MHD Flow of A Non-Newtonian Fluid with Volume Fraction Through an Inclined Rectangular Channel

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Abstract- *In this paper MHD flow of a non-Newtonian fluid with volume fraction have been studied. The flow of fluid is through an inclined rectangular channel. The magnetic field applied is transverse in nature. Depending upon the physical nature of the problem equations has been made and results have been derived. In the end graphs have been made depending on the values chosen. Findings of the study reveal that on increasing the value of magnetic field parameter the velocity of the fluid and particle increases.*

Keywords- Electrically conducting, MHD flow, Magnetic field, Non –Newtonian fluid, Rectangular channel

I. INTRODUCTION

The importance of the flow of dusty viscous non Newtonian through various channels in the presence of magnetic field is increasing day by day, as it is very helpful in the industries like power generation, chemical processing, nuclear reactor, space sciences and mechanical engineering. As a result many scientists are attracted towards this field.Reddy (1972) discussed the effect of presence of dust particles with velocity profiles for the unsteady laminar flow of a fluid with uniform distribution of dust through rectangular channel.Gupta and Gupta (1976) obtained the expressions using operational method for velocities of gas and particles in a dusty gas flow through a rectangular channel Kumar and Singh (1991) observed the unsteady MHD flow of a dusty viscous liquid through an open rectangular channel. Kundu and Sengupta (2001) observed the unsteady flow of a visco-elastic Oldroyd fluid with pressure gradient through a rectangular channel.Madhuret (2009) discussed the motion of a dusty gas through porous medium in an open rectangular channel and found out the expression for skin friction at the boundaries. Gireesha (2010) worked on the unsteady flow of a dusty fluid through a rectangular channel under the effect of pulsating pressure gradient with uniform magnetic field. Rai and Khare (2012) also worked on the MHD flow of a Dusty non Newtonian fluid through rectangular channel under the influence of a uniform transverse magnetic field and found out the relation for the mean velocity of the flow and magnetic field which includes other parameters like nonNewtonian factor, electrical conductivity of the fluid, non dimensional parameters and viscosity of the fluid.

II. FORMULATION OF THE PROBLEM

Consider the motion of an unsteady incompressible non–Newtonian electrically conducting viscous fluid with uniform distribution of dust particles through inclined rectangular channel placed under the effect of uniform transverse magnetic field.

The velocities of fluid and dust particles are u and v respectively.

Then the equation of motion are given by

$$\nabla . u' = 0 \text{ (for fluid phase)} \quad (1)$$

$$(1-\phi)\frac{\partial u'}{\partial t'} + (u'.\nabla)u') = -\frac{1}{\rho}\nabla p + \nu\nabla^2 u' + \frac{f}{\tau}(v'-u') - \frac{\sigma B_0^2 u'}{\rho(1+c^2)} + g\sin\theta \quad (2)$$

So the equation for fluid phase becomes

$$(1-\phi)\frac{\partial u\prime}{\partial t\prime} = -\frac{1}{\rho}\frac{\partial p}{\partial z\prime} + \nu\left(\frac{\partial^2 u'}{\partial x'^2} + \frac{\partial^2 u'}{\partial y'^2}\right) + \frac{f}{\tau}(v'-u') - \frac{\sigma B_0^2 u'}{\rho(1+c^2)} + g\sin \quad (3)$$

Where g is the gravity and θ is the angle of inclination of the channel

$$\nabla . v' = 0 \text{(for dust phase)} \quad (4)$$

$$\frac{\partial v\prime}{\partial t\prime} + (v'.\nabla)v' = \frac{1}{\tau}(u'-v') \quad (5)$$

So the equation for dust phase becomes

$$\frac{\partial v\prime}{\partial t\prime} = \frac{1}{\tau}(u'-v') \quad (6)$$

Pressure gradient

$$-\frac{1}{\rho}\frac{\partial p}{\partial z\prime} = A(1+\varepsilon e^{i\omega t}) \quad (7)$$

Where
u: velocity of fluid ,
v: velocity of particle ,
m: mass of dust particle,
ρ: density of fluid,
P: static pressure of fluid,
N_o: number of dust particles per unit volume,

K: Stoke's resistance coefficient,
B_0: external magnetic field,
σ : Electrical conductivity of fluid,
v: kinetic viscosity of fluid,
f $=\frac{mN_0}{\rho}$: mass concentration ratio,
$\tau = \frac{m}{K}$: Relaxation time parameter,
c : non-Newtonian factor,
θ: Angle of inclination of the rectangular channel,
g: gravity.

