Influence of MHD on Peristaltic Flow of Couple-Stress Fluid Through a Porous Medium with Slip Effect

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Abstract

This paper investigates the influence of MHD on a peristaltic flow of Newtonian fluid with couple stress through porous medium, where the no-slip assumption between wall and the fluid is no longer valid. Along wavelength approximation and low Reynolds number are used in the flow analysis. The flow is considered in the wave frame of reference moving with the velocity of the wave. Analytical solution for axial velocity, pressure gradient, frictional force, stream function, magnetic field are obtained. Effects of different physical parameters, reflecting couple-stress parameter, permeability parameter, slip parameter, Hartman number, as well as amplitude ration on pumping characteristics and frictional force, stream lines pattern and trapping of peristaltic flow pattern studied with particular emphasis. This study are discussed through graphs.

Keywords: Peristaltic Transport, Couple-Stress, Magnetic Field, Newtonian Fluid, Porous Medium, Reynolds Number.

1 Introduction

The peristaltic transport through porous medium have attracted considerable attention due to their wide applications in medical and engineering sciences, such as, in physiology, roller and finger pumps, sanitary fluid transport, transport of corrosive fluids. Several review articles have been reported by (Mahmoud 2008) about interaction of couple stresses and slip flow on peristaltic transport in uniform and non uniform Channels. Flow through a porous medium have several practical applications especially in geophysical fluid dynamics. Examples of natural porous media are beach sand, sandstone, limestone, the human lung, bile duct, gall bladder with stones in small blood vessels. (Dharmendra 2012) studied the peristaltic flow of a Newtonian fluid thorough a porous medium. Furthermore, the MHD effect on peristaltic flow is important in technology (MHD pumps) and biology (blood flow) studied (Vasudev 2011) about peristaltic flow of a Newtonian fluid through a porous medium under the effect of a magnetic field. Such analysis is of great value in medical research. (Mahmood *et al*. 2011) investigated the Peristaltic transport of walters' B. fluid in an asymmetric channel. In all the above mentioned studies, the interaction of peristalsis with heat transfer has not been taken into account. However, some researchers (Eldabe *et al*. 2003) have analyzed the interaction of peristalsis with heat transfer. Recently,(Vasudev 2011) have investigated the effect of heat transfer on the peristaltic flow of a Newtonian fluid through a porous medium in an asymmetric vertical channel. (Hina 2010) have studied the effect of heat transfer on the peristaltic flow of an electrically conducting fluid in a porous space.

Studies pertaining to couple-stress fluid behavior are very useful in understanding various physical problems, such studies bear the potential to better explain the behavior of rheological complex fluids, such as liquid crystals, polymeric suspensions that have long chain molecules ,lubrication as well as human/sub-human blood. Couple- stress fluid is a special type of non-Newtonian fluid, whose particle sizes are taken into account. While the classical continuum theory does not study the particle sizes effects. Some of the recent studies on peristaltic transport of couple- stress fluid have been done by (Srivastava 1986, Elshehawey 1994 & 2001, Mekheimer 2002 & 2004, Ali *et al.* 2007) . Some of the studies on couple- stress fluid just mentioned considered the blood as a couple stress fluid and they were carried out using no slip conditions, although in real systems there is always a certain amount of slip. There are two extremely different types of fluids that appear to slip. One class contains the rarefied gases (Kawang-Hua 2000),while the other fluids have a much more elastic character. In such fluid, some slippage occurs under a large tangential traction. It has been claimed that slippage can occur in non-Newtonian fluid, concentrated polymer solution, and molten polymer. Furthermore, in the flow of dilute suspensions of particles, a clear layer is sometimes observed next to the wall. Poiseuille, in a work that won a prize in experimental physiology, observed such a layer with a microscope in the flow of blood through capillary vessels (Mahmood *et al* 2011).

Peristaltic flow of a fluid through a porous medium with couple –stress slip condition in a magnetic felid have not been studied. In the present paper, we investigated the effects of couple- stress and magnetic field with peristaltic flow of a viscous incompressible Newtonian fluid through a porous medium with slip condition under the assumptions of long wave length and low Reynolds number. The closed form solutions of velocity field and magnetic field are obtained. The influence of various pertinent parameters on the flow characteristics, this study are discussed through graphs.

2 Mathematical Formulation and Analysis

We consider the peristaltic flow of a viscous incompressible Newtonian fluid with couple –stress through a porous a medium in magnetic field. The flow is generated by sinusoidal wave trains propagating with constant speed along the wall of the outer rube. A uniform magnetic field B_0 is applied in the transverse direction to the flow. The electrical conductivity of the fluid is assumed to be small so that the magnetic Reynolds number is small and the induced magnetic field is neglected in comparison with the applied magnetic field. Fig. 1 depicts the geometry model of the problem.

