been considered. The fluid flow is due to the uniformly accelerated movement of the lower plate of the channel with constant pressure gradient. The nonlinear partial differential equations governing the flow have been solved by finite difference method and implemented in MATLAB. Numerical results have been presented graphically for various physical parameters like Magnetic parameter, suction. The velocity and temperature profiles have been determined. The effect of the induced magnetic field and suction on the flow variables has also been determined. An increase in suction leads to a decrease in the induced magnetic field, the velocity and temperature profiles. Suction has a retarding influence to fluid velocity. As the angle of inclination and the magnetic parameter increase, velocity and the induced magnetic field increase. The results will be of great use to engineers to improve the efficiency of machines in dyeing industry.**

***Index Terms*—MHD, incompressible fluid, unsteady flow, Couette flow, suction.**

I. INTRODUCTION

Unsteady MHD Couette flow of an incompressible electrically conducting fluid between two parallel infinite plates in the presence of an inclined variable magnetic field has many applications in our daily lives. MHD is the field of study that deals with the interaction of electromagnetism and hydrodynamics. The study of interaction between electric and magnetic fields is known as electromagnetism while hydrodynamic is the science that deals with the flow of fluids. MHD has many varied applications in industries, engineering, mineral industry, polymer technology, designing of cooling systems with liquid metals, MHD pumps and generators, nuclear reactors using liquid metal coolant, dying industry and extraction of iron metal from the ores. Hartmann [1] investigated steady MHD flow between two infinite parallel stationary and insulated plates in the presence of a transverse uniform magnetic field.

Tao [2] investigated magneto hydro magnetic effects on the formation of Couette flow where one plate executed a constant speed u_0 and the results indicated that in the presence of a magnetic field the flow rat was reduced.

Katagiri *et al* [3] investigated MHD Couette flow of a viscous incompressible electrically conducting fluids under the influence of a uniform transverse magnetic field when the fluid flow within the channel is induced due to impulsive motion of one of the plates. The results indicated that for the case impulsive and accelerated motion of one of the plates, the magnitude of the shear stress component is due to the primary flow decrease. Muhuri *et al*[4] studied the formation of a Couette flow between two parallel walls due to impulsive and uniformly motion of one of the walls in an electrically conducting viscous incompressible fluid where a uniform suction velocity was imposed on the walls. The skin friction was observed to increase as both the Harmann number and the suction increases. Singh *et al* [5] studied MHD of a viscous, incompressible and electrically conducting fluid in the presence of a uniform transverse magnetic field when the fluid flow within the channel is induced due to time dependent movement of one of the plates of the channel and magnetic field is fixed relative to the moving plate. Singh considered two particular cases of interest in their study viz. (i) impulsive movement of one of the plates of the channel and (ii) uniformly accelerated movement of one of the plates of the channel and concluded that the magnetic field tends to accelerate fluid velocity when there is impulsive movement of one of the plates of the channel and when there is uniformly accelerated movement of one of the plates of the channel. Seth *et al* [6] studied the problem considered by Singh and Kumar *et al* (1983) considering when the fluid is confined to porous boundaries with suction and injection considering two cases of interest namely (i) the impulsive movement of the lower plate, (ii) and the accelerated movement of the lower plate. Seth *et al* concluded that the suction exerted a retarding influence on the flow while the magnetic field and injection reduce shear stress at the lower plate in both cases while suction increases shear stress at the lower plate. Mutua *et al* [7] investigated Stokes problem of a convective flow past a vertical infinite plate in a rotating system in presence of variable magnetic field. The

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variable magnetic field reduces the velocity vectors and leads to an increase in the rate of heat transfer in a free convectional heating. Ismail *et al* [8] investigated unsteady MHD flow between two parallel plates through a porous medium with one plate moving uniformly and the other at rest with uniform suction and found out that as the suction increases the fluid velocity increases. Edward *et al* [9] investigated unsteady hydro magnetic Couette flow with magnetic field lines fixed relative to the moving upper plate with suction and injection. And they noted that the magnetic field, pressure gradient, time and injection have an accelerating influence whereas suction and viscosity exerts a retarding influence on the fluid flow between parallel porous plates with injection/suction with a constant pressure gradient applied in the direction of the flow. Maswai *et al* [10] investigated a turbulent incompressible fluid flow past a semi-infinite vertical rotating plate in the presence of a strong inclined constant magnetic field and found out that an increase in the angle of inclination leads to an increase in the primary velocity while an increase in the Eckert number leads to a decrease in the primary velocity profiles. Most research has been done on unsteady MHD Couette flow of a viscous, incompressible, electrically conducting fluids between two parallel porous plates but no consideration has been given on MHD Couette flow between a non-porous plate and a porous plate with suction having a variable magnetic field which is inclined relative to the moving lower plate with constant pressure gradient.