The boundary conditions are
$u' = 0\,, v' = 0\ at\ \ y' = 0,$
$u' = 0, v' = 0\ \ at\ y' = h,$
$u' = 0, v' = 0\ at\ x' = -d$
$and\ u' = 0, v' = 0\ at\ x' = d$ (8)
Where h is the distance between the plates
Where A and ω are constants.

Non Dimensional parameters are
$u* = \frac{u'\omega}{A},\ \ v* = \frac{v'\omega}{A},\ \ t* = t'\omega, \xi = \frac{x'}{h}, \eta = \frac{y'}{h}, \varphi = \frac{z'}{h}, p* = \frac{p'}{A\rho h}\ and\ Re = \frac{\omega h^2}{v}$ (9)

Using the non Dimensional parameters above equations for fluid phase and dust phase becomes

$$(1-\phi)\frac{\partial u*}{\partial t*} = -\frac{\partial p}{\partial \varphi} + v\left(\frac{\partial^2 u^*}{\partial \xi^2} + \frac{\partial^2 u^*}{\partial \eta^2}\right) + \frac{f}{\tau\omega}(v^* - u^*) - \frac{\sigma B_0^2 u^*}{\rho(1+c^2)\omega} + R \quad (10)$$

Where $R = g\ sin\theta$.(gravity parameter)

$$\frac{\partial v*}{\partial t*} = \frac{1}{\tau\omega}(u* - v*) \quad (11)$$

Now for the sake of simplicity removing the (*) from the above equations we get

$$(1-\phi)\frac{\partial u}{\partial t} = -\frac{\partial p}{\partial \varphi} + v\left(\frac{\partial^2 u}{\partial \xi^2} + \frac{\partial^2 u}{\partial \eta^2}\right) + f\beta(v-u) - \alpha u + R \quad (12)$$

$$\frac{\partial v}{\partial t} = \beta(u - v) \quad (13)$$

Where
$\alpha = \frac{\sigma B_0^2}{\rho(1+c^2)\omega}$ and $\beta = \frac{1}{\tau\omega}$,
$-\frac{\partial p}{\partial \varphi} = (1 + \varepsilon e^{it})$

Then accordingly the boundary conditions are
$u = 0\,, v = 0\ at\ \ \eta = 0,$
$u = 0, v = 0\ \ at\ \eta = 1,$
$u = 0, v = 0\ at\ \xi = -r$
$and\ u = 0, v = 0\ at\ \xi = r$ (14)
Where $r = \frac{d}{h}$.

Now suppose the solution of velocity
$u(\xi, \eta, t) = u_0(\xi, \eta) + \varepsilon u_1(\xi, \eta)e^{it},$
$v(\xi, \eta, t) = v_0(\xi, \eta) + \varepsilon v_1(\xi, \eta)e^{it}$ (15)

Now putting these values in (12) and (13)

$$(1-\phi)\varepsilon i u_1 e^{it} = 1 + \varepsilon e^{i\omega t} + \frac{1}{Re}\left(\frac{\partial^2 u_0}{\partial \xi^2} + \varepsilon\frac{\partial^2 u_1}{\partial \xi^2}e^{it} + \frac{\partial^2 u_0}{\partial \eta^2} + \varepsilon\frac{\partial^2 u_1}{\partial \eta^2}e^{it}\right) + f\beta(v_0 + \varepsilon v_1 e^{it} - u_0 - \varepsilon u_1 e^{it}) - \alpha(u_0 + \varepsilon u_1 e^{it}) + R \quad (16)$$

And

$$\varepsilon i v_1 e^{it} = \beta(u_0 - v_0) + \beta\varepsilon(u_1 - v_1)e^{it} \quad (17)$$

Collecting the coefficient of similar powers of ε on both the sides, we get the following

Steady part (coefficient of ε^0).

$$1+\frac{1}{Re}\left(\frac{\partial^2 u_0}{\partial \xi^2} + + \frac{\partial^2 u_0}{\partial \eta^2}\right) + f\beta(v_0 - u_0) - \alpha u_0 + R = 0$$

Or

$$\frac{1}{Re}\left(\frac{\partial^2 u_0}{\partial \xi^2} + + \frac{\partial^2 u_0}{\partial \eta^2}\right) + f\beta(v_0 - u_0) - \alpha u_0 + R = -1 \quad (18)$$

and

$$\beta(u_0 - v_0) = 0 \quad (19)$$

Now
Unsteady part (coefficient of ε^1).

