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Effect of couple stresses on hydromagnetic flow of blood through a stenosed coronary artery

[1]S. O Adesanya, [2]S. O. Ajala and [3]R. O. Ayeni
[1]*Department of Mathematical Sciences Department,*
Redeemer's University, Redemption City, Nigeria
[2]*Department of Mathematics,*
University of Lagos, Akoka, Nigeria
[3]*Department of Pure and Applied Mathematics,*
Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

Abstract

The function of the coronary network is to supply blood to the heart; however, in cases of Coronary Artery Disease, the geometry has great influence on the nature of the blood flow and the overall performance of the heart. In this paper, the unsteady non-Newtonian flow of blood under couple stresses and a uniform external magnetic field is analysed by using Eyring – Powell model. We also assumed that blood viscosity is not constant but a function of cell aggregation. The momentum equation for the flow is non-dimensionalized and the non-linear dimensionless equation is then solved numerically by using Adomian decomposition method (ADM) for fixed value of suction parameter. Variations of different flow parameters are conducted and discussed.

Keywords
ADM, unsteady flow, viscoelastic, hemodynamics, stenosed Artery.

1.0 Introduction

Blood is an important body fluid which is assumed to be homogeneous suspension consisting of platelets white blood cell, red blood cell plasma. Following [1], Magnets are composed of metal alloys such as iron, nickel or cobalt and they will attract different types of metallic particles. The blood contains irons and when therapeutic magnets are placed on skin, the magnetic field penetrates through the skin and into the surrounding tissues and blood stream and the increased activities causes the blood flow to improve. The increase in blood flow is localised to the area where the magnets are placed. When magnets placed over a major artery, there is a much larger perfusion of blood flow, so the magnetic field is carried further around the body. When body's blood flow is increased, oxygen, nutrients and hormones are distributed to the organ and tissues more effectively and quickly. Then the organs will have fresh rich supply of oxygen and nutrients to nourish them. Also, the tissues gain oxygen, healing nutrients and hormones including endorphins, which are body's normal pain killing hormones. If there is

[1]**Corresponding author**
[1]**e-mail address: -adesanyaolumide@yahoo.com**

[1]Telephone: +234-0805-516-1181 and +234-0707-001-5244

an injury or ailment which is supplied with regular fresh oxygen, nutrients and endorphins, then the injury or ailment will heal much faster and the pain will be reduced by the body's own pain killing hormones (endorphins).

The effect of couple stresses on the unsteady MHD flow numerically with the assumption that blood viscosity is constant has been studied in [2]. The fluid-structure interaction of blood flow through a stenosed vessel has been studied extensively by [3] using power law model thus neglecting the elasticity property of blood. The effect of viscosity variation on hemodynamics stability of large blood vessel was investigated by [4].

In this present work, we use the result [4] to generalized the previous work of [2], the main objective is to investigate the effect of couple stresses on the unsteady hydro-magnetic flow of blood through porous walls with the assumption that the viscosity in not constant. This is a more realistic model for studying blood flow in a stenosed large blood vessel,

The paper is organized in this form; in section 1 we give brief introduction and the statement of problem, in section 2 of the work, the problem is formulated and non-dimensionalized, in section 3, the problem is solved while results are presented and discussed in section. Section 4 concludes the paper.

2.0 Mathematical formulation

Consider a laminar, viscous and oscillatory non-Newtonian unsteady electrically conducting incompressible flow of blood between constricted axis-symmetrical and elastic tube porous walls under the effect of couple stresses. Due to symmetry, we take the x and y axes along and transverse to the parallel walls and assume a uniform magnetic field B acting along the y-axis. The fluid is injected into the lower wall at y=0 and sucked through the upper wall at y=h with the uniform velocity v_0. The electric field is assumed to be zero and the induced magnetic field is assumed to be very small and the electric conductivity σ of the fluid is sufficiently large. The geometry of the flow is similar to [3].

The geometry of the flow under consideration in this present study is given below.

