Pulsatile Flow of Blood with Volume Fraction of Micro-organisms in the Presence of Transverse Magnetic Field through Stenosed Tube

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Abstract:This paper presents an analytical study of pulsatile flow of blood with micro-organisms through stenosed tubes in presence of transverse magnetic field.The effect of externally applied magnetic field on velocity, flow rate is studied.The analytical solutions for the velocity, volumetric flow rate are obtained using finite Hankel and Laplace transforms,and their natures are shown graphically for different values of involved parameters.

Key Words: Stenosis, Couple Stress fluid, Transverse magnetic field, Micro-organisms.

1.1) *Introduction:*It is well established that the external magnetic field considerable effect on the biological system of human life. Many cardiovascular diseases, particularly atherosclerosis, have been found to be responsible for deaths in both developed and developing countries. The study of blood flow through a stenotic artery is very important because the nature of blood movement and mechanical behaviour of vessel walls are causes of many cardiovascular diseases. Most of the authors (Bali and Awasthi [1], Chakravarty [2], Deplano and Siouffi [4], Haldar [5] Liu et al., 2004; Mandal [6]) studied the pulsatile blood flow in the artery having single mild stenosis. The multiple stenosis is commonly found in the femoral and pulmonary arteries, so the problem of blood flow becomes more acute in the presence of overlapping stenosis (Chakravarty and Mandal [7] Ismail et al., [8]). The study of blood rheology and blood flow has several objectives such as not only understanding health and disease but also in essence, what kind of fluid it is (Buchanan et al., [3], Hernan and Gonzalez, [9], Ismail et al.,[8], Mandal, [6]). Some authors in the area of blood flow feel that blood can be assumed to be Newtonian in nature especially in large blood vessels such as the aorta (Katiyar and Basavasarajappa, [10]; Liepsch, [11], Liu et al.[12], Prakash et al.[13], Tashtoush and Magableh[14], Tzirtzilakis [15]). In fact blood is a suspension of cells in plasma. The plasma which is a solution of proteins, electrolyte and other substances, is an incompressible virtually Newtonian fluid. From biomechanical point of view, blood is considered as an intelligent fluid, probably the most one in the nature, capable of adapting itself in a great extent in order to provide nutrients to the organs.

It is well known that blood behaves differently when flowing in large vessels, in which Newtonian behaviour is expected and in medium and small vessels where non-Newtonian effects appear (Buchanan et al.,[3]; Chakravarty and Mandal, [7] Deplano and Siouffi [4] Ismail et al.[8] Mandal [6]). Blood can be regarded as magnetic fluid, in which red blood cells are magnetic in nature. Liquid carriers in the blood contain the magnetic suspension of the particle (Tzirtzilakis [15]).Human body experiences magnetic fields of moderate to high intensity in many situations of day to day life. In recent times, many medical diagnostic devices especially those used in diagnosing cardiovascular disease make use of magnetic fields. It is known from the magneto-hydrodynamics that when a stationary, transverse magnetic field is applied externally to a moving electrically conducting fluid, electrical currents are induced in the fluid. The interaction between these induced currents and the applied magnetic field produces a body forces (known as the Lorentz force) which tends to retard the movement of blood (Sud and Sekhon, [16]), Chester [17] analyzed the interaction of the magnetic field with the electric current to propose the pressure of body forces in stokes problem for the discussion of the motion of the fluids in the classical hydrodynamics. Low frequency, low intensity magnetic energy has been employed for treating chronic pain secondary to tissue ischemia and slow healing and non healing ulcers with satisfactory to excellent results. This type of energy appears to affect biological process, not through heat production but through electrically induced changes in the environment of cells within the organism. Jauchem [18] studied the effects of low frequency electromagnetic energy on the peripheral blood circulation and concluded that low frequency, low intensity magnetic field increased blood flow in the great majority. It is believed that the magnetic flux stimulates the functions of various system of the body and regenerates the tissues of the body. Most of the biomedical problem may aptly be described as fluid flow problems involving channels or tubes**.** It is known that blood is an electrically conducting fluid. So the flow of blood in human system can be decelerated by applying the magnetic field and in turn it may help in the treatment of certain cardio-vascular diseases and also in the diseases with accelerated blood circulation such as hyper-tension, haemorrhages and so on. In the year1936 Kolin [19] was first to coin the idea of electro-magnetic field in the medical research. The possibility of regulating the blood movement in human system by applying magnetic field was discussed by Korchevskii and Marchink [20] for the prevention and rational therapy of arterial hypertension apparently of no less importance is close study of hydronamics changes associated with the electrically conducting fluid, then one such factor may be a magnetic field. By the Lenz's law the Lorentz's force will act on the constituent particles of blood. In other words this force will oppose the motion of conducting fluid and in general it will alter the haemodynamics indicators of the blood flow. Therefore, the prolonged exposure to a magnetic field and the associated haemodynamics shifts will lead to disturbance in the normal functioning of the cardio-vascular system. Now a days electromagnetic field is applied in treating the patients with fractures in conditions of non-union, delayed union, compound fracture of severe nature, infections and fresh closed fractures with massive combination and large but limited fracture gaps where the treatment method available are very limited. The fractured portion requires more nutrition than the normal supply. If the e.m.f (electro magnetic force) is applied to that particular portion the velocity of the blood could be decelerated, so that the nutrition can be supplied abundantly and in turn the healing process will be fast. The medical practitioners have suggested that, for the lower limb fractures, in the initial stages of the treatment, samples treatment time of atleast 10hrs/day, effective magnetic field are all very much essential in acquiring good results.