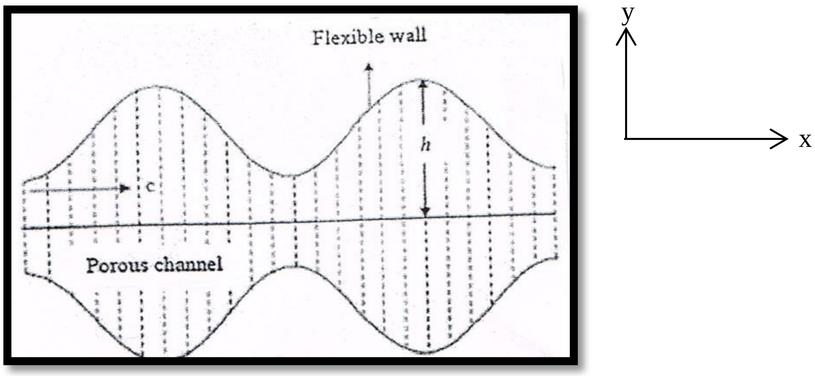

Fig.1 Geometry of oscillating peristaltic flow through porous medium

The constitutes equates for the geometry of peristaltic flow pattern in given as

$$\bar{h} = a + b\sin\frac{2\pi}{\lambda}\,(\bar{x} - c\,\bar{t}) \quad (1)$$

where a, b, λ , x, c, and t are the half width of the channel, amplitude, wavelength, axial coordinate, wave velocity, and time respectively. The equation of motion for incompressible couple- stress fluid in porous medium in the present of magnetic field are :

$$\frac{\partial \bar{u}}{\partial \bar{x}} + \frac{\partial \bar{v}}{\partial \bar{y}} = 0 \quad (2)$$

$$\rho\left(\frac{\partial \bar{u}}{\partial \bar{t}} + \bar{u}\,\frac{\partial \bar{u}}{\partial \bar{x}} + \bar{v}\,\frac{\partial \bar{u}}{\partial \bar{y}}\right) = -\frac{\partial \bar{p}}{\partial \bar{x}} + \mu\nabla^2\,\bar{u} - \mu_1\nabla^4\,\bar{u} - \mu\frac{\bar{u}}{\bar{k}} - \sigma\beta_o^2\,\bar{u} \quad (3)$$

$$\rho\left(\frac{\partial \bar{v}}{\partial \bar{t}} + \bar{u}\,\frac{\partial \bar{v}}{\partial \bar{x}} + \bar{v}\,\frac{\partial \bar{v}}{\partial \bar{y}}\right) = -\frac{\partial \bar{p}}{\partial \bar{y}} + \mu\nabla^2\,\bar{v} - \mu_1\nabla^4\,\bar{v} - \mu\frac{\bar{v}}{\bar{k}} \quad (4)$$

where the $\rho, \bar{u}, \bar{u}, \bar{v}, \bar{y}, \bar{p}, \mu, \mu_1, \bar{k}, \beta_o$, are the fluid density ,axial velocity , transverse velocity, transverse coordinate , pressure, viscosity , material constant associated with couple-stress, permeability parameter, magnetic field. and

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}, \quad \nabla^4 = \nabla^2\,(\nabla^2)$$

Introducing the following dimensionless parameters

$$x = \frac{\bar{x}}{\lambda}, \; y = \frac{\bar{y}}{a}, \; u = \frac{\bar{u}}{c}, \; v = \frac{\bar{v}}{c\delta}, \; \phi = \frac{a}{b}, \; h = \frac{\bar{h}}{a} = 1 + \phi\sin(2\pi x)$$

$$P = \frac{\bar{p}a^2}{\mu c\lambda} \ , k = \frac{\bar{k}}{a^2} \ , \quad Re = \frac{\rho c a}{\mu} \ , \quad \delta = \frac{a}{\lambda} \ , \alpha = a\sqrt{\frac{\mu}{\mu 1}} \ , Ha = \sqrt{\frac{\sigma}{\mu}} \ a B_o \qquad (5)$$

where δ , ε , ϕ , Re , α , Ha , are the wave number , ratio of the width of channels , amplitude ratio, Reynolds number , couple – stress parameter, Hartman parameter respectively . Using the set of non- dimensional variables and parameters (5) in Eqs. (2-4) applying the long wavelength and low Reynolds number approximation we get.

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

$$\frac{\partial p}{\partial x} = \frac{\partial^2 u}{\partial y^2} - \frac{1}{\alpha^2}\frac{\partial^4 u}{\partial y^4} - \frac{u}{k} - Ha\, u \qquad (7)$$

$$\frac{\partial p}{\partial y} = 0 \qquad (8)$$

The associated boundary conditions are

Slip condition : $u = -\beta\frac{\partial u}{\partial y}$ at $y=h$ (9)

Where β is the slip parameter,

Regularity condition: $\frac{\partial u}{\partial y} = 0$ at $y = 0$ (10)

Vanishing of couple stresses, $\frac{\partial^2 u}{\partial y^2} = 0$ at $y = h$, $\frac{\partial^3 u}{\partial y^3} = 0$ at $y = 0.$ (11)

The solution of Eq.(7) subject to the associated boundary conditions (9-11) is found of the form

$$u = -\frac{\left(\frac{\partial p}{\partial x}\right)}{N}\left[1 + f\left\{\frac{m_2^2 \cosh(m_1 y)}{\cosh(m_1 h)} - \frac{m_1^2 \cosh(m_2 y)}{\cosh(m_2 h)}\right\}\right] \qquad (12)$$

where

$$m_1 = \sqrt{\frac{\alpha^2 + \sqrt{\alpha^2 - 4N}}{2}} \qquad (13)$$

$$m_2 = \sqrt{\frac{\alpha^2 - \sqrt{\alpha^2 - 4N}}{2}} \qquad (14)$$

$$N = \frac{1}{k} + (Ha)^2 , \qquad (15)$$

$$f = \frac{1}{m_1^2 - m_2^2}\left\{1 + \frac{\beta f_1}{m_1^2 - m_2^2}\right\} , \qquad (16)$$

$$f_1 = \frac{m_2^2}{m_1}\tanh(m_1 h) - \frac{m_1^2}{m_2}\tanh(m_2 h) \qquad (17)$$

2.1 Volume Flow Rate

In laboratory frame $(\bar{x}, \bar{y})$ the flow is unsteady. However if observed in a coordinate moving at the wave speed c (wave frame) $(\bar{X}, \bar{Y})$ it can be treated as steady. The coordinate frame are related in the following

$\bar{X} = \bar{x} - ct$, $\bar{Y} = \bar{y}$, $\bar{U} = \bar{u} - c$, $\bar{V} = \bar{v}$, (18)

Where $(\bar{U}, \bar{V})$ and $(\bar{u}, \bar{v})$ are the velocity components in the wave and fixed frames, respectively.