II. MATHEMATICAL ANALYSIS

Consider a two dimensional fluid flow between two parallel plates at y=0 and y=h of infinite length in x and z directions in the presence of an inclined variable magnetic field H_0 with velocity components u and v along the x and y directions respectively. Assuming also that the flow is purely along the x-axis which implies that v=0. At time t<0 both the plate and the fluid are at rest. When t>0 the lower plate(y=0) starts moving with time dependent velocity $u = u_0 t^n$ (where n is a positive integer and u_0 is a constant)

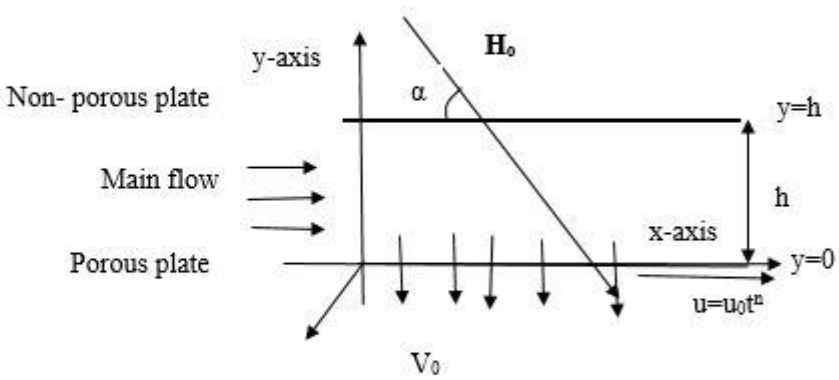

Fig 1: Physical model of the problem

The fluid velocity **q** and the magnetic field H_0 are given as; $\mathbf{q} = (u, v, 0)$, $H_0 = H_0(B_x, B_y, 0)$ where $B_x = \mu_e H_0 \cos\alpha, B_y = \mu_e H_0 \sin\alpha$

Governing Equations

1. Equation of continuity

The equation of continuity is derived by taking a mass balance on a fluid entering and leaving a volume element in the flow field and in component form is given as;

$$\frac{\partial \rho}{\partial t} + \nabla(\rho q) = 0 \qquad \textbf{(1)}$$

Since the fluid is assumed to be incompressible and the plates are of infinite length $\frac{\partial \rho}{\partial t} = 0$ and $\frac{\partial u}{\partial x} = 0$, the continuity reduces to;

$$\frac{\partial v}{\partial y} = 0 \qquad (2)$$

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On integration equation (2) gives v=constant and this constant is equal to injection velocity v_0

2. Equation of conservation of Momentum

Equation of conservation of momentum is derived from Newton's second law of motion which requires that the sum of all the forces acting on a control volume must be equal to the rate of change of momentum.

$$\rho[\frac{\partial \mathbf{q}}{\partial t}+(\mathbf{q}\bullet\nabla)\mathbf{q}]=-\nabla p+\mu\nabla^2\mathbf{q}+\mathbf{F} \quad (3)$$

F is the Lorentz force generated when a magnetic field is applied is applied to the flow and is given as $\mathbf{J}\times\mathbf{B}$

In component form the momentum is;

$$\frac{\partial u}{\partial t}+v_0\frac{\partial u}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\frac{\partial^2 u}{\partial y^2}-\frac{\mathbf{J}\times\mathbf{B}}{\rho} \quad (4)$$

The generalized ohms law is given as

$$\mathbf{J}=\sigma(\mathbf{E}+\mathbf{q}\times\mathbf{B}) \quad (5)$$

Neglecting the electric field **E** equation (4) reduces to

$$\mathbf{J}=\sigma(\mathbf{q}\times\mathbf{B}) \quad (6)$$

$\frac{\partial p}{\partial x}=p^*$, hence the momentum equation in the x-direction is given as;

$$\frac{\partial u}{\partial t}+v_0\frac{\partial u}{\partial y}=-\frac{p^*}{\rho}+\nu\frac{\partial^2 u}{\partial y^2}-\frac{\sigma\mu_e^{\,2}H_0^{\,2}u(\sin\alpha)^2}{\rho} \quad (7)$$

Equation (7) holds when the magnetic field is fixed relative to the moving fluid but since the magnetic field lines are fixed relative to the moving lower plate hence the velocity is considered to be relative velocity. Hence equation (7) becomes

$$\frac{\partial u}{\partial t}+v_0\frac{\partial u}{\partial y}=-\frac{p^*}{\rho}+\nu\frac{\partial^2 u}{\partial y^2}-\frac{\sigma\mu_e^{\,2}H_0^{\,2}(\sin\alpha)^2[u-u_0t^n]}{\rho} \quad (8)$$