Mathews [21], Bhatnagar and Rakesh [22] have analyzed the flow of a visco-elastic fluid confined between a pair of infinite parallel rotating discs in the presence of an externally applied magnetic field in a direction perpendicular to the discs. Ramachandra Rao and Deshikachar [23] have studied the effect of transverse magnetic field on physiological type of flow in uniform circular pipe. Shastri and Seetaramaswamy [24] have studied the flow of the dusty viscous incompressible fluid through a circular pipe under the influence of a transverse magnetic field. They have mentioned that as the Hartmann number increases the velocities of the fluid and dust particle decreases Debnath and Ghosh [25] have investigated the motion of an incompressible viscous conducting fluid with embedded small spherical particles bounded by two infinite rigid non-conducting plates in the presence of an external transverse magnetic field. They have shown that the effect of dust particles on the fluid velocity depends on the time period. Unsteady MHD flow of a dusty viscous liquid in an annulus bounded by two co-axial cylinders under the influence of exponential pressure gradient when the outer cylinder is moving with time dependent velocity has been studied by Kour and Sharma [26]. Rathod and Shakera [27] have studied the pulsatile flow of blood through a porous medium under the influence of periodic body acceleration by considering blood as a couple-stress, incompressible, electrically conducting fluid in the presence of magnetic field. Magnetic force therapy could be useful for the reperfusion of ischemic tissue or during sepsis. When blood flow to a tissue becomes blocked or reduced, necrosis will eventually occur. Local exposure of a magnetic field could potentially result in blood vessel relaxation and increased blood flow. The effects of magnetism on blood vessels and the cardiovascular system are very interesting. There is still no experiment that shows the effect of quite magnetic field on blood circulation. In recent years some studies (Katiyar and Basavarajappa [7], Kinouchi et al. [28], Sud and Sekhon [16], Tashtoush and Magableh [14], Tzirtzilakis [15]) have been reported on the analysis of blood flow through single arteries in the presence of externally applied magnetic field. However there are very few studies focusing on the effect of magnetic field in the stenotic artery. Considering the influence of magnetic field on the stenotic artery, in this study, we look at the effect of transverse magnetic field and multi-stenosis on the blood flow in blood vessel. It is assumed that the arterial segment is cylindrical tube with time dependent multi-stenosis and the flowing blood is characterized by generalized Power-law model. Governing equations are solved by using suitable finite difference method. The effect of externally applied magnetic field on velocity, flow rate, flow resistance and wall shear stress is studied

Our object in the present paper is to study the effect of magnetic field on pulsatile flow of blood through a stenosed tube with volume fraction of micro-organism. The velocity expressions for both blood and microorganisms have been obtained in Bessel-Fourier series form, by applying the Laplace and finite Hankel transforms**.** Further, by assuming blood as couple stress fluid and dusty particles as microorganisms, analytical expressions are obtained for velocities of blood and microorganisms. The changes in the velocity profiles are shown graphically.. Discussions drawn from the results may be important from medical points of view.