The dimensional volume flow rate in the laboratory frame is

$$Q_1 = \int_0^{\bar{h}(\bar{x},\bar{y})} u(\bar{x}, \bar{y}, \bar{t})\ d\bar{y} \qquad (19)$$

Where $\bar{h}$ is a function of x , t. Eq.(19) in the wave frame can be expressed as

$$q_1 = \int_0^{\bar{h}(x)} \bar{U}(\bar{X}, \bar{Y}) d\bar{Y} \qquad (20)$$

In which $\bar{h}$ is a function at $\bar{x}$ only . By using Eqs. (18), (19) and (20) we have

$Q_1 = q_1 + ch$ (21)

Averaging volume flow rate along a period T, we have

$$\overline{Q}_1 = \frac{1}{T}\int_0^T Q_1 dt. \;\; = q_1 + ca \tag{22}$$

Now, introducing the dimensionless mean flow Q in the laboratory frame

$\overline{Q} = \frac{Q_1}{ca}$, $q = \frac{q_1}{cq}$

Eq.(22) can be written as

$$\overline{Q} = q + 1 = Q + 1 - h \tag{23}$$

Here the dimensionless from at Eq.(21) has been used. The dimensionless form at Eq.(20) is

$$Q = \int_0^h u dy \tag{24}$$

Invoking Eq.(12) into Eq.(24) and then integrating one can write

$$Q = -\frac{\left(\frac{\partial p}{\partial x}\right)}{N}(h + f * f1) \tag{25}$$

Now, the substitution of Eq.(23) into(25) gives

$$\frac{\partial p}{\partial x} = -N\left\{\frac{\overline{Q}-1+h}{h+f*f1}\right\} \tag{26}$$

The pressure difference (Δp) and frictional force (F), respectively, across the one wavelength, are given by

$$\Delta p = \int_0^1 \frac{\partial p}{\partial x}\, dx, \tag{27}$$

$$F = \int_0^1 h\left(-\frac{\partial p}{\partial x}\right)dx. \tag{28}$$

From Eqs.(12), (26) ,and using transformation of Eq.(18),the stream function in wave form $U = \frac{\partial \varphi}{\partial y}$ and $V = -\frac{\partial \varphi}{\partial x}$ is obtained as

$$\varphi(x,y) = \frac{\overline{\vartheta}-1+h}{h+f(x)f_1(x)}\left[y + f(x)\left\{\frac{{m_2}^2 \sinh(m_1 y)}{m_1 \cosh(m1h)} - \frac{{m_1}^2 \sinh(m_2\, y)}{m_2 \cosh(m_2 h)}\right\}\right] - y. \tag{29}$$

2.2 Mechanical Efficiency

Mechanical efficiency is the ratio of the average rate per wavelength at which work is done by the moving fluid against a pressure head and the average rate at which the walls do work on the fluid. It is derived as

$$E = -\frac{\overline{Q}\,\Delta P}{\emptyset\, I}\,, \tag{30}$$

Where

$$I = \int_0^1 \frac{\partial P}{\partial x}\sin(2\pi\, x)\, dx. \tag{31}$$

3 Numerical Results and Discussion

In this section , the numerical and computational result are discussed through the graphical illustration. Mathematica software is used to find out numerical results and illustration. The salient feature of uniform peristaltic flow of couple-stress fluids through the porous medium in magnetic felid are discussed through Figs.(2,3,4) and (5). Based on Eq.26, Fig.(2a-e) is drawn between pressure difference across one wavelength and averaged flow rate. The variation of the volumetric flow rate of peristaltic waves with pressure gradient for different values of the couple –stress parameter, with Hartman parameter , permeability parameter, slip parameter, and amplitude ratio are studied through these figures. These figures demonstrate that here is a linear relation between pressure and average flow rate. On the basis of the values of pressure gradient, different regions examined in this study, the region for $\Delta p > 0$ is entire pumping region, the region for $\Delta p = 0$ is free pumping zone and the for $\Delta p < 0$ is co-pumping region. In figure(2) we can see that form Fig.(2a) with increases the Hartman parameter, the volumetric flow rate gradually increasing in the entire pumping region and free pumping region, in co-pumping region the volumetric gradually decreasing . (2b) shows that, with increases the couple –stress parameter, the volumetric flow rate gradually reduce in the entire pumping but the volumetric flow rate decreasing in free pumping and co-pumping. From the same figure we can show that for a Newtonian fluid(α