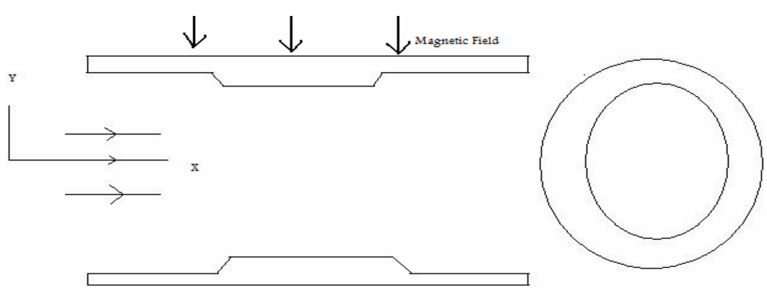

Figure 2.1: Flow geometry

2.1 Governing equation

The field equations are [2],

The continuity equation

$$\dot{\rho} + \rho v_{i,j} = 0 \tag{2.1}$$

Cauchy's first law of motion

$$\rho a_i = T_{ji,j} + \rho f_i \tag{2.2}$$

Cauchy's second law of motion

$$M_{ji,j} + \rho l_i + e_{ijk} T_{jk} = 0 \quad (2.3)$$

The constitutive equation for a linear perfectly elastic solid as obtained by is in the form

$$T_{ji,j} = T^S_{ji,j} + T^A_{ji,j} \quad (2.4)$$

where $T^S_{ji,j}$ is the symmetric part of the stress tensor

$$T^S_{ji,j} = -P_{,i} + (\lambda + \mu) v_{j,ji} + \mu v_{i,jj} = -P_{,i} + (\tau_{ji})_{,j,} \quad (2.5)$$

and $$T^A_{ji,j} = -2\eta \omega_{ji,jll} + \frac{1}{2} e_{ijk} (\rho l_k), j, \quad (2.6)$$

Where ω_{ij} is the spin tensor and is considered as a measure of the rates of rotation of elements in a certain average sense, τ_{ij} is the stress tensor, $\omega_{ij} = e_{ijk}\omega_k$, ω_i is the vorticity vector

Since $\omega_i = \frac{1}{2} e_{ijk} v_{k,j}$ one has $\omega_{ij} = \frac{1}{2}(v_{j,i} - v_{i,j})$ and we can write

$$T^A_{ji,j} = -2\eta \omega_{i,jjll} + \eta v_{j,jill} + \frac{1}{2} e_{ijk} (\rho l_k), j, \quad (2.7)$$

and the equation of motion becomes

$$\rho a_i = T^S_{ji,j} + \eta (v_{j,j})_{,ikk} - \eta v_{i,jjkk} + \frac{1}{2} e_{ijsk} (\rho l_k), j, + \rho f_i \quad (2.8)$$

For incompressible fluids and if the body force and body moments are absent, the equations of motion reduce to

$$\rho a_i = T^S_{ji,j} - \eta v_{i,jjkk} \quad (2.9)$$

This in vector notation can be written as

$$\rho a_i = -\nabla P + \nabla.(\tau_{ij}) - \eta \nabla^4 v \quad (2.10)$$

The last term in this equation gives the effect of couple stresses. Thus, for the effect of couple stresses to be present, $v_{i,rrss}$ must be non zero represent the stress tensor in the case of the non polar theory of fluids.

The stress tensor in the model for non-Newtonian fluids takes the form

$$\tau_{xy} = \mu\left(\frac{\partial u}{\partial x} + \frac{\partial u}{\partial y}\right) + \frac{1}{\alpha}\sinh^{-1}\left(\frac{1}{c}\frac{\partial u}{\partial x} + \frac{1}{c}\frac{\partial u}{\partial y}\right) \quad (2.11)$$

where the first part represent the viscous part and second term denote the elastic effect μ represents the dynamic viscosity and α, c are characteristics of the Eyring–Powel model u = velocity, ρ = density, μ = viscosity, *p* = pressure, *x* = co-ordinate in the direction of flow, y= coordinate across the flow, *u*= velocity in *x*-direction, *v* = velocity in y direction

Now let $v = (u(y,t), v_0, 0)$

Continuity Equation: $$\frac{du}{dx}=0 \tag{2.12}$$

Momentum Equation:

$$\rho\left(\frac{\partial u}{\partial t}+v_0\frac{\partial u}{\partial y}\right)=-\frac{dp}{dx}+\frac{\partial}{\partial y}\tau_{xy}+\sigma B_0\left(E-uB_0\right)-\eta\frac{\partial^4 u}{\partial y^4} \tag{2.13}$$