$$(1-\phi)u_1 + \alpha u_1 = 1 + \frac{1}{Re}\left(\frac{\partial^2 u_1}{\partial \xi^2} + \frac{\partial^2 u_1}{\partial \eta^2}\right) + f\beta(v_1 - u_1),$$

Or

$$\frac{1}{Re}\left(\frac{\partial^2 u_1}{\partial \xi^2} + \frac{\partial^2 u_1}{\partial \eta^2}\right) + f\beta(v_1 - u_1) - \left(\alpha + (1-\phi)\right)u_1 = -1 \quad (20)$$

$$\beta(u_1 - v_1) - i v_1 = 0, \quad (21)$$

Then accordingly the boundary conditions are
$u_0 = 0\,, v_0 = 0\ at\ \ \eta = 0,$
$u_0 = 0, v_0 = 0\ \ at\ \eta = 1,$
$u_0 = 0, v_0 = 0\ at\ \xi = -r$
$and\ u_0 = 0, v_0 = 0\ at\ \xi = r,$ (22)
And
$u_1 = 0\,, v_1 = 0\ at\ \ \eta = 0,$
$u_1 = 0, v_1 = 0\ \ at\ \eta = 1,$
$u_1 = 0, v_1 = 0\ at\ \xi = -r$
$and\ u_1 = 0, v_1 = 0\ at\ \xi = r,$ (23)

Putting equation (19) in (18)

$$\left(\frac{\partial^2 u_0}{\partial \xi^2} + + \frac{\partial^2 u_0}{\partial \eta^2}\right) + \alpha\, Re\, u_0 = -Re(1 - R) \quad (24)$$

Now to solve equation we assume
$u_0(\xi, \eta) = X(\xi, \eta) + Y(\xi)$

Then equation (24) becomes

$$\left(\frac{\partial^2 X}{\partial \varepsilon^2} + + \frac{\partial^2 X}{\partial \eta^2} + \frac{\partial^2 Y}{\partial \varepsilon^2}\right) + \alpha\, Re\,(X+Y) = -Re(1-R),$$

So,

$$\frac{\partial^2 Y}{\partial \varepsilon^2} - \alpha\, Re\, Y + Re(1-R) = 0 \quad (25)$$

$$\frac{\partial^2 X}{\partial \varepsilon^2} + \frac{\partial^2 X}{\partial \eta^2} - \alpha Re X = 0 \quad (26)$$

Now the corresponding boundary conditions changes to

$$u_0(-r,\eta) = X(-r,\eta) + Y(-r) = 0,$$
$$u_0(r,\eta) = X(r,\eta) + Y(r) = 0,$$
$$u_0(\varepsilon,0) = X(\varepsilon,0) + Y(\varepsilon) = 0,$$
$$u_0(\varepsilon,1) = X(\varepsilon,1) + Y(\varepsilon) = 0, \quad (27)$$

And

$$u_1(-r,\eta) = X_1(-r,\eta) + Y_1(-r) = 0,$$
$$u_1(r,\eta) = X_1(r,\eta) + Y_1(r) = 0,$$
$$u_1(\varepsilon,0) = X_1(\varepsilon,0) + Y_1(\varepsilon) = 0,$$
$$u_1(\varepsilon,1) = X_1(\varepsilon,1) + Y_1(\varepsilon) = 0, \quad (28)$$

The solutions of the equation (25)

$y(\varepsilon)$= complimentary function + particular integral,

$$Y(\varepsilon) = B^1 e^{\sqrt{\alpha\, Re}\,\varepsilon} + B^2 e^{\sqrt{\alpha\, Re}\,\varepsilon} + \frac{1}{\alpha} \quad (29)$$

$y(\varepsilon)$= complimentary function + particular integral,

$$B^1 = -\left(\frac{1-R}{\alpha}\right)\left[\frac{1}{2\cos h\sqrt{\alpha\, Re}\, r}\right],$$

$$B^2 = -\left(\frac{1-R}{\alpha}\right)\left[\frac{1}{2\cos h\sqrt{\alpha\, Re}\, r}\right],$$

$$Y(\varepsilon) = -\left(\frac{1-R}{\alpha}\right)\left[1 - \frac{2\cos h\sqrt{\alpha\, Re}\,\varepsilon}{2\cos h\sqrt{\alpha\, Re}\, r}\right] \quad (30)$$