$\rightarrow\infty$), the magnitude of the pressure is less than that for the couple-stress fluid in both pumping and co-pumping regions. Fig.(2c) we see that, with increases the permeability parameter, the volumetric flow rate can be gradually reduced in the pumping region and the free pumping region but decreasing in co-pumping region. Fig.(2d) shows that, with the rise in the magnitude of slip parameter, the volumetric flow rate decreases with the same distance between of them in the pumping region and in free pumping and co-pumping the flow rate increasing. Fig.(2e) shows that, when the magnitude of amplitude ratio increases, the volumetric flow rate increasing in the pumping region and free pumping region but in co-pumping region the volumetric flow rate decreasing. Frictional force (F) in the case of couple-stress fluid with magnetic felid is calculated over one wave period in the term of averaged volume flow rate. Fig.(3a-e) is illustrated to show the variation of frictional force with averaged flow rate for different values pertinent parameters. It can be seen that the effect of increasing the flow rate is to enhance the frictional force. In fig.(3a) we can see that with increasing the magnitude of Hartman parameter, increasing the volumetric flow rate. Fig.(3b) shows that frictional force enhances with rise in couple- stress parameter. It is also revealed that the magnitude of the frictional force for a Newtonian fluid is less than that in the case of couple-stress fluid.-The quantum of influence of the permeability parameter on frictional force is shown in Fig.(3c). This figure indicates that the magnitude of frictional force reduces with the increasing in the value of permeability parameter. Fig. (3d) shows that with An increase in the slip parameter, the magnitude of the frictional force increases for $Q1<0.58$ and decreasing for $Q1>0.58$. The effect of amplitude ratio on frictional force is shown in Fig.(3e), with reduce the magnitude of amplitude ratio parameter the magnitude of fractional force increasing for $Q1<0.3$ and decreasing for $Q1>0.3$. In Fig. (4a-e) we draw graphs between mechanical efficiency E and the averaged flow rate to study the variations of mechanical efficiency for different maximum value and decreases to zero. It is found that the efficiency decreases with increasing the magnitude of couple-stress parameter , Hartman parameter, and slip parameter, whereas it increases with decreasing the magnitude of amplitude ratio as well as permeability parameter. The streamline on the center line in the wave frame reference are found to split in order to enclosed a bolus of fluid particles circulating along closed streamline under certain conditions. This phenomenon is referred to as trapping, which is a characteristic of peristaltic motion. Since this bolus appears to be trapped by the wave, the bolus moves with the same speed as that of the wave. Fig.(5) drawn for streamline patterns. The impacts of couple- stress parameter, Hartman parameter, permeability parameter and slip

parameter on trapping are discussed through these figures. It is important to observe that the size of trapping bolus reduces when the magnitude of said parameters (Ha, α, k and β) increases.

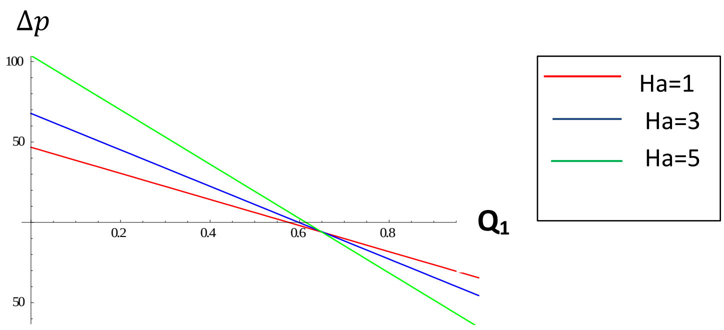

Figure 2a. Pressure versus averaged flow rate for difference value of Ha at α=10,β=0.1,k= 0.1 , Φ =0.5.

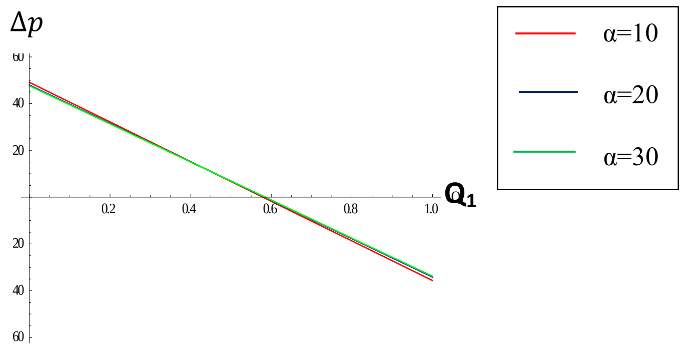

Figure 2b. Pressure versus averaged flow rate for difference value of α at Ha =2,k= 0.1,β=0.1 , Φ=0.5.

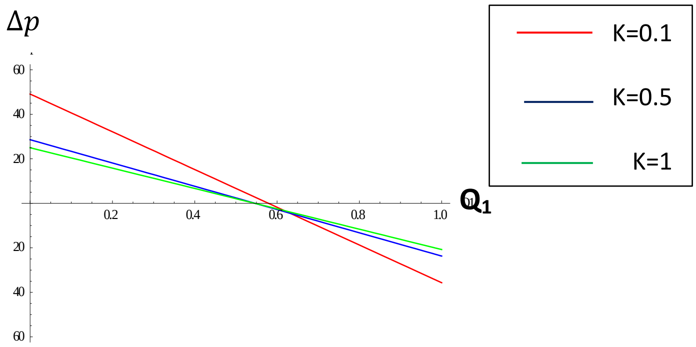

Figure 2c. Pressure versus averaged flow rate for difference value of k at Ha=2 , α=10,β=0.1 , Φ=0.5.