By assuming a small electric field, (2.13) can be written as

$$\rho\left(\frac{\partial u}{\partial t}+v_0\frac{\partial u}{\partial y}\right)=-\frac{dp}{dx}+\frac{\partial}{\partial y}\left(\mu\frac{\partial u}{\partial y}+\frac{1}{\alpha}\sinh^{-1}\left(\frac{1}{c}\frac{\partial u}{\partial y}\right)\right)-\sigma B_0^2 u-\eta\frac{\partial^4 u}{\partial y^4} \tag{2.14}$$

with $$\sinh^{-1}\left(\frac{1}{c}\frac{\partial u}{\partial y}\right)\cong\frac{1}{c}\frac{\partial u}{\partial y}+\frac{1}{6}\left(\frac{1}{c}\frac{\partial u}{\partial y}\right)^3 \quad \left|\frac{1}{c}\frac{\partial u}{\partial y}\right|<1 \tag{2.15}$$

Neglecting the second approximation for being small. Now introducing the following dimensionless parameters

$$\begin{gathered}u'=\frac{u}{u_0},\ t'=\frac{t}{t_0},\quad x'=\frac{x}{h},\ y'=\frac{y}{h},\ G=-\frac{t_0}{\rho u_0}\frac{\partial p}{\partial x},\ Ha^2=\frac{\sigma B_0^2 h^2}{\mu_0},\\ a=\frac{t_0}{\alpha\rho h^2 c},\ S=\frac{v_0 t_0}{h},\ u_0=\frac{\mu_0}{\rho h},\ \xi=\frac{\mu_0}{\rho h},\ \varsigma=\frac{1}{h},\ b=\frac{\eta}{\mu_0},\ \mu'=\frac{\mu}{\mu_0}\end{gathered} \tag{2.16}$$

Introducing (2.16) we obtain the dimensionless equation with appropriate initial and boundary conditions after dropping bars since (there is no confusion)

$$\frac{\partial u}{\partial t}+S\frac{\partial u}{\partial y}=G+\frac{\partial}{\partial y}\left(\mu'\frac{\partial u}{\partial y}\right)+a\frac{\partial^2 u}{\partial y^2}-Ha^2\xi u-b\varsigma\frac{\partial^4 u}{\partial y^4} \tag{2.17}$$

where u : velocity in flow direction, S : suction parameter, a is the characteristic of Eyring-Powell model, β is the viscosity variation parameter, Ha is the Hartman number, b is the stress parameter. Makinde [4] gave the dynamic viscosity as

$$\mu'=e^{\beta\left(1-y^2\right)} \tag{2.18}$$

We have

$$\frac{\partial u}{\partial t}+\frac{\partial u}{\partial y}=G+\frac{\partial}{\partial y}\left(e^{\beta\left(1-y^2\right)}\frac{\partial u}{\partial y}+a\frac{\partial u}{\partial y}\right)-Ha^2\xi u-b\varsigma\frac{\partial^4 u}{\partial y^4} \tag{2.19}$$

subject to initial and boundary conditions

$$\begin{gathered}t=0: u=\sin(\pi y)\ \forall\ y\\ t>0: u(-1)=0=u''(-1)\\ u(1)=0=u''(1)\end{gathered} \tag{2.20}$$

2.2 Existence theorem [6]

Let D denote the region in (n +1) dimensional space, one dimension for t and n dimensions for the vector x)

$$\left|t-t_0\right|\le a,\quad \left\|X-X_0\right\|\le b \tag{2.21}$$

and suppose that $f(x,t)$ satisfies the condition

$$\frac{\partial f_i}{\partial x_j} \quad \text{i,j} = 1,\ldots,n \tag{2.22}$$

are continuous in *D*. Then there is a constant δ>0 such that there exists a unique continuous vector solution *X*(*t*) of the system

$$\begin{aligned} X_1' &= f_1(X_1,\ldots,X_n,t), X_1(t_0) = X_{10} \\ X_2' &= f_2(X_1,\ldots,X_n,t), X_2(t_0) = X_{20} \\ X_n' &= f_n(X_1,\ldots,X_n,t), X_n(t_0) = X_{n0} \end{aligned} \tag{2.23}$$

In the interval $|t - t_0| \le \delta$.