Now the solution for the (26) is obtained by the method of separation of variables

$X(\varepsilon,\eta) = Z(\varepsilon)N(\eta)$,

Now

$$\frac{1}{Z}\frac{d^2 N}{d\varepsilon^2} = -\frac{1}{N}\frac{d^2 N}{d\eta^2} + \alpha Re = -p^2(say),$$

Or

$$\frac{1}{Z}\frac{d^2 N}{d\varepsilon^2} + p^2 = 0,$$

Or

$$\frac{d^2 N}{d\varepsilon^2} + p^2 Z = 0 \quad (31)$$

And

$$\frac{1}{N}\frac{d^2 N}{d\eta^2} - (\alpha Re + p^2) = 0 \quad (32)$$

Now the solution of equation (31) is

Z = Complimentary function + Particular Integral

Z=$C\cos p\varepsilon + D\sin p\varepsilon$,

Now the solution of equation (32)

N = Complimentary function + Particular Integral

$$N = (E_3 + E_4)\cosh\sqrt{\alpha Re + p^2}\,\eta + (E_3 - E_4)\sin h\sqrt{\alpha Re + p^2}\,\eta,$$

Hence the complete solution i

$$X(\varepsilon,\eta) = (C\cos p\varepsilon + D\sin p\varepsilon)\left\{(E_3 + E_4)\cosh\sqrt{\alpha Re + p^2}\,\eta + (E_3 - E_4)\sin h\sqrt{\alpha Re + p^2}\,\eta\right\} \quad (33)$$

Now applying the boundary conditions equation (27) in equation (33) we get

$$X(\varepsilon,\eta) = \frac{2(1-R)}{\alpha}\sum_{n=1}^{\infty} sin\left(\frac{n\pi}{r}\varepsilon\right)\left(\frac{\sin h\, S\,(\eta-1) - \sin h\, S\,\eta}{\sin h\, S}\right) \times \left(\frac{1}{n\pi} - \frac{\alpha Re(-1)^n}{S^2 n\pi} - \frac{n\pi}{r^2 S^2 \cos h\sqrt{\alpha\, Re}\, r}\right) \quad (34)$$

So putting the equations (34) and(30) in

$$u_0(\varepsilon,\eta) = X(\varepsilon,\eta) + Y(\varepsilon)$$

we have

$$u_0(\varepsilon,\eta) = \left(\frac{1-R}{\alpha}\right)\left[1 - \frac{2\cos h\sqrt{\alpha\, Re}\,\varepsilon}{2\cos h\sqrt{\alpha\, Re}\, r}\right] + \frac{2(1-R)}{\alpha}\sum_{n=1}^{\infty} sin\left(\frac{n\pi}{r}\varepsilon\right)\left(\frac{\sin h\, S\,(\eta-1) - \sin h\, S\,\eta}{\sin h\, S}\right) \times \left(\frac{1}{n\pi} - \frac{\alpha Re(-1)^n}{S^2 n\pi} - \frac{n\pi}{r^2 S^2 \cos h\sqrt{\alpha\, Re}\, r}\right), \quad (35)$$

Now since we know that $v_0 = u_0$

$$v_0(\varepsilon,\eta) = \left(\frac{1-R}{\alpha}\right)\left[1 - \frac{2\cos h\sqrt{\alpha\, Re}\,\varepsilon}{2\cos h\sqrt{\alpha\, Re}\, r}\right] + \frac{2(1-R)}{\alpha}\sum_{n=1}^{\infty} sin\left(\frac{n\pi}{r}\varepsilon\right)\left(\frac{\sin h\, S\,(\eta-1) - \sin h\, S\,\eta}{\sin h\, S}\right) \times \left(\frac{1}{n\pi} - \frac{\alpha Re(-1)^n}{S^2 n\pi} - \frac{n\pi}{r^2 S^2 \cos h\sqrt{\alpha\, Re}\, r}\right), \quad (36)$$

Now for unsteady part we have

$$\frac{1}{Re}\left(\frac{\partial^2 u_1}{\partial \varepsilon^2} + \frac{\partial^2 u_1}{\partial \eta^2}\right) + f\beta(v_1 - u_1) - (\alpha + (1-\phi))u_1 = -1,$$