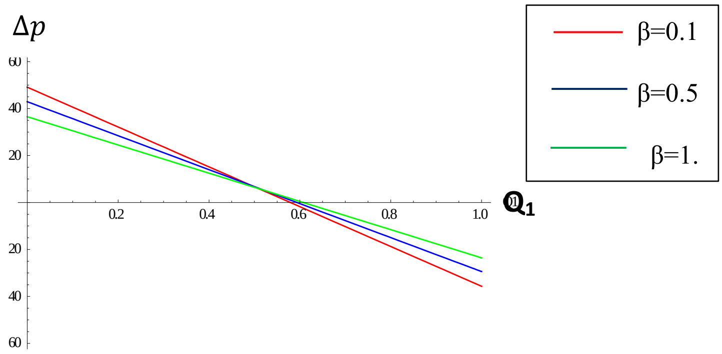

Figure 2d. Pressure versus averaged flow rate for difference value of β at Ha =2 , k= 0.1 , α =10, Φ=0.5.

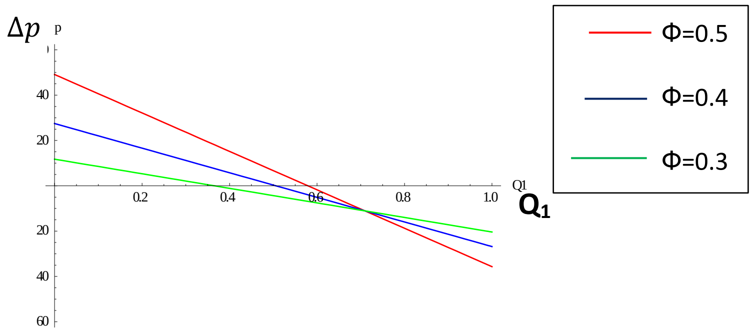

Figure 2e. Pressure versus averaged flow rate for difference value of Φ at Ha=2 , α =10, k=0.1,β =0.1.

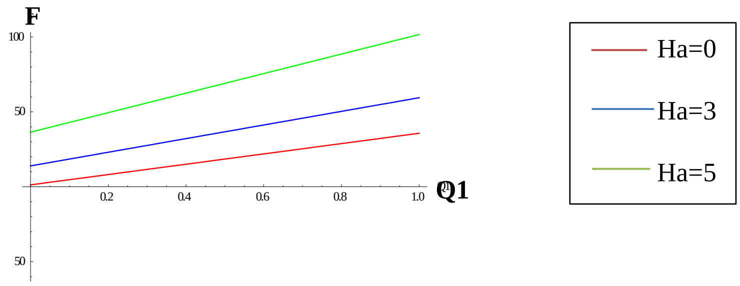

Figure 3a. Frictional force versus averaged flow rate for various value of Ha at k=0.1, β =0.1 , α=10 , Φ=0.5

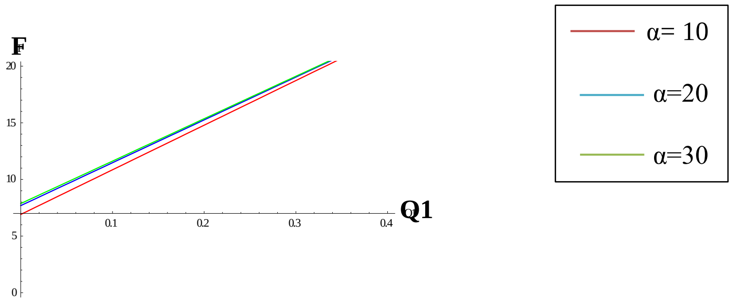

Figure 3b. Frictional force versus averaged flow rate for various value of α at k=0.1 , β =0.1 ,Ha=2 , Φ=0.5

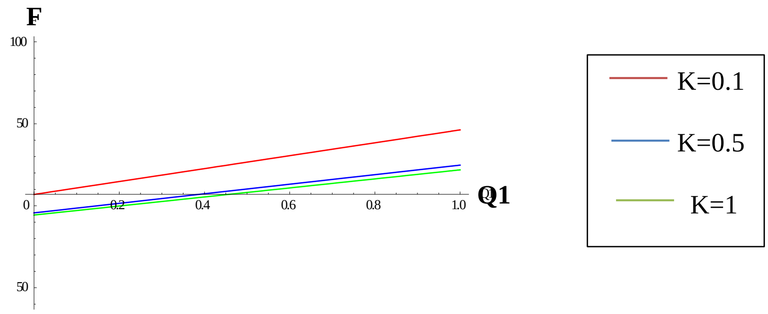

Figure 3c. Frictional force versus averaged flow rate for various value of k at Ha=2 , β =0.1 α=10, Φ=0.5

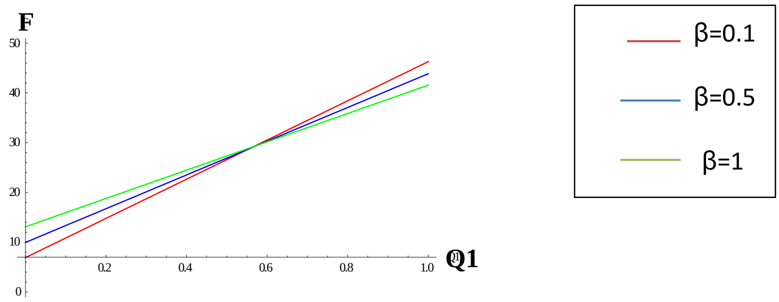

Figure 3d. Frictional force versus averaged flow rate for various value of β at Ha=2 , k=0.1, α=10, Φ=0.5