***Theorem* 2.1**

Let $$\frac{\partial u}{\partial t} + \frac{\partial u}{\partial y} = G + \frac{\partial}{\partial y}\left(e^{\beta(1-y^2)}\frac{\partial u}{\partial y} + a\frac{\partial u}{\partial y}\right) - Ha^2\xi u - b\varsigma\frac{\partial^4 u}{\partial y^4} \tag{2.24}$$

with

$$t = 0 : u = \sin(\pi y)\forall\ y, t > 0 : u(-1) = 0 = u''(-1), u(1) = 0 = u''(1), \beta = 0 = S\ ,\ \varsigma = \frac{1}{t},\quad \xi = \frac{1}{t}$$

Then there exists a unique solution of the problem

Proof

Let us assume that the wall porosity is negligible then introducing the similarity variable

$$\eta = \frac{y}{2\sqrt{t}} \tag{2.25}$$

Then (2.24) can be written as

$$\begin{aligned} -\frac{\eta}{2t}\frac{du}{d\eta} &= G + \frac{1}{2\sqrt{t}}\frac{d}{d\eta}\left(\frac{1}{2\sqrt{t}}\frac{du}{d\eta} + \frac{a}{2\sqrt{t}}\frac{du}{d\eta}\right) - \frac{Ha^2}{t}u - \frac{b}{16t}\frac{d^4u}{d\eta^4} \\ -\eta\frac{du}{d\eta} &= G + (1+a)\frac{d^2u}{d\eta^2} - Ha^2u - \frac{b}{16}\frac{d^4u}{d\eta^4} \end{aligned} \tag{2.26}$$

Now let

$$x_1 = \eta, x_2 = u, x_3 = u', x_4 = u'', x_5 = u''' \tag{2.27}$$

To obtain

$$\begin{pmatrix} x_1' \\ x_2' \\ x_3' \\ x_4' \\ \\ x_5' \end{pmatrix} = \begin{pmatrix} 1 \\ x_3 \\ x_4 \\ x_5 \\ \\ \frac{16}{b}\left(G + (1+a)x_4 - Ha^2x_2 + x_1x_3\right) \end{pmatrix} = \begin{pmatrix} f_1\,(x_1,\ldots,x_5) \\ f_2(x_1,\ldots,x_5) \\ f_3(x_1,\ldots,x_5) \\ f_4(x_1,\ldots,x_5) \\ \\ f_5(x_1,\ldots,x_5) \end{pmatrix} \tag{2.28}$$

subject to the initial conditions $x_1(0)=0, x_2(0)=-1,\ x_3(0)=D$

Now we need to proof that $\frac{\partial f_i}{\partial x_j}$ are continuous in the domain

Differentiating each term of f_i with respect to x_i

We obtain

$$\frac{\partial f_1}{\partial x_1}=0, \frac{\partial f_1}{\partial x_2}=0, \frac{\partial f_1}{\partial x_3}=0, \frac{\partial f_1}{\partial x_4}=0, \frac{\partial f_1}{\partial x_5}=0$$

$$\frac{\partial f_2}{\partial x_1}=0, \frac{\partial f_2}{\partial x_2}=0, \frac{\partial f_2}{\partial x_3}=1, \frac{\partial f_2}{\partial x_4}=0, \frac{\partial f_2}{\partial x_5}=0$$

$$\frac{\partial f_3}{\partial x_1}=0, \frac{\partial f_3}{\partial x_2}=0, \frac{\partial f_3}{\partial x_3}=0, \frac{\partial f_3}{\partial x_4}=1, \frac{\partial f_3}{\partial x_5}=0$$

$$\frac{\partial f_4}{\partial x_1}=0, \frac{\partial f_4}{\partial x_2}=0, \frac{\partial f_4}{\partial x_3}=0, \frac{\partial f_4}{\partial x_4}=0, \frac{\partial f_4}{\partial x_5}=1 \tag{2.29}$$

$$\frac{\partial f_5}{\partial x_1}=x_3, \frac{\partial f_5}{\partial x_2}=-Ha^2, \frac{\partial f_5}{\partial x_3}=x_1, \frac{\partial f_5}{\partial x_4}=(1+a), \frac{\partial f_5}{\partial x_5}=0$$

From above, it is now obvious that $\frac{\partial f_i}{\partial x_j}$ exist and continuous. Hence the proof

Clearly, $\frac{\partial f_i}{\partial x_j}=k$ therefore the function satisfies the Lipschitz condition.