1.2) ***Formulation of the Problem:*** We have considered the one-dimensional motion for a dusty unsteady, viscous, incompressible, electrically conducting couple-stress fluid through a circular pipe with an insulating wall in the presence of an imposed transverse magnetic field. The motion of the fluid is taking along the axis of the pipe. Hence there is only one non-zero component of velocity of the fluid and dust particle.

The governing equations of motion of blood with microorganisms are given by

$$(1-\phi)\rho\left\{\frac{\partial U}{\partial t}+(U.\nabla_1)U\right\}=(1-\phi)\left\{-gradP+\mu\nabla_1^2U-\eta\nabla_1^4U\right\}+KN(V-U)-\frac{\sigma B_0^2U}{\rho} \tag{1.2.1}$$

$$\left\{\frac{\partial V}{\partial t}+(V.\nabla_1)V\right\}=\phi\left\{-gradP+\mu\nabla_1^2U-\eta\nabla_1^4U\right\}+\frac{K}{m}(U-V) \tag{1.2.2}$$

$$divU=0 \tag{1.2.3}$$

$$\frac{\partial N}{\partial t}+div(NV)=0 \tag{1.2.4}$$

where U and V denote the local velocity vectors of fluid and microorganisms respectively, ρ - density, P- static fluid pressure, ν - kinematic viscosity, N - number density of micro-organisms, K- Stoke's resistance coefficient ($6\pi\mu\varepsilon_1, \varepsilon_1$- the radius of spherical particles), μ - the fluid viscosity, m – mass of microorganisms, g – gravity, ϕ - volume fraction , B_0 – the magnetic field strength σ - the electrical conductivity, r is the radial coordinate and

$$\nabla_1^2=\left(\left(\frac{1}{r}\right)\frac{\partial}{\partial r}\right)\left(r\frac{\partial}{\partial r}\right)$$

For the present problem, the velocity distribution is taken only in Z – direction and is function of r and t only. Then the equations (1.2.1) and (1.2.2) reduces to

$$(1-\phi)\rho\frac{\partial w_1}{\partial t}=(1-\phi)\left[-\frac{\partial p}{\partial z}+\mu\nabla_1^2 w_1-\eta\nabla_1^4 w_1\right]+KN(w_2-w_1)-\frac{\sigma B_0^2 w_1}{\rho} \qquad (1.2.5)$$

$$\frac{\partial w_2}{\partial t}=\phi\left[-\frac{\partial p}{\partial z}+\mu\nabla_1^2 w_1-\eta\nabla_1^4 w_1\right]+\frac{K}{m}(w_1-w_2) \qquad (1.2.6)$$

where w_1 and w_2 are the velocity components of blood and microorganisms respectively.

The boundary conditions are:

w_1, w_2 and $\nabla_1^2(w_1, w_2)$ are all finite at $r=0$

$w_1=0=w_2$ and $\nabla_1^2(w_1,w_2)=0$ at $r=R$ (1.2.7)

Introduce the non-dimensional quantities,

$$u=\frac{w_1 n\rho}{M},\quad v=\frac{w_2 n\rho}{M},\quad y=\frac{r}{R},\quad \phi^*=\frac{\phi}{b}$$

$$\frac{\partial^2}{\partial r^2}+\frac{1}{r}\frac{\partial}{\partial r}=\frac{1}{R^2}\left[\frac{\partial^2}{\partial y^2}+\frac{1}{y}\frac{\partial}{\partial y}\right]=\frac{1}{R^2}\nabla^2 \qquad (1.2.8)$$

And assuming Womersley [29] type of pressure gradient of the form

$$-\frac{\partial p}{\partial z}=M\cos(nt+\theta) \qquad (1.2.9)$$

Where M is the modulus, n is the circular frequency and θ is the phase in the complex representation of the Fourier coefficient of the velocity analogous to the pressure gradient gives,

$$u=u_0(y)e^{int}$$
$$v=v_0(y)e^{int} \qquad (1.2.10)$$

With the help of equations (1.2.8), (1.2.9), (1.2.10) the equations (1.2.5) and (1.2.6) reduce to

$$\nabla^4 u_0-\bar{\alpha}^2\nabla^2 u_0+Xu_0+\bar{\alpha}^2 M_1^2 u_0=\frac{\bar{\alpha}^2}{1+i\alpha^2\beta(1-\phi b)}+\bar{\alpha}^2\alpha^2 e^{i\theta} \qquad (1.2.11)$$