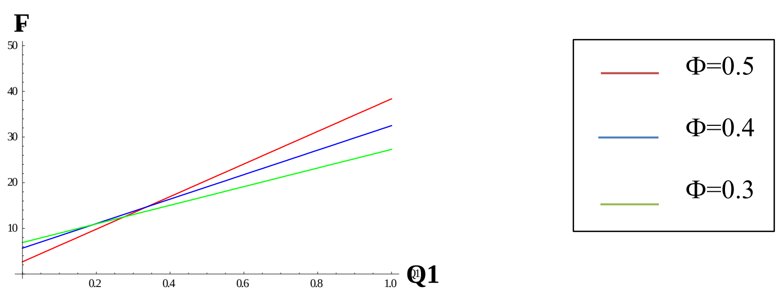

Figure 3e Frictional force versus averaged flow rate for various value of Φ at Ha=2 , k=0.1, β=0.1 , α=10

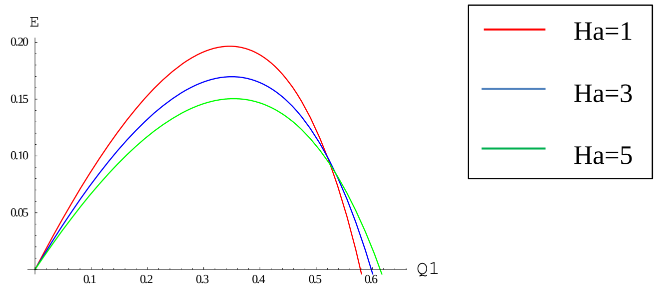

Figure 4a. Mechanical Efficiency versus averaged flow rate for various value of Ha at k=0.1, β =0. 1, α=10, Φ=0.5

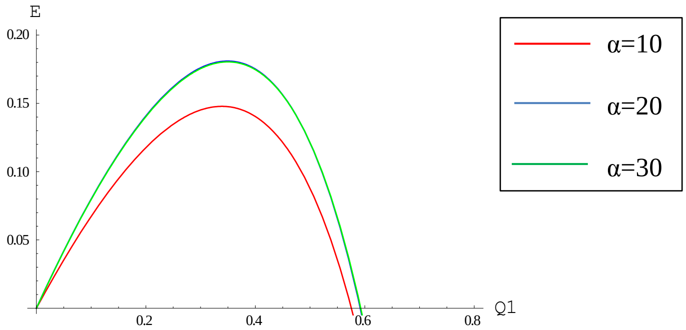

Figure 4b Mechanical Efficiency versus averaged flow rate for various value of α at k=0.1 , β =0.1 ,Ha=2 , Φ =0.5

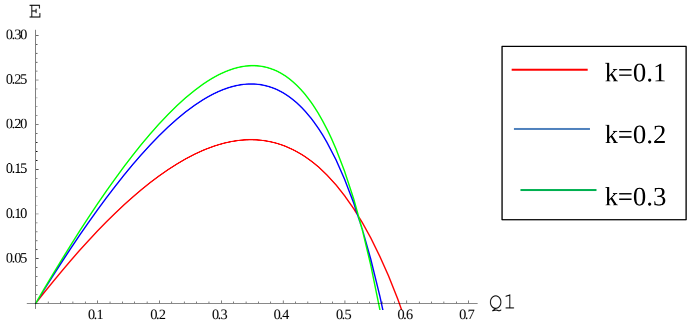

Figure 4c Mechanical Efficiency versus averaged flow rate for various value of k at Ha=2 , β =0.1 α= 10, Φ=0.5

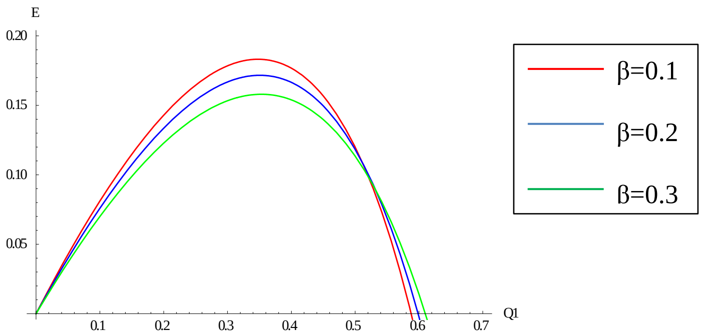

Figure 4d Mechanical Efficiency versus averaged flow rate for various value of β at Ha=2 , k=0.1 , α=10, Φ=0.5

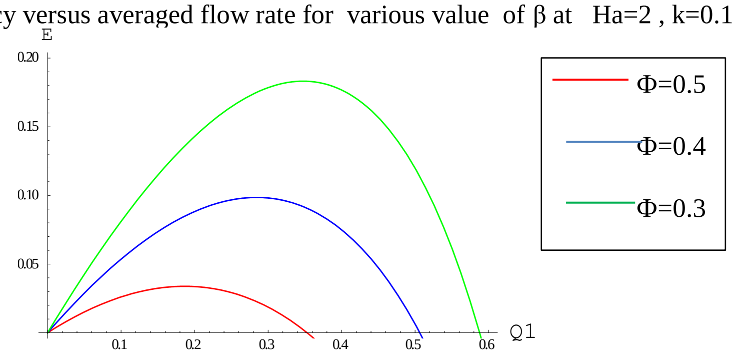

Figure 4e Mechanical Efficiency versus averaged flow rate for various value of Φ at Ha=2 , k=0.1, β=0.1 , α=10