2.3 **Analysis of the adomian decomposition method** [5]

The principal algorithm of the Adomian decomposition method when applied to a general non-linear equation is in the form

$$Lu+Ru+Nu=f(x) \tag{2.30}$$

the linear terms are decomposed into $L + R$ while the non-linear terms are represented by Nu. L is taken as the highest order derivative to avoid derivative to avoid difficult integration involving complicated Green's function and R is the remainder of the linear operator. L^{-1} is regarded as the inverse operator of L and is defined by a definite integration from 0 to t, for example, for a first-order operator

$$L^{-1}(.)=\int_0^t (.)dt \Rightarrow L^{-1}Lu=u(x,t)-u(x,0) \tag{2.31}$$

and for a second-order, we have

$$L^{-1}(.)=\int_0^t\int_0^t (.)dtdt \Rightarrow L^{-1}Lu=u(x,t)-u(x,0)-t\frac{\partial u(x,0)}{\partial t} \tag{2.32}$$

Taking the inverse operator of (2.30), we have

$$L^{-1}Lu=L^{-1}f(x)-L^{-1}Ru-L^{-1}Nu \tag{2.33}$$

$$u(x,t)=u(x,0)+L^{-1}f(x)-L^{-1}Ru-L^{-1}Nu \tag{2.34}$$

and $$u(x,t) = g(x) - L^{-1}Ru - L^{-1}Nu \qquad (2.35)$$

with $g(x)$ arising from the initial and or boundary condition s. The decomposition method represents the solution of (2.35) as a series

$$u(x,t) = \sum_{n=0}^{\infty} u_n(x,t) \qquad (2.36)$$

Now, we have to decompose the non-linear term Nu. To do this Adomian developed a very elegant technique as follows; define the composition parameter λ as $u = \sum_{i=0}^{\infty} \lambda^i u_i$ then Nu will be a function of $\lambda, u_0, u_1, \ldots$ next expanding Nu in Maclurent series with respect to λ, we obtain

$$Nu = \sum_{i=0}^{\infty} \lambda^i A_i \qquad (2.37)$$

where A_i represent the Adomian polynomial for the non-linear term

$$A_n = \frac{1}{n!}\frac{d^n}{d\lambda^n}\left[f\left(\sum \lambda^i u_i(y,t)\right)\right]_{\lambda=0} \qquad (2.38)$$

$$\begin{aligned} A_0 &= F(u_0) \\ A_1 &= u_1 F'(u_0) \\ A_2 &= u_2 F'(u_0) + \frac{1}{2!}u_1^2 F''(u_0) \\ &\vdots \\ A_3 &= u_3 F'(u_0) + u_1 u_2 F''(u_0) + \frac{1}{3}u_1^3 F'''(u_0) \end{aligned} \qquad (2.39)$$

Substituting for (2.37)-(2.39) in (2.36), we can write the solution in series form as $u = u_0 + u_1 + u_2 + .. +$. Adomian gave the final solution as

$$\begin{aligned} u_0 &= g(x) \\ u_1 &= -L^{-1}Ru_0 - L^{-1}A_0 \\ &\vdots \\ u_{n+1} &= -L^{-1}Ru_n - L^{-1}A_n, \qquad n \geq 0 \end{aligned} \qquad (41)$$

The accuracy of this numerical scheme is enhanced by computing components as far as possible. However, there have been several modifications on the Adomian decomposition method that makes the method much better than many other numerical methods.