Substituting n=1 and taking $P=\frac{p^*}{\rho}$

$$\frac{\partial u}{\partial t}+v_0\frac{\partial u}{\partial y}=-P+\nu\frac{\partial^2 u}{\partial y^2}-\frac{\sigma\mu_e^{\,2}H_0^{\,2}(\sin\alpha)^2[u-u_0t\;]}{\rho} \quad (9)$$

3. Energy Equation

The energy equation is based on the law of conservation of energy. Due to electrical resistance of the fluid, Ohmic heating has been considered hence the energy equation becomes;

$$\rho C_p\frac{DT}{Dt}=\kappa\nabla^2T+\mu(\frac{\partial u}{\partial y})^2+\frac{j^2}{\sigma} \quad (10)$$

$|J|=j$ And $J=\sigma\mu_eH_0(u\sin\alpha-v\cos\alpha)k$ hence $j^2=\sigma^2\mu_e^{\,2}H_0^{\,2}(u\sin\alpha)^2$. $v=0$ (Since the flow was considered along the x-direction) and equation (10) becomes;

$$\rho C_p(\frac{\partial T}{\partial t}+v_0\frac{\partial T}{\partial y}=\kappa(\frac{\partial^2 T}{\partial y^2})+\mu(\frac{\partial u}{\partial y})^2+\sigma\mu_eH_0^{\,2}u^2(\sin\alpha)^2 \quad (11)$$

Velocity of the is considered as a relative velocity which shows how fast the fluid is moving relative to the plate since the magnetic field lines are fixed relative to the moving lower plate. Equation is replaced by

$$\rho C_p(\frac{\partial T}{\partial t}+v_0\frac{\partial T}{\partial y}=\kappa(\frac{\partial^2 T}{\partial y^2})+\mu(\frac{\partial u}{\partial y})^2+\sigma\mu_eH_0^{\,2}(\sin\alpha)^2[u-u_0t^n]^2 \quad (12)$$

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Due to the uniformly accelerated movement of the lower plate n=1

$$\rho C_p(\frac{\partial T}{\partial t}+v_0\frac{\partial T}{\partial y}=\kappa(\frac{\partial^2 T}{\partial y^2})+\mu(\frac{\partial u}{\partial y})^2+\sigma\mu_e H_0^{\,2}(\sin\alpha)^2[u-u_0 t\ \ ]^2 \quad (13)$$

4. Induction equation

Induction equation has been considered to determine the effect of the magnetic fields distribution and their interactions.

$$\frac{\partial H}{\partial t}=v_H\nabla^2 H+\frac{\nabla}{\mu_e}\times(q\times B) \quad (14)$$

$$\frac{\partial H_x}{\partial t}+v_0\frac{\partial H_x}{\partial y}=H_0\sin\alpha\frac{\partial u}{\partial y}+v_H\frac{\partial^2 H_x}{\partial y^2} \quad (15)$$

Initial and boundary conditions

$$u=0, T=T_\infty, H_x=0\ \ 0\le y\ge h\quad at\ t<0$$

$$u=u_0 t\quad at\quad y=o\quad t>0$$

$$u=0, T=T_w\quad at\ \ y=h\ \ t>0$$

$$H_x=H_0\ \ t>0$$

The following transformations are used to non dimensionalize the equations governing the flow i.e. equation (9), (13) and (15)

$$\theta=\frac{T-T_\infty}{T_w-T_\infty}, y^*=\frac{y}{h}, u^*=\frac{uh}{\nu}, t^*=\frac{t\nu}{h^2}, H_x^{\,*}=\frac{H_x}{H_0}$$

In dimensional form equation

$$\frac{\partial\theta}{\partial t}+S\frac{\partial\theta}{\partial y}=\frac{1}{P_r}(\frac{\partial^2\theta}{\partial y^2})+E_c(\frac{\partial u}{\partial y})^2+R\sin^2\alpha[u^2-2tu\frac{R_e h^2}{\nu}+t^2\frac{R_e^{\,2}h^4}{\nu^2}]$$

(16)

$$\frac{\partial u}{\partial t}+S\frac{\partial u}{\partial y}=-\frac{h^3}{\nu^2}P+\frac{\partial^2 u}{\partial y^2}-M^2\sin^2\alpha[u-uR_e\frac{h^2}{\nu}] \quad (17)$$

$$S=\frac{v_0 h}{\nu}, M^2=\frac{\sigma\mu^2{}_e H_0^{\,2}h^2}{\mu}, R_e=\frac{u_0 h}{\nu}$$

$$\frac{\partial H_x}{\partial t}+\frac{\partial H_x}{\partial y}=\sin\alpha\frac{\partial u}{\partial y}+\frac{1}{R_m}\frac{\partial^2 H_x}{\partial y^2} \quad (18)$$