And since $v_1 = \frac{\beta u_1}{\beta + i}$,

So

$$\left(\frac{\partial^2 u_1}{\partial \varepsilon^2} + \frac{\partial^2 u_1}{\partial \eta^2}\right) + Re\left\{\frac{f\beta i}{\beta + i} + \alpha + (1-\phi)\right\}u_1 = -Re \quad (37)$$

Let

$$u_1(\varepsilon,\eta) = X_1(\varepsilon,\eta) + Y_1(\varepsilon) \quad (38)$$

$$\frac{\partial^2 X_1}{\partial \varepsilon^2} + \frac{\partial^2 X_1}{\partial \eta^2} + \frac{\partial^2 Y_1}{\partial \varepsilon^2} - Re\left\{\frac{f\beta i}{\beta + i} + \alpha + (1-\phi)\right\}(X_1 + Y_1) = -Re,$$

$$\frac{\partial^2 Y_1}{\partial \varepsilon^2} - Re\left\{\frac{f\beta i}{\beta + i} + \alpha + (1-\phi)\right\}Y_1 + Re = 0 \quad (39)$$

$$\frac{\partial^2 X_1}{\partial \varepsilon^2}+\frac{\partial^2 X_1}{\partial \eta^2}-Re\left\{\frac{f\beta i}{\beta+i}+\alpha+(1-\phi)\right\}X_1=0 \quad (40)$$

Or we can write

$$\frac{\partial^2 Y_1}{\partial \varepsilon^2}-Q^2Y_1+Re=0,$$

Where $\left\{\frac{f\beta i}{\beta+i}+\alpha+(1-\phi)\right\}=Q^2$

And the solution becomes

$$Y_1=B^3e^{Q\varepsilon}+B^4e^{-Q\varepsilon}+\frac{Re}{Q^2} \quad (41)$$

Where B^3 and B^4 are constants. Now solving for constants using boundary conditions

$B^3=-\frac{Re}{Q^2 2\cosh(Qr)}$, and $B^4=\frac{Re}{Q^2 2\cosh(Qr)}$

So $Y_1=\frac{Re}{Q^2}\left(1-\frac{\cosh Q\varepsilon}{\cosh Qr}\right)$ (42)

Now for the solution of equation (40)

Let $X_1=Z_1(\varepsilon)N_1(\eta)$,

So the equation becomes

$$\frac{1}{Z_1}\frac{d^2Z_1}{d\varepsilon^2}=-\frac{1}{N_1}\frac{d^2N_1}{d\eta^2}+Q^2=-p^2,$$

$$\frac{d^2Z_1}{d\varepsilon^2}+p^2Z_1=0 \quad (43)$$

$$\frac{d^2N_1}{d\eta^2}-(Q^2+p^2)N_1=0 \quad (44)$$

Solution of (43) is given as

Z_1 = complimentary function + particular function,

$$Z_1=(E_5\cos p\varepsilon+E_6\sin p\varepsilon), \quad (45)$$

And the solution of (44) is

$$N_1=\{(E_7+E_8)\cosh\sqrt{p^2+Q^2}\eta+(E_7-E_8)\sinh\sqrt{p^2+Q^2}\eta\} \quad (46)$$

Combining equation (45) and (46) we get

$$X_1(\varepsilon,\eta)=(E_5\cos p\varepsilon+E_6\sin p\varepsilon)\{(E_7+E_8)\cosh\sqrt{p^2+Q^2}\eta(E_7-E_8)\sinh\sqrt{p^2+Q^2}\eta\},$$

Now applying boundary condition we get

$$X_1(\varepsilon,\eta)=E_6\sin\left(\frac{n\pi}{r}\varepsilon\right)\{(E_7+E_8)\cosh T\eta+(E_7-E_8)\sinh T\eta\} \quad (47)$$

$$T=\sqrt{\frac{n^2\pi^2}{r^2}+Q^2},$$

Solving by similar method

$$X_1(\varepsilon,\eta)=\frac{2Re}{Q^2}\sum_{n=1}^{\infty}\sin\left(\frac{n\pi}{r}\varepsilon\right)\left(\frac{\sinh\beta(\eta-1)-\sinh\beta\eta}{\sinh\beta}\right)\times\left(\frac{1}{n\pi}-\frac{Q^2}{n\pi B^2}(-1)^n-\frac{n\pi}{r^2T^2\cosh(Qr)}\right), \quad (48)$$