3.0 Adomian decomposition method for the hemodynamics model

Given that

$$\frac{\partial u}{\partial t} + \frac{\partial u}{\partial y} = \lambda + \frac{1}{\mathrm{Re}}\frac{\partial}{\partial y'}\left(e^{\beta(1-y^2)}\frac{\partial u}{\partial y}\right) + \frac{a}{\mathrm{Re}}\frac{\partial^2 u}{\partial y^2} - Ha^2 u - \frac{b}{\mathrm{Re}}\frac{\partial^4 u}{\partial y^4} \qquad (3.1)$$

Subject to initial and boundary conditions

$$t = 0 : u = \sin(\pi y) \forall\ y$$
$$t > 0 : u(-1) = 0 = u''(-1) \qquad (3.2)$$
$$u(1) = 0 = u''(1)$$

Special Case 1: Pulsatile pressure gradient

It is a known fact that blood flow through the heart is pulsatile in nature,

Suppose a gradient $\lambda = -\frac{\partial P}{\partial x} = \left(\frac{\partial P}{\partial x}\right)_s + \left(\frac{\partial P}{\partial x}\right)_0 e^{i\omega t} = P_s + P_0 e^{i\omega t}$ (3.3)

Here P_s, P_0 are constants; with P_0 as the pulsation pressure parameter. To obtain the solution we use the perturbation technique as follows

$$u = U + Ve^{i\omega t} \qquad (3.4)$$

Substituting, (3.4) in (2.19),

We obtain two ordinary differential equations

$$\frac{d^4U}{dy^4} = \frac{1}{b}\{P_s + \frac{d}{dy}\left(e^{\beta(1-y^2)}\frac{dU}{dy} + a\frac{dU}{dy}\right) - \frac{dU}{dy} - H^2U\} \qquad (3.5)$$

and

$$\frac{d^4V}{dy^4} = \frac{1}{b}\{P_0 + \frac{d}{dy}\left(e^{\beta(1-y^2)}\frac{dV}{dy} + a\frac{dV}{dy}\right) - \frac{dV}{dy} - \left(i\omega + H^2\right)V\} \qquad (3.6)$$

By using Adomian Decomposition method described above, we obtain the following results

$$U_0(y,t) = U(y,0) = a_1 + ya_2 + \frac{y^2}{2}a_3 + \frac{y^3}{6}a_4 + L_{yyyy}^{-1}P_S$$
$$U_{n+1}(y,t) = L_{yyyy}^{-1}L_y\left\{\left(1 + \beta(1-y^2) + (1-y^2)^2\frac{\beta^2}{2}\right)L_yU_n + aL_yU_n\right\} - L_{yyyy}^{-1}\left\{L_yU_n + H^2U_n\right\} \qquad (3.7)$$

and $$V_0(y) = b_1 + yb_2 + \frac{y^2}{2}b_3 + \frac{y^3}{6}b_4 + L_{yyyy}^{-1}P_0$$

$$V_{n+1}(y,t) = L_{yyyy}^{-1}L_y\left\{\left(1 + \beta(1-y^2) + (1-y^2)^2\frac{\beta^2}{2}\right)L_yV_n + aL_yV_n\right\} - L_{yyyy}^{-1}\left(i\omega + H^2 + L_y\right)V_n \qquad (3.8)$$

Substituting (3.7) and (3.8) in (3.4), Then the iteration is done by using mathematical version 6 to obtain the following numerical results, due to the large size of the solution we only show the graphical solutions in figure 3.1-3.4