The non-dimensional boundary conditions for $u(y,t)$ and $\theta(y,t)$ are

$$t\le 0: u=0, \theta=0\ at\ \ 0\le y\le 1$$

$$t<0:\ H_x=0$$

$$t>0: u=R_e\frac{h^2 t}{\nu}, \theta=1\ at\ \ y=0$$

$$t>0: u=0, \theta=0\ at\ \ y=1$$

III. METHOD OF SOLUTION

The finite difference approximation for derivatives is used to solve the differential equations. The derivatives in differential equations (16), (17) and (18) are replaced by finite difference approximation which gives rise to algebraic systems of equations to be solved in place of the differential equations. Due to the nonlinear nature of the governing equations together with their boundary conditions are solved numerically. The initial and the boundary conditions are applied to get the solutions of the equations. The Crank Nicolson Method has been used where the second derivative is replaced by the average of its finite difference approximations on the jth and j+1 row. Equations in finite difference form are given as

$$\frac{u_j^{k+1}-u_j^{k}}{\Delta t}+\frac{S}{4\Delta y}[u_{j+1}^{k+1}-u_{j-1}^{k+1}+u_{j+1}^{k}-u_{j-1}^{k}]=-P\frac{h^3}{\nu^2}+\frac{1}{2(\Delta y)^2}[u_{j+1}^{k}-2u_{j}^{k}+u_{j-1}^{k}+u_{j+1}^{k+1}-2u_{j}^{k+1}+u_{j-1}^{k+1}]$$
$$-\frac{M^2\sin\alpha}{2}[u_j^{k+1}+u_j^{k}]+\frac{M^2\sin^2\alpha R_e t_j}{\nu}$$

(19)

Multiplying equation by Δt and letting

$$A=\frac{S\Delta t}{2\Delta y},\ B=-\frac{h^3}{\nu^2}P,\ C=\frac{\Delta t}{2(\Delta y)^2},\ D=\frac{\Delta t M^2\sin\alpha}{2},\ E=\frac{\Delta t M^2\sin^2\alpha R_e}{\nu}$$

Equation (19) it becomes

$$u_j^{k+1}-u_j^{k}+A[u_{j+1}^{k+1}-u_{j-1}^{k+1}+u_{j+1}^{k}-u_{j-1}^{k}]=B+C[u_{j+1}^{k}-2u_{j}^{k}+u_{j-1}^{k}+u_{j+1}^{k+1}-2u_{j}^{k+1}+u_{j-1}^{k+1}]$$
$$-D[u_j^{k+1}+u_j^{k}]+Et_j$$

(20)

Rearranging equation (20) so that the values of u at time k+1 are on the left and others on the right and the values of k are assumed to be known, putting the like terms together and rearranging it again we have

$$(-A-C)u_{j-1}^{k+1}+(1+2C+D)u_j^{k+1}+(A-C)u_{j+1}^{k+1}=(A+C)u_{j-1}^{k}+(1-2C-D)u_j^{k}+(-A+C)u_{j+1}^{k}+Et_k+B$$

(21)

The following represents the coefficients of interior nodes

$$a_j=(-A-C),\ b_j=(1+2C+D),\ c_j=A-C,\ d_j=(A+C)u_{j-1}^{k},\ e_j=(1-2C-D)u_j^{k},$$
$$f_j=(-A+C)u_{j+1}^{k},\ g_j=Et_k,\ h=B$$

$$a_j u_{j-1}^{k+1}+b_j u_j^{k+1}+c_j u_{j+1}^{k+1}=d_j+e_j+f_j+g_j+h \qquad (22)$$

Taking j=2 equation was represented in a tridiagonal matrix as shown and implemented in matlab

$$\begin{bmatrix} a_2 & b_2 & c_2 & 0 & 0 & .. & 0 & 0\\ 0 & a_3 & b_3 & c_3 & 0 & .. & 0 & 0\\ 0 & 0 & a_4 & b_4 & c_4 & .. & 0 & 0\\ .. & .. & .. & .. & .. & .. & .. & ..\\ 0 & 0 & 0 & 0 & 0 & a_{N-1} & b_{N-1} & c_{N-1}\end{bmatrix}\begin{bmatrix} u_1^{k+1}\\ u_2^{k+1}\\ u_3^{k+1}\\ ..\\ u_{N-1}^{k+1}\end{bmatrix}=\begin{bmatrix} d_2\\ d_3\\ d_4\\ ..\\ d_{N-1}\end{bmatrix}+\begin{bmatrix} e_2\\ e_3\\ e_4\\ ..\\ e_{N-1}\end{bmatrix}+\begin{bmatrix} f_2\\ f_3\\ f_4\\ ..\\ f_{N-1}\end{bmatrix}+\begin{bmatrix} g_2\\ g_3\\ g_4\\ ..\\ g_{N-1}\end{bmatrix}+\begin{bmatrix} h\\ h\\ h\\ ..\\ h\end{bmatrix}$$