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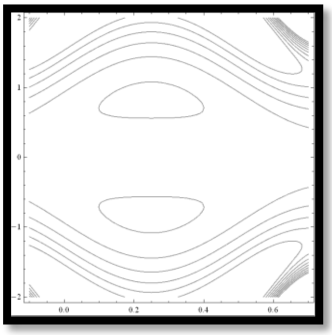
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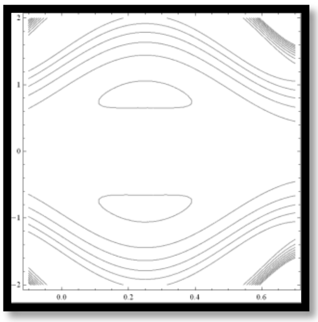
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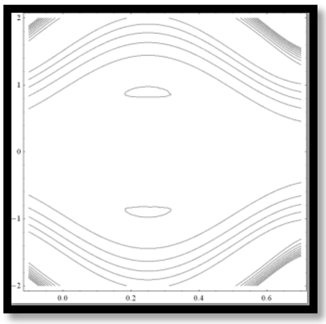
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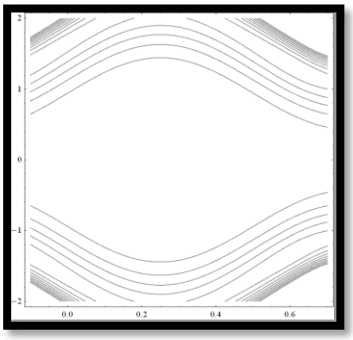
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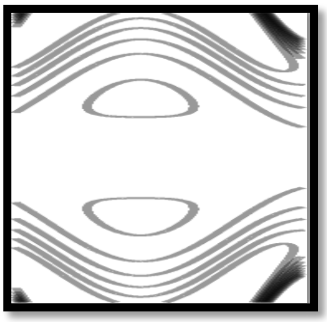
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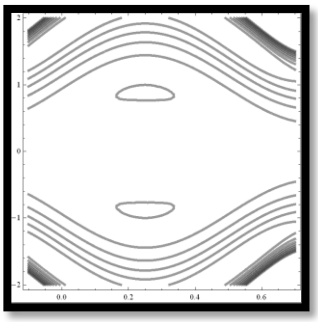
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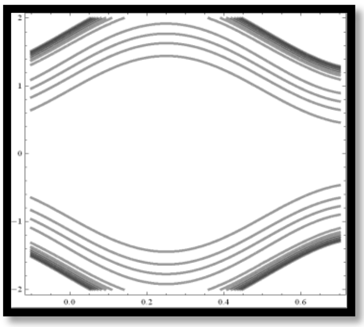
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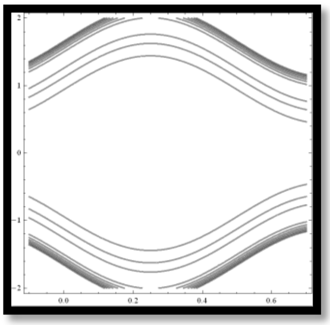
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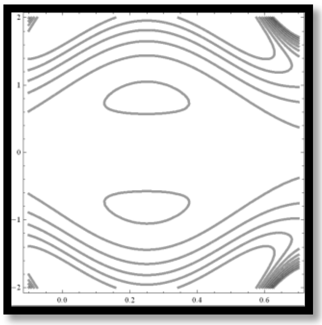
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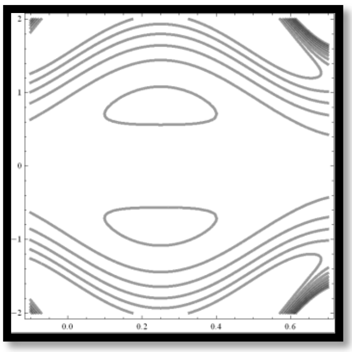
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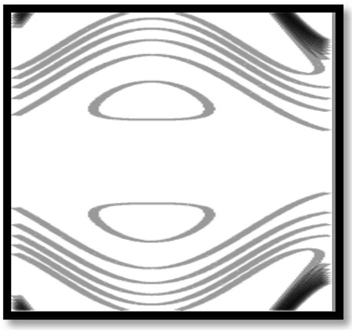
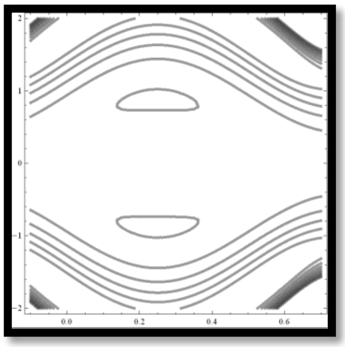
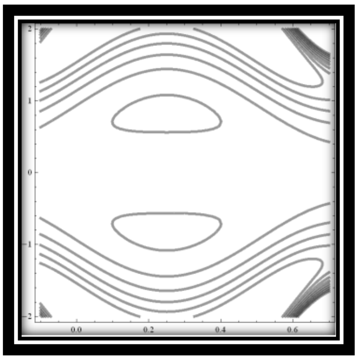
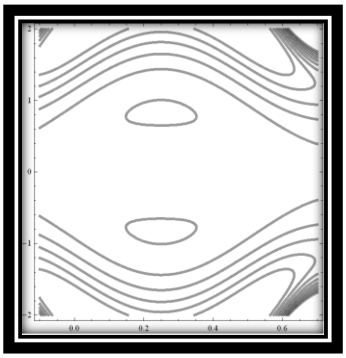