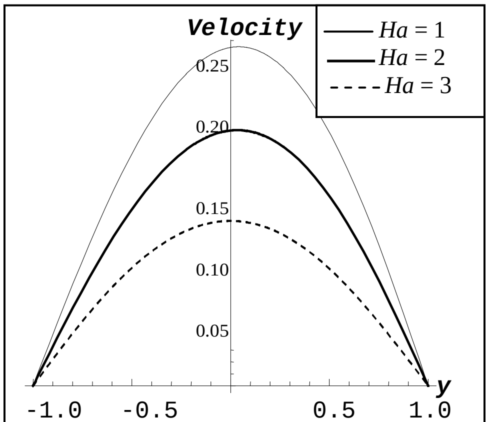

Figure 3.1: Velocity against *y*

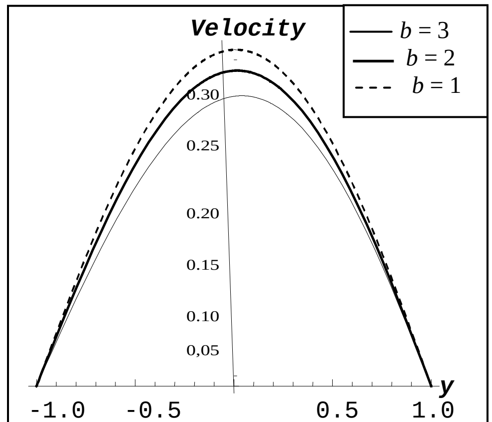

Figure 3.3: Velocity against *y*

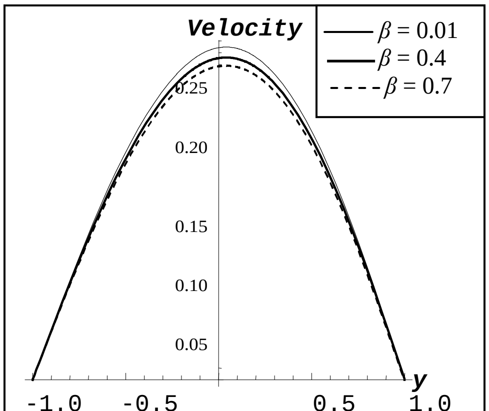

Figure 3.2: Velocity against *y*

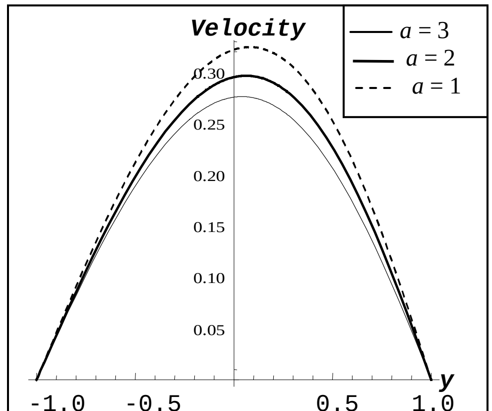

Figure 3.4: Velocity against *y*

Special Case 2:- Constant pressure gradient

However, for flow in the capillaries the flow is no more pulsatile it is assumed to have reached a mean steady state from (2.19)

$$\frac{\partial u}{\partial t}+\frac{\partial u}{\partial y}=\lambda+\frac{1}{\mathrm{Re}}\frac{\partial}{\partial y'}\left(e^{\beta\left(1-y^2\right)}\frac{\partial u}{\partial y}\right)+\frac{a}{\mathrm{Re}}\frac{\partial^2 u}{\partial y^2}-Ha^2u-\frac{b}{\mathrm{Re}}\frac{\partial^4 u}{\partial y^4}$$

So by Adomian a direct integration of (2.19) yields,

$$u(y,t)=u(y,0)+L_t^{-1}\left\{\lambda-L_yu+L_y\left(e^{\beta\left(1-y^2\right)}L_yu\right)+aL_{yy}u-Ha^2u-bL_{yyyy}u\right\} \tag{3.9}$$

Taking Taylor's expansion of $Exp[\beta(1-y^2)]$ about β. We obtain

$$Exp[\beta(1-y^2)]=1+\beta(1-y^2)+\frac{1}{2}(1-y^2)^2\beta^2+\text{other terms} \tag{3.10}$$

Substituting (3.9) in (3,8) we have the recurrence formula

$$u(y,t)=u(y,0)+L_t^{-1}\lambda$$

$$u_{n+1}u(y,t)=L_t^{-1}\left\{-L_yu_n+L_y\left(e^{\beta\left(1-y^2\right)}L_yu_n\right)+aL_{yy}u_n-Ha^2u_n-bL_{yyyy}u_n\right\} \tag{3.11}$$

Then (3.10) is iterated using mathematical version 6. Again we shall only show the graphical results due to the large size of the solution in figures 3.5 – 3.8