In finite form energy equation is given as

$$\frac{\theta_j^{k+1}-\theta_j^{k}}{\Delta t}+\frac{S}{4\Delta y}[\theta_{j+1}^{k+1}-\theta_{j-1}^{k+1}+\theta_{j+1}^{k}-\theta_{j-1}^{k}]=\frac{1}{2(\Delta y)^2P_r}[\theta_{j+1}^{k}-2\theta_{j}^{k}+\theta_{j-1}^{k}+\theta_{j+1}^{k+1}-2\theta_{j}^{k+1}+\theta_{j-1}^{k+1}]$$
$$+E_c\left(\frac{u_{j+1}^{k+1}-u_{j-1}^{k+1}+u_{j+1}^{k}-u_{j-1}^{k}}{4\Delta y}\right)^2+R\sin^2\alpha\left[\frac{(u_j^{k+1}+u_j^{k})^2}{4}-\frac{R_e h^2 t(u_j^{k+1}+u_j^{k})}{\nu}+\frac{t^2h^4R_e^{\,2}}{\nu^2}\right]$$

(23)

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Also induction equation is given as

$$\frac{H_j^{k+1}-H_j^k}{\Delta t}+\frac{S}{4\Delta y}[H_{j+1}^{k+1}-H_{j-1}^{k+1}+H_{j+1}^{k}-H_{j-1}^{k}]=\frac{1}{R_m}\left(\frac{H_{j+1}^{k}-2H_j^k+H_{j-1}^{k}+H_{j+1}^{k+1}-2H_j^{k+1}+H_{j-1}^{k+1}}{2(\Delta y)^2}\right)$$
$$+\frac{\sin\alpha}{4\Delta y}[u_{j+1}^{k+1}-u_{j-1}^{k+1}+H_{j+1}^{k}-H_{j-1}^{k}] \quad (24)$$

Similarly the same was done to equations (21) and (22) as the momentum equation and implemented using matlab.

IV. RESULTS AND DISCUSSIONS

The following are the results obtained when equations were implemented in Matlab and represented graphically as shown in figures 2 to 7.

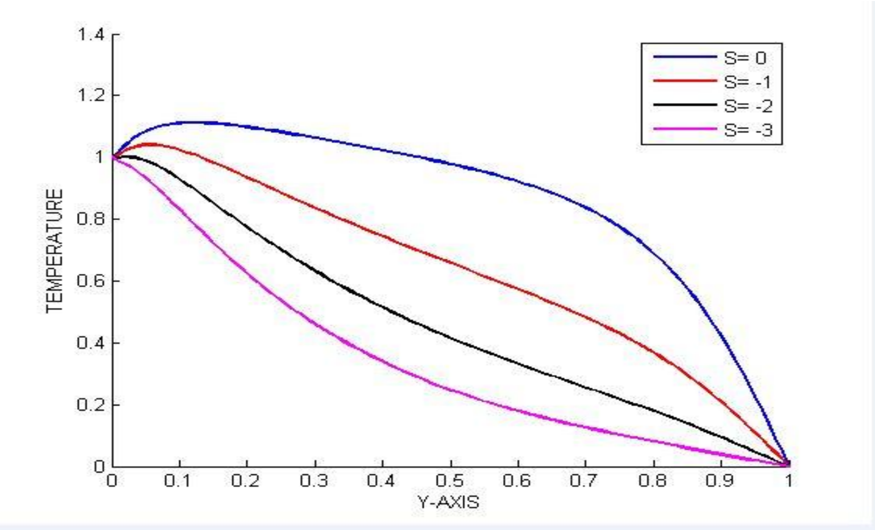

Fig2:

var *ying suction* $\quad for\ M=3, \nu=3, P_r=0.73, P_0=0.05, R=1, R_m=0.1, E_c=0.6, R_e=0.1,\ \alpha=\frac{\pi}{6}$

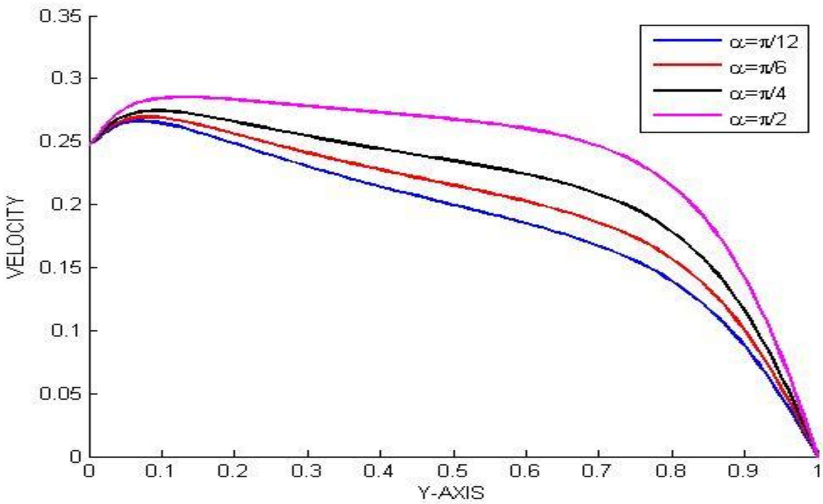

Fig3:

Varying $\alpha \quad for\ M=3, \nu=3, P_r=0.73, P_0=0.05, R=1, R_m=0.1, E_c=0.6, R_e=0.1, S=-1$

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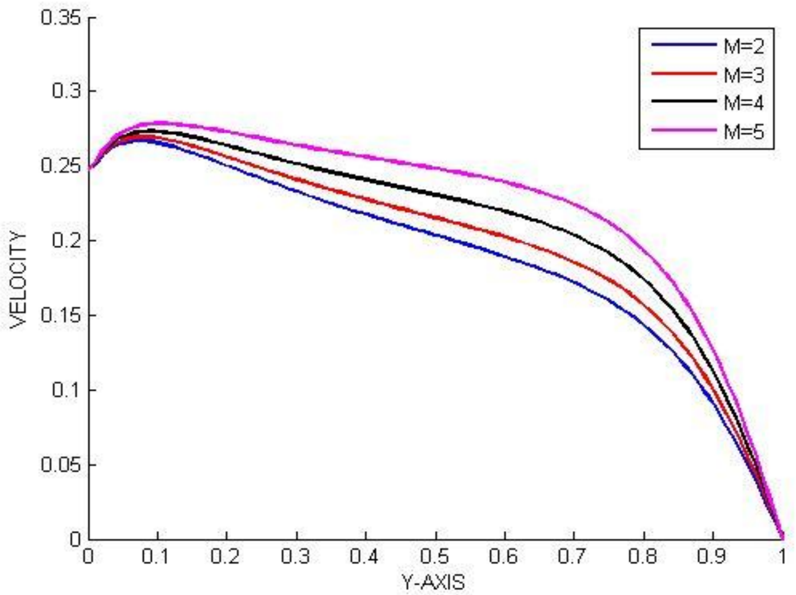

Fig 4:

$$\text{var}\,ying\ M\ \ for\ \ S=-1, \nu=3, P_r=0.73, P_0=0.05, R=1, R_m=0.1, E_c=0.6, R_e=0.1, \alpha=\frac{\pi}{6}$$

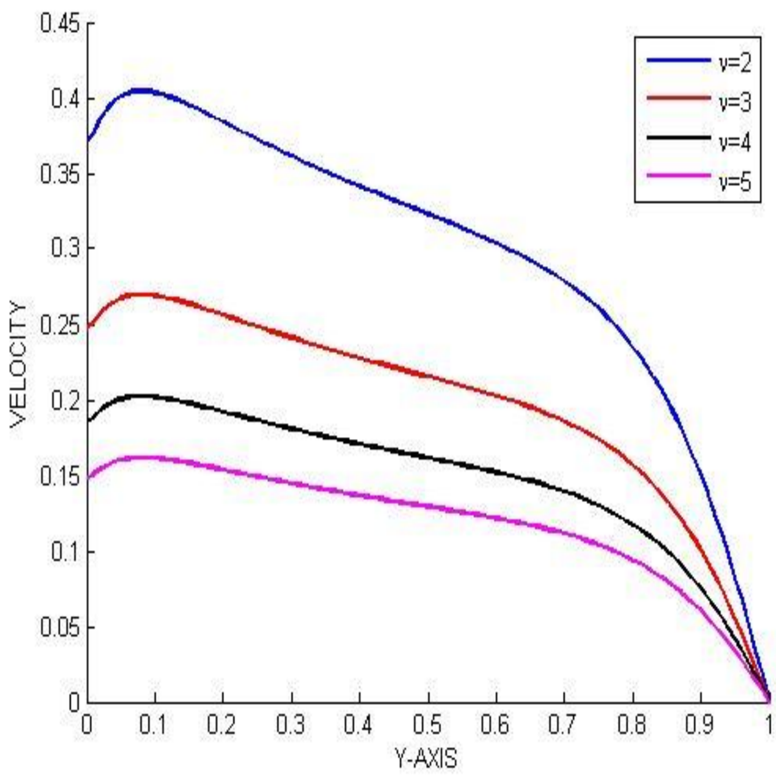

Fig 5: Varying suction for

$$M=3, S=1, P_r=0.73, P_0=0.05, R=1, R_m=0.1, E_c=0.6, R_e=0.1, \alpha=\frac{\pi}{6}$$