Now

$$u_1=\frac{Re}{Q^2}\left(1-\frac{\cosh Q\varepsilon}{\cosh Qr}\right)+\left[\frac{2Re}{Q^2}\sum_{n=1}^{\infty}\sin\left(\frac{n\pi}{r}\varepsilon\right)\left(\frac{\sin\beta h(\eta-1)-\sinh\beta\eta}{\sinh\beta}\right)\times\left(\frac{1}{n\pi}-\frac{Q^2}{n\pi B^2}(-1)^n-\frac{n\pi}{r^2T^2\cosh(Qr)}\right)\right] \quad (49)$$

Now

$$v_1=\frac{\beta}{\beta+i}\left[\frac{Re}{Q^2}\left(1-\frac{\cosh Q\varepsilon}{\cosh Qr}\right)+\frac{2Re}{Q^2}\sum_{n=1}^{\infty}\sin\left(\frac{n\pi}{r}\varepsilon\right)\left(\frac{\sin\beta h(\eta-1)-\sinh\beta\eta}{\sinh\beta}\right)\times\left(\frac{1}{n\pi}-\frac{Q^2}{n\pi B^2}(-1)^n-\frac{n\pi}{r^2T^2\cosh(Qr)}\right)\right],$$

As $v_1=\frac{\beta}{\beta+i}u_1$,

$$u(\varepsilon,\eta,t)=u_0(\varepsilon,\eta)+\varepsilon u_1(\varepsilon,\eta)e^{it},$$

$$u(\varepsilon,\eta,t)=\left(\frac{1-R}{\alpha}\right)\left[1-\frac{2\cosh\sqrt{\alpha Re}\,\varepsilon}{2\cosh\sqrt{\alpha Re}\,r}\right]+\frac{2(1-R)}{\alpha}\sum_{n=1}^{\infty}\sin\left(\frac{n\pi}{r}\varepsilon\right)\left(\frac{\sinh S(\eta-1)-\sinh S\eta}{\sinh S}\right)\times\left(\frac{1}{n\pi}-\frac{\alpha Re(-1)^n}{S^2n\pi}-\frac{n\pi}{r^2S^2\cosh\sqrt{\alpha Re}\,r}\right)+\varepsilon\left[\frac{Re}{Q^2}\left(1-\frac{\cosh Q\varepsilon}{\cosh Qr}\right)+\varepsilon\left[\frac{2Re}{Q^2}\sum_{n=1}^{\infty}\sin\left(\frac{n\pi}{r}\varepsilon\right)\left(\frac{\sin\beta h(\eta-1)-\sinh\beta\eta}{\sinh\beta}\right)\times\left(\frac{1}{n\pi}-\frac{Q^2}{n\pi B^2}(-1)^n-\frac{n\pi}{r^2T^2\cosh(Qr)}\right)\right]e^{it}\right. \quad (50)$$

$$v(\varepsilon,\eta,t)=\left(\frac{1-R}{\alpha}\right)\left[1-\frac{2\cosh\sqrt{\alpha Re}\,\varepsilon}{2\cosh\sqrt{\alpha Re}\,r}\right]+\frac{2(1-R)}{\alpha}\sum_{n=1}^{\infty}\sin\left(\frac{n\pi}{r}\varepsilon\right)\left(\frac{\sinh S(\eta-1)-\sinh S\eta}{\sinh S}\right)\times\left(\frac{1}{n\pi}-\frac{\alpha Re(-1)^n}{S^2n\pi}-\frac{n\pi}{r^2S^2\cosh\sqrt{\alpha Re}\,r}\right)+\varepsilon\left[\frac{\beta}{\beta+i}\left\{\frac{Re}{Q^2}\left(1-\frac{\cosh Q\varepsilon}{\cosh Qr}\right)+\frac{2Re}{Q^2}\sum_{n=1}^{\infty}\sin\left(\frac{n\pi}{r}\varepsilon\right)\left(\frac{\sin\beta h(\eta-1)-\sinh\beta\eta}{\sinh\beta}\right)\times\left(\frac{1}{n\pi}-\frac{Q^2}{n\pi B^2}(-1)^n-\frac{n\pi}{r^2T^2\cosh(Qr)}\right)\right]\right. \quad (51)$$

Figure 1
Velocity of fluid(u) and Magnetic parameter(M)