$$v_0=\frac{-\phi\beta}{\bar{\alpha}^2 b(1+i\alpha^2\beta)}\left\{\nabla^4 u_0-\bar{\alpha}^2\nabla^2 u_0-\bar{\alpha}^2\alpha^2 e^{i\theta}\right\}+\frac{u_0}{1+i\alpha^2\beta}+\frac{\beta}{b(1+i\alpha^2\beta)} \qquad (1.2.12)$$

where $\bar{\alpha}^2=\frac{R^2\mu}{\eta}$ is the couple – stress parameter, $\alpha^2=\frac{R^2 n}{\nu}$ is the Pulsatile Reynolds' number, $b=\frac{mN}{\rho}$ is the mass concentration, $\beta=\frac{m\nu}{KR^2}$ is the relaxation time parameter, $M_1=B_0R\sqrt{\frac{\sigma}{\mu}}$ Hartman number, $i=(-1)^{1/2}$, $\nu=\frac{\mu}{\rho}$ is kinematics viscosity.

The modified boundary conditions are :

u_0, v_0 and $\nabla^2(u_0,v_0)$ are all finite at $y=0$

$u_0=0=v_0$ and $\nabla^2(u_0,v_0)=0$ at $y=1$ (1.2.13)

$$\text{where } \nabla_1^2=\frac{1}{R^2}\left[\frac{1}{y}\frac{d}{dy}\left[y\frac{d}{dy}\right]\right]=\frac{1}{R^2}\nabla^2 \qquad (1.2.14)$$

1.3)*Solution of Problem*:For the present mathematical model of the fourth order partial differential equation in cylindrical co-ordinate system has solved by using finite Hankle transform technique in fourier Bessel series form, which is given by

$$\bar{u}_0(k)=\int_0^1 u_0(y)yJ_0(ky)dy \qquad (1.3.1)$$

where k's are the positive roots of the equation

$$J_0(k)=0 \qquad (1.3.2)$$

$J_0(k)$ Denotes the Bessel function of the first kind of order zero

The Inverse transform is given by

$$\bar{u}_0(y)=2\sum_k \bar{u}_0(k)\frac{J_0(ky)}{J_1^2(k)} \qquad (1.3.3)$$

The summation is taken over all the positive roots of (1.3.2). Applying the Hankel transfrom (1.3.1) and inverse transform (1.3.3) to the equation (1.2.11) and by using (1.2.10) and boundary conditions (1.2.13), we get the velocity of blood in non-dimensional form in the presence of microorganisms and magnetic effect as,

$$u(y,t)=2\sum_k\left\{\frac{\bar{\alpha}^{-2}\alpha^2e^{i(nt+\theta)}}{\left[k(k^4+\bar{\alpha}^{-2}k^2+X+\bar{\alpha}^{-2}M_1^2)\right]}\right\}\frac{J_0(ky)}{J_1(k)} \quad (1.3.4)$$

where $$X=\frac{i\bar{\alpha}^{-2}\alpha^2\left[(1-\phi)(1+i\alpha^2\beta)+b\right]}{1+i\alpha^2\beta(1-\phi b)} \quad (1.3.5)$$

Using the equation (1.3.4) and (1.2.10) in (1.2.12), we get the velocity for microorganisms in non-dimensional form as

$$v(y,t)=2\sum_k\left[\left(\frac{\beta}{b(1+i\alpha^2\beta)}-M^*\right)\frac{J_0(ky)}{kJ_1(k)}+u(y,t)\left(M^*X+\frac{1}{1+i\alpha^2\beta}\right)\right] \quad (1.3.5)$$

where $$M^*=\frac{\phi\beta}{\bar{\alpha}^{-2}b(1+i\alpha^2\beta)}$$

Expression for flow rate Q is defined as,

$$Q=2\pi\int_0^1 y\left(u(y,t),v(y,t)\right)dy \quad (1.3.6)$$

Expressions for flow rate for blood and microorganisms respectively are obtained from expressions (1.3.4), (1.3.5) and (1.3.6)

$$Q_u=4\pi\sum_k\left\{\frac{(\bar{\alpha}^{-2}\alpha^2e^{i(nt+\theta)})}{\left\{k^2\left(k^4+\alpha^2k^2+X+\bar{\alpha}^{-2}M_1^2\right)\right\}}\right\} \quad (1.3.7)$$

$$Q=4\pi\left[\sum_k\frac{1}{k}\left\{\left(\frac{\beta}{b(1+i\alpha^2\beta)}-M^*\right)+\frac{\bar{\alpha}^{-2}\alpha^2e^{i(nt+\theta)}}{k(k^4+\bar{\alpha}^{-2}k^2+X+\bar{\alpha}^{-2}M_1^2)}\left(M^*X+\frac{1}{1+i\alpha^2\beta}\right)\right\}\right] \quad (1.3.8)$$