(m)


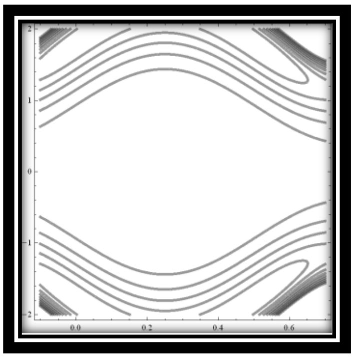
(n)



(o)



(p)



(w)

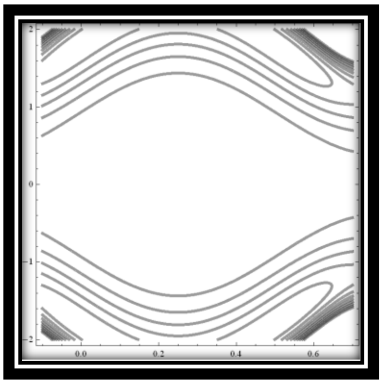


Figure 5. Streamline in the wave frame(axial coordinate. transverse coordinate in Q1 = .95 & Φ = 0.5

at **a**: Ha = 0, k = .1 , B = .1, α = 1.0 , **b**:Ha = 4, k = .1, B = .1, α = 1.0, **c**:Ha = 6, k = .1, B = .1, α = 1.0, **d** :Ha = 10, k = .1, B = .1, α = 1.0 , **e** :Ha = 0, k = .1, B = .1, α = 1.0 , **f**: Ha = 1, k = .1, B = .1, α = 2..0, **g** : Ha = 3, k = .1, B = .1, α = 3.5 , **h** : Ha = 6, k = .1, B = .1, α = 4.0, **i** : Ha = 0, k = .1, B = .1, α = 1.0 , **j** :Ha =1, k =0.3, B = .1, α = 1.0, **l** :Ha = 3, k = .6, B = .1, α = 1.0, **m**: Ha = 6, k = .9, B = .1, α = 1.0.

References

Ali , N., Hayat, and Sajid, M., (2007), Peristaltic Flow of a Couple Stress Fluid in Asymmetric Channel, *J. of Biorheology*, 44, 125-138.

Coleman ,B.D., Markovitz, H. and Noll, W.,(1966), Viscometric Flws of Non-Newtonian Fluids, *Springer-Verlag* , Berlin, Heidelberg, New York.

David,T., and Beresnev,I., (2009), Non-Newtonian in the peristaltic flow of a Maxwell fluid 1Space and Astrophysics Group, Physics Department, University of Wick, *IA* 50011-3212, U.S.A.

Dharmendra,T., (2012), Peristalic Hemodynamic Flow of Couple-Stress Fluids Through a Porous Medium with Slip Effect, Transp porous med.92.pp:559-572.

Eldabe, A.N. Hassan, and Mona T. M. A. Mohamed, A. (2003), Effect of Couple Stresses on the MHD of a Non-Newtonian Unsteady Flow between Two Parallel Porous Plates, Egypt . 58A, pp. 204 – 210.

Elshehawey ,E.F., and Sobh, A.M., (2001), Peristaltic Viscoelastic Fluid Motion in a Tube , *International Journal of Mathematics and Mathematical Sciences*, 26 , 21-34.

Elshehawey,E.F., and Mekheimer, Kh. S., (1994), Couple-Stress in Peristaltic Transport of Fluids, *Journal of Physics D*, 27, 1163-1170.

Hina,S.H.,T., (2010), The in of wall properties on the MHD peristaltic flow of a Maxwell fluid with heat and mass transfer. Non- linear Anal, Real World Apple. 11,3155-3169.

Kawang-Hua Chu,W., and Fang,J., (2000), Peristaltic Transport in a Slip Flow, *European Physical Journal B*, 16,543-547.

Mahmood, O.US.Shafie, and N.Mustapha(2011), Peristaltic transport of ters'B Flud In An Asymmetric channel, *math and mech*.7(21), pp:1-9

Mahmoud SOBH.A., (2008), Interaction of Couple Stresses and Slip Flow on Peristaltic Transport in Uniform and Non uniform Channels, Turkish *J. Eng. Env.*32 , pp: 117 – 123.

Mekheimer ,K.S., (2002), Peristaltic Transport of a Couple-Stress Fluid in a Non-Uniform Channels, *Biorheology* , 39,755-765.

Mekheimer ,K.S., (2004), Peristaltic Flow of Blood under Effect of a Magnetic Field a Non-Uniform Channels, *Applied Mathematics and Computation*, 153, 763-777.

Muhammad Awaisa,T.,H., Ambreen Safdara, Awatif A. Hendi.(2012), Unsteady three dimensional flow of couple stress fluid over a stretching surface with chemical reaction, Pakistan. Vol. 17, No. 1, pp:47–59.

Srivastava ,L.M., (1986), Peristaltic Transport of a Couple-Stress Fluid , *Rheologica Acta*, 25, 638-641.

Vasudev ,C., Prof. Rajeswara Rao U. , .Prabhakara Rao, G. , Subba Reddy M.V. (2011) (Peristaltic flow of a Newtonian fluid through a porous medium in a vertical tube under the effect of a magnetic field, *Int. J Cur. Sci. Res.*1(3),pp: 105- 110