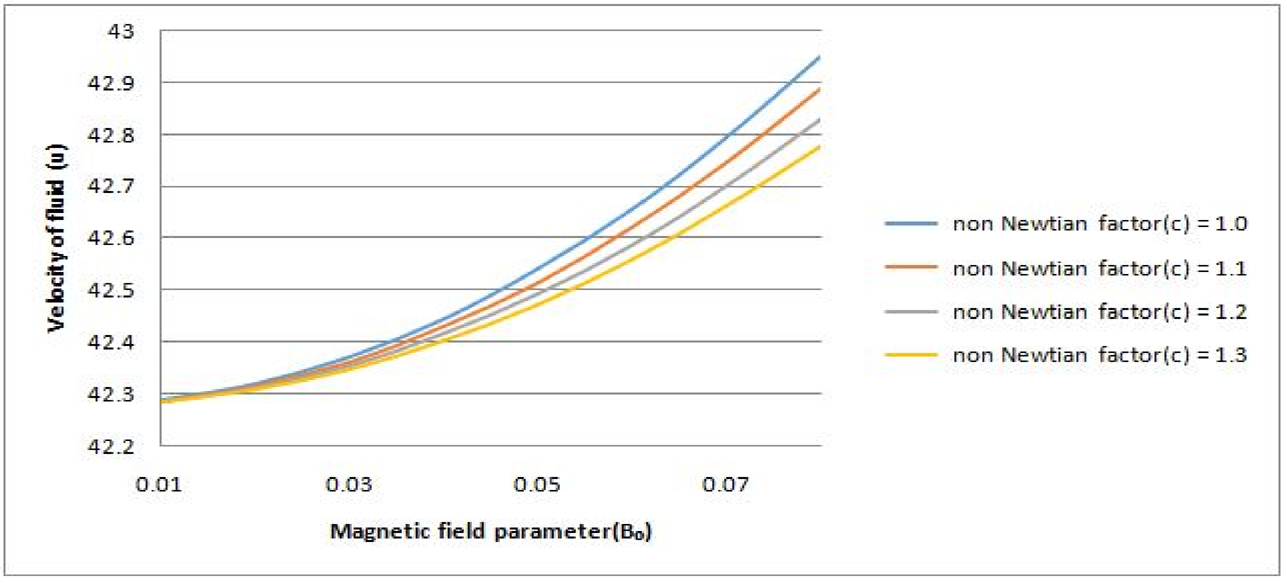
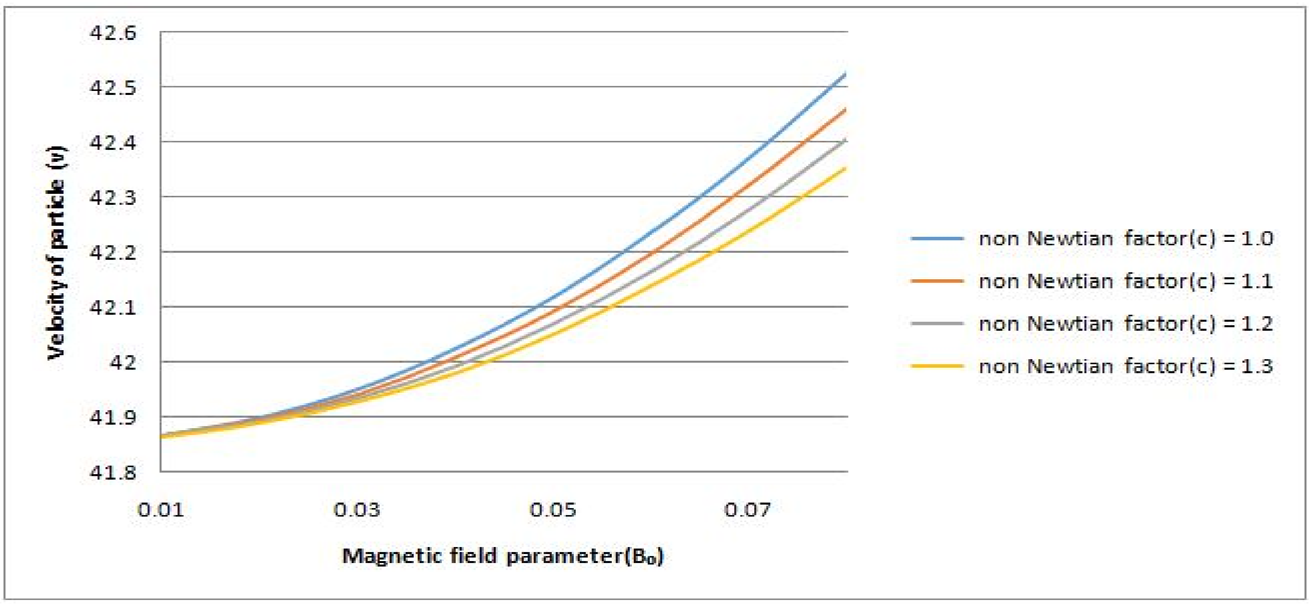


Figure 2
Velocity of particle(v) and Magnetic parameter(M)



III. RESULT AND DISCUSSION

The above graphical representation shows the change in the velocity of the fluid and particle with increases in the value of magnetic field under the effect of non Newtonian factor.