The general apparent viscosity is defined by,

$$\mu=\frac{\pi R^4Me^{i(nt+\theta)}}{8Q} \quad (1.3.9)$$

The apparent viscosity for blood and microorganisms respectively are given by the following expressions:

$$\mu_b=\frac{\mu e^{i\theta}}{32(\bar{\alpha}^{-2}\alpha^2e^{i\theta})}\sum_k k^2(k^4+\bar{\alpha}^{-2}k^2+X+\bar{\alpha}^{-2}M_1^2) \quad (1.3.10)$$

$$\mu_m=\frac{\mu e^{i\theta}}{32\sum_k\frac{1}{k}\left[\left(\frac{\beta}{b(1+i\alpha^2\beta)}-M^*\right)+\frac{\bar{\alpha}^{-2}\alpha^2e^{i\theta}}{k(k^4+\bar{\alpha}^{-2}k^2+X+\bar{\alpha}^{-2}M_1^2)}\left(M^*X+\frac{1}{1+i\alpha^2\beta}\right)\right]} \quad (1.3.11)$$

1.4)*Results and Discussions:* It is very interesting to note that the velocity expressions obtained in the present analysis are most general one.From these expressions, one can obtain the expressions for the pulsatile and steady flow of Non-Newtonain fluid i.e., blood Newtonain fluid in the presence & absence of microorganisms and with or without magnetic effect by simple & proper substitutions. The expression (1.3.4) can be reduced to pulsatile flow of blood with magnetic effect in the absence of microorganisms by a substituting
m = 0 (i.e., in equation (1.3.5)).

$$u(y)=2\sum_k\left\{\frac{\bar{\alpha}^{-2}\alpha^2e^{i(nt+\theta)}}{\left[k(k^4+\bar{\alpha}^{-2}k^2+i\bar{\alpha}^{-2}\alpha^2+\bar{\alpha}^{-2}M_1^2)\right]}\right\}\frac{J_0(ky)}{J_1(k)} \quad (1.4.1)$$

The above velocity expression can further be reduced to steady blood flow in dimensional form by substituting n = 0.

$$w(y)=\sum_k\frac{2MR^2\bar{\alpha}^{-2}e^{i\theta}}{\mu k(k^4+\bar{\alpha}^{-2}k^2+\bar{\alpha}^{-2}M_1^2)}\frac{J_0(ky)}{J_1(k)} \quad (1.4.2)$$

In equation (1.3.4), if $\bar{\alpha} \to \infty$, then it reduces to the velocity for pulsatile Newtonian fluid with microorganisms and magnetic effect as follow.

$$u(y) = 2\sum_k \left\{ \frac{\alpha^2 e^{i(nt+\theta)}}{\left[k(k^2 + X + M_1^2) \right]} \right\} \frac{J_0(ky)}{J_1(k)} \tag{1.4.3}$$

By substituting n = 0 in the above expression (1.4.3), it reduces to the expression of steady Newtonian fluid in the dimensional form, without microorganisms under magnetic effect as,

$$w(y) = \sum_k \frac{2MR^2 e^{i\theta}}{\mu k(k^2 + M_1^2)} \frac{J_0(ky)}{J_1(k)} \tag{1.4.4}$$

With m = 0, the expression (1.4.3) will reduces to the pulsatile flow of Newtonian fluid in te absence of microorganisms along with magnetic effect as,

$$u(y) = 2\sum_k \left\{ \frac{\alpha^2 e^{i(nt+\theta)}}{\left[k(k^2 + i\alpha^2 + M_1^2) \right]} \right\} \frac{J_0(ky)}{J_1(k)} \tag{1.4.5}$$