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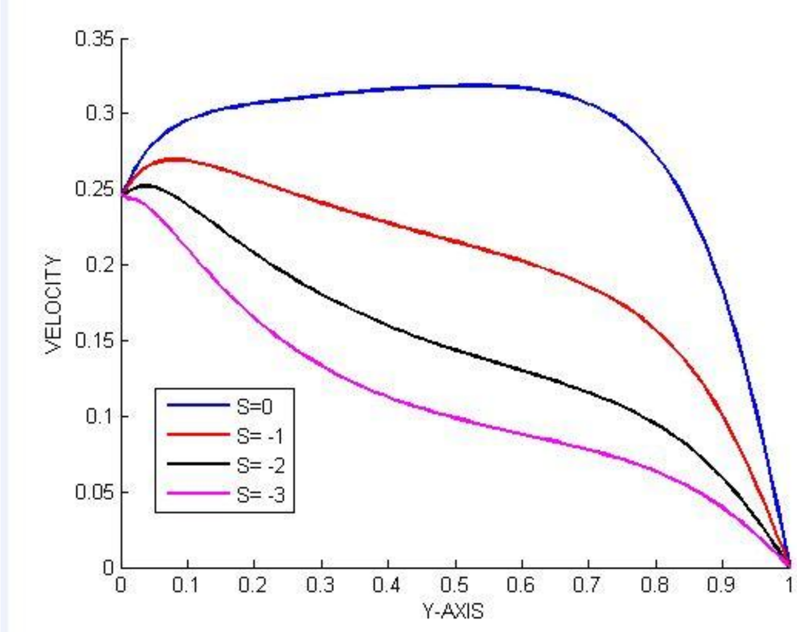

Fig 6: Varying suction for

$$M = 3, \nu = 3 P_r = 0.73, P_0 = 0.05, R = 1, R_m = 0.1, E_c = 0.6, R_e = 0.1, \alpha = \frac{\pi}{6}$$

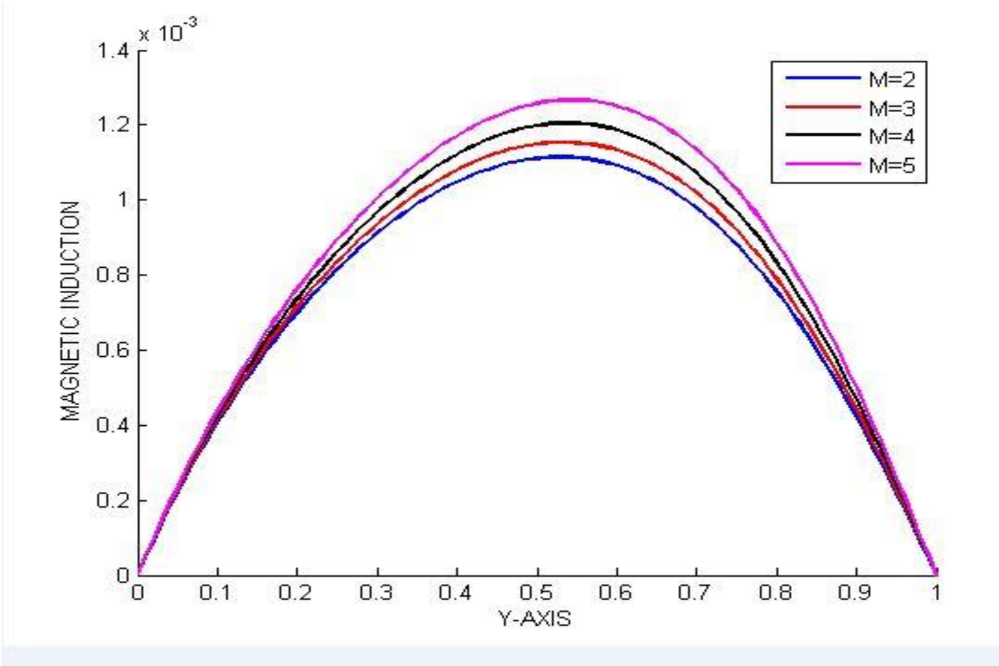

Fig 7:

$$Varying\ M\ \ for\ S = -1, \nu = 3 P_r = 0.73, P_0 = 0.05, R = 1, R_m = 0.1, E_c = 0.6, R_e = 0.1, \alpha = \frac{\pi}{6}$$

The temperature and velocity profiles have been discussed so as get the physical insight of the problem under consideration. In figures 2 to 7 various values of suction parameter S, magnetic Parameter M^2, the angle of inclination α and the kinematic viscosity ν have been assigned and the results are in good agreement with the results obtained by Seth *et al* (2011) and Edward *et al* (2015).