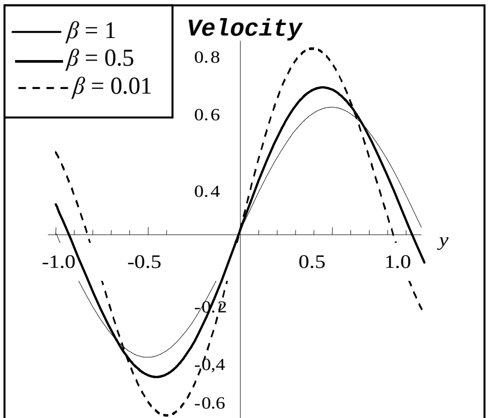

Figure: 3.5: Velocity against y

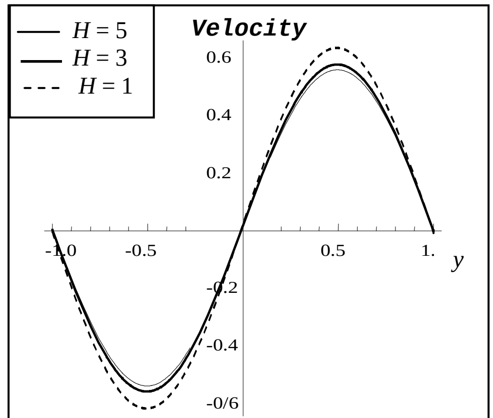

Figure: 3.6: Velocity against y

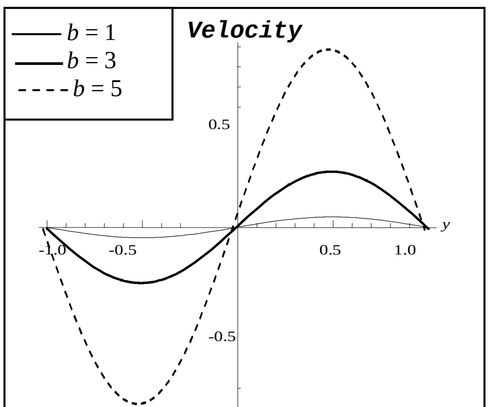

Figure: 3.7: Velocity against y

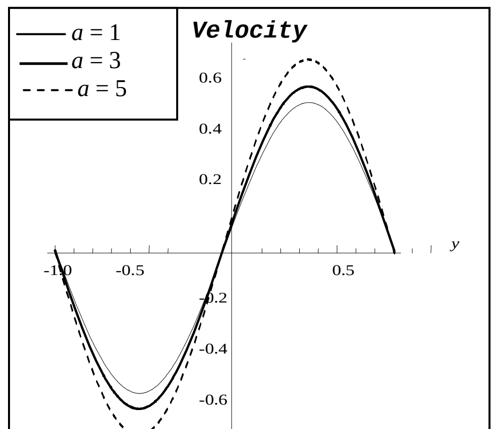

Figure: 3.8: Velocity against y

4.0 Discussion of results

In figures 3.1 and 3.2 we observe that as both magnetic parameter and viscosity parameter increases the blood flow velocity reduces this is physically true for magnetic effect in major artery and as viscosity increases the non Newtonian property become significant.

In figure 3,3 we observed that as the couple stress parameter increases its inverse reduces and the flow velocity increases and for figure 3.4 an increase in the elastic parameter improves the flow

One of the major risk factor of high blood pressure is that it destroys the tiny and very fine capillary walls causing pepperish sensation this effect is seen in figure 3.5. while the effect of therapic magnetic place on the skin is shown in figure 3.6 evidently the magnetic effect causes improvement I the flow velocity

The effects of couple stresses parameter shown in figure 3.7 and elastic parameter effect in figure 3.8

4.0 Concluding remarks

We have studied the effect of couple stresses on the unsteady blood flow through stenosed artery using the Adomian decomposition approach our results generally sows that

i increasing the Hartmann number improves the flow at the capillary level while it has reduction effect at the artery level

ii increasing the couple stress parameter causes reduction in the flow velocity

iii. increasing the elastic parameter causes reduction in the flow velocity

iv. increasing the viscosity parameter reduces the flow velocity however at the capillary level the fine walls may be disturbed if the situation is not checked

It is therefore recommended that people should go for periodic medical examination of there blood pressure as people that are hypertensive do no know until they come down with the complications like pep perish skin (in which case the walls of the capillary must have been destroyed), loss of sight, kidney diseases or stroke.

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