Figure 1 shows the change in the velocity of the fluid with changes in magnetic field of the system while under the effect of nonNewtonian fluid. It has been observed that on increasing the magnetic parameter of the fluid the velocity of the fluid also increases. Physically it happens due to negative velocity gradient. The graph of the fluid velocity id an increasing curve .The result found is also verified by the mathematical equations.

Further it has been observed that on increasing the value of non Newtonian factor the initial velocity of the fluid decreases. This is due to the fact that on increasing the value of Non-Newtonian factor the fluid becomes non ideal.

Figure 2 shows the change in the velocity of the dust with respect to changes in the magnetic field parameter and nonNewtonian factor. It is found that on increasing the effect of magnetic parameter the velocity of the particle increases in the form of a curve because of negative velocity gradient. It has also been observed that as the fluid becomes nonNewtonian its velocity decreases. Due to the fact that on increasing non –Newtonian factor the fluid becomes non ideal.

Hence going through the above results we can conclude that the effect of both the parameters (magnetic field and nonNewtonian parameter) is same on the velocity of the system. The graph in both the cases takes the form of the curve .Initially the graph starts from a point and then splits into several curves for different values of nonNewtonian factor. The difference in both the cases is only because of the numerical values. The results obtained are true mathematically also. From the figures the combined effect of both the parameters can be seen on the velocity of the system.

REFERENCES

[1] **Reddy (2007):** “MHD Unsteady free convective Walter’s memory flow with constant suction and heat Sink”. Asian Research Publishing Network (ARPN) Journal of Engineering and Applied Sciences.Vol. 2, No.5, pp. 12 – 16.

[2] **Kundu,.S.K., and Segupta,P.R.(2001):** “ Unsteady flow of visco-elastic Oldroyd fluid with transient pressure gradient through a rectangular channel”, Proceedings of National Academy of Sciences , India 371(A) pp 253-297.

[3] **Gireesha, B.J. , Bagewadi,c.s. and Prasannakumar, B.C.(2010):** “ Pulsatile flow of an unsteady fluid through rectangular channel”, Communications in Non linear Science and Numerical Simulation,Vol.14, No.5, pp 2103-2118.

[4] **Gireesha, B.J.,Ramesh,G.K.,Lokesh, H.J., Bagewadi, C.S.,(2011):** “ Bounday Lyer Flow and Heat Transfer of a Dusty Fluid over a Stretching Vertical Surface”,Applied Mathematics, Vol 2 , pp. 475-481.

[5] **Hadaman, M.H. and Barron, R.M. (1992):** “Analysis of the squeezing flow of dusty fluids”, Applied Science and research., Vol.49, pp 345-354.

[6] **Joshi, N., Kumar, M. and Saxena, P.(2010):** “Chemical reaction in steady mixed convection MHD viscous flow over shrinking sheet”, International Journal of stability and fluid mechanics, Vol. 1, No. 1, pp- 155-161.

[7] **Khaled, A. R. A. and Vafai, K.(2004):** “The effect of the slip condition on stokes and couette flows due to an oscillating wall: exact solutions”, International Journal of Nonlinear Mechanics Vol. 39, pp. 795–809.

[8] **Khandelwal ,A.K. and Jain , N.C. (2005):** “Unsteady MHD flow of stratified fluid through porous plate in slip flow regime”, Indian Journal of Theoretical Physics, Vol.53,No.1, pp 25-35.

[9] **Khare, R. and Singh, N (2010):** “MHD flow of a dusty viscous Incompressible fluid confined between two vertical walls with volume fraction of dust”, Journal of International Academy of Physical Sciences, Vol.14 no:2, pp 215-219.

[10] **Makinde, O. D. and Osalusi, E.(2006):** “MHD Steady flow in a channel with slip at the permeable boundaries”, Romanian Journal of Physics,Vol. 51(3–4) ,pp.319–328.