Figure 2 shows that temperature profiles decrease with increase in suction. As suction increases the rate at which the fluid particles collide decreases implying decreased kinetic energy which leads to fall in temperature of the fluid. From figure 3 it is observed that velocity profiles increases with increase in the angle of inclination. Figure 4 shows that velocity profiles increases as the magnetic parameter increases which shows that magnetic parameter facilitates fluid flow. Magnetic parameter gives the measure of the relative importance of drug forces resulting from the magnetic induction to the viscous forces. An increase in the magnetic parameter leads to a decrease in the drug forces hence increased velocities. From Figure 5 we note that as the kinematic viscosity increases the velocity decreases. As the kinematic viscosity increases the fluid becomes more viscous that is the drag forces increase hence the velocity of the fluid decreases. Figure 6 shows that when other parameters are kept constant, an increase in suction leads to a decrease in the fluid velocity. Suction reduces the pressure between the plates which decreases the force of the fluid hence decreased velocities. Suction stabilizes the boundary layer leading to increased viscous forces hence decrease in the velocity of the fluid. Figure 7 shows that the induced magnetic field increases with increase in the magnetic parameter. Magnetic parameter is directly proportional to the electromagnetic force which implies that as you increase the magnetic parameter the electromagnetic force increases leading to an increase in the magnetic induction.

V. CONCLUSION

The unsteady hydro magnetic Couette flow in the presence of an inclined magnetic field between a lower porous plate moving with a uniform velocity and a non-porous upper plate has been investigated. The magnetic parameter and the angle of inclination have an accelerating influence on the fluid flow with a constant pressure gradient in the direction of the fluid flow but suction and kinematic viscosity have a retarding influence on the fluid flow. The magnetic parameter and the angle of inclination have a positive influence on the magnetic induction while suction and the kinematic viscosity have a negative influence on the magnetic induction. Suction and kinematic viscosity have a retarding influence to velocity.

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NOMENCLATURE

Symbol	Meaning
J	Current density, $[AM^{-2}]$
B	Magnetic field vector, $[wbm^{-2}]$
μ_e	Magnetic Permeability
H_0	Fixed magnetic field intensity, $[AM^{-}]$
α	Angle of inclination
$\frac{D}{Dt}$	Material derivative
$\frac{\partial p}{\partial x}$	Pressure gradient
κ	Thermal conductivity, $[Wm^{-1}K^{-1}]$
μ	Dynamic viscosity, $[kgm^{-1}s^{-1}]$
ν	Kinematic viscosity, $[m^2 s^{-1}]$
C_p	Specific heat at constant pressure, $[JKg^{-1}K^{-1}]$
R_m	Magnetic Reynolds number
M	Magnetic parameter
R_e	Reynolds number
S	suction

REFERENCES

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 6, Issue 2, March 2017
[1] Moutaman Mirghani, Radar Signal Coding and Waveform Design, Lambert Academic Publishing, 2016.Hartmann, J. and Lazarus, F. (1937). The influence of a transverse uniform magnetic field on the flow of a conducting fluid between two infinite parallel, stationary and insulated plates. Mat-Fys, 15:346{369.

[2] Tao, L. N. (1960). Magnetohydrodynamic effects on the formation of Couette flow. Journal of the Aerospace Sciences, 27(5), 334-338.

[3] Katagiri, M. (1962). Flow formation in Couette motion in magnetohydrodynamics. Journal of the Physical Society of Japan, 17(2), 393-396.

[4] K. Muhuri, P. (1963). Flow formation in Couette motion in magnetohydrodynamics with suction. Journal of the Physical Society of Japan, 18(11), 1671-1675.

[5] Singh, A. and Kumar, N. (1983). Unsteady magnetohydrodynamic couette ow. Wear, 89:125-129.

[6] Seth, G. S., Singh, J. K., & Mahato, G. K. (2011). Unsteady hydromagnetic Couette flow within a porous channel with Hall effects. International Journal of Engineering, Science and Technology, 3(6), 172-183.

[7] Mutua, N. (2013). Stokes problem of a convective flow past a vertical infinite plate in a rotating system in presence of variable magnetic field (Doctoral dissertation).

[8] Ismail, A. M., Ganesh, S., & Kirubhashankar, C. K. (2014). Unsteady MHD flow between two parallel plates through porous medium with one plate moving uniformly and the other plate at rest with uniform suction. Int. J. Sci. Eng. Tech. Res, 3, 6-10.

[9] Onyango, E. R., Kinyanjui, M. N., & Uppal, S. M. (2015). Unsteady Hydromagnetic Couette Flow with Magnetic Field Lines Fixed Relative to the Moving Upper Plate. American Journal of Applied Mathematics, 3(5), 206-214.

[10] Maswai, R. C., M.N. Kinyanjui, J.K. Kwanza (2015). Mhd turbulent flow in presence of inclined magnetic field past a rotating semi-infinite plate. International Journal of Engineering Science and Innovative Technology (IJESIT), 4(2).

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