When the Hartmann number M_1 is zero in all the above expressions, we get the earlier results Ref [98], for velocity of blood and Newtonian fluid for pulsatile and steady cases with and without microorganisms in the absence of magnetic effect. The results of Chaturani and Rathod [30] for pulsatile flow of Newtonian fluid in the absence of microorganisms and magnetic effect in non-dimensional form can be obtained from the present model simply by substituting the Hartmann number $M_1 = 0$ in the expression (1.4.5), which gives

$$u(y) = 2\sum_k \left\{ \frac{\alpha^2 e^{i(nt+\theta)}}{\left[k(k^2 + i\alpha^2) \right]} \right\} \frac{J_0(ky)}{J_1(k)} \tag{1.4.6}$$

Further, the expression (1.4.6) will reduce to the expression for Newtonian fluid in the dimensional form and is given by the equation

$$w(y) = \sum_k \frac{2MR^2 e^{i\theta}}{\mu k^3} \frac{J_0(ky)}{J_1(k)} \tag{1.4.7}$$

The velocity expression (1.4.7) is exactly same as that of Ref [31] (equation (1.4.5)). The velocity profiles obtained from this expression are in good agreement with the experimental results of Bugliarello and Sevilla [32].

Table-1.8: *Comparison of velocity profiles*

Y	Present			Expeimental [Bugliarello & sevilla (1970)]
	M = 76.0 $\bar{\alpha}$ = 0.174	M = 67.5 $\bar{\alpha}$ =0.184	M = 52.7 $\bar{\alpha}$ =0.209	
0.0	24.96	25.02	24.99	25.00
0.2	23.46	23.46	23.46	24.00
0.4	19.10	19.13	19.13	20.00
0.6	14.15	14.17	14.17	16.00
0.8	7.03	7.04	7.04	7.50
1.0	0.00	0.00	0.00	0.00

The dimensional velocity expression for steady flow of blood in the absence of magnetic effect can be obtained by setting M_1 = 0 in the expression (1.4.2) as,

$$w(y) = \sum_k \frac{2MR^2 \bar{\alpha}^2 e^{i\theta}}{\mu k(k^4 + \bar{\alpha}^2 k^2)} \frac{J_0(ky)}{J_1(k)} \tag{1.4.8}$$

The velocity profiles obtained from expressions (1.4.8) are in good agreement with the experimental velocity profiles of Ref [32] and Bugliarello et at [33] respectively. The comparison of these velocity profiles have been shown through Table.1.8 and figure 1.7 respectively. It can be seen that the velocity profiles obtained from the present model are in close agreement with that of experimental one.

The velocity profiles for different values of $\bar{\alpha}$ ($\bar{\alpha}^2 = 2,4$), α^2 ($\alpha^2 = 4,8$) and nt (b=1, β =0.2, θ = 15°, K=2.4, ϕ=0.5**)** have been shown through figures for both blood and microorganisms. From figures (1.1.1, 1.1.2, 1.1.3, 1.1.4) it is clear that the velocity profile for blood and microorganisms is parabolic upto 75^0 and the reverse flow start as nt increases. With and without Hartmann number M_1 = {0, 5, 10}, It is observed that for different values of M_1 ($M_1 = 0,5$) there is much difference in both velocities.

From figure-1.2, it has observed that the velocity of blood and microorganisms decrease as the Hartmann number is increased. Here the couple-stress parameter $\bar{\alpha}$ is increased from $\bar{\alpha} = 2$ to 4. In figure-1.3, the velocity curve is drawn for fixed value of couple-stress parameter and for different values of Reynolds' number and Hartmann number. The velocity flow for blood and microorganisms decrease. From fig-1.4, it is been noticed that as mass concentration 'b' increased the velocity of blood is more compared to the velocity of microorganisms. From fig-(1.5.1, 1.5.2) the velocity flow for blood and microorganisms decrease. With Hartmann number M_1 increases and the velocity flow for blood and microorganisms increases, as Stenosis δ and Hartmann number M_1 increases.

It has confirmed from figures 1.6 and 1.7 that the flow rate is directly proportional to pulsatile Reynolds number and the couple-stress parameter. The flow rate is directly proportional to the Hartmann number, but for smaller value of couple-stress parameter ($\overline{\alpha} = 2$) and for smaller value of pulsatile Reynolds number ($\alpha^2 = 4$), there is slight difference in flow rate when the Hartmann number M_1 increases from 0 to 5. In this graph pressure gradient curve is also drawn. It is clear from the figure that there is a phase difference between the flow rate curves of blood and there is wider phase difference between the flow rate curves of microorganisms with pressure gradient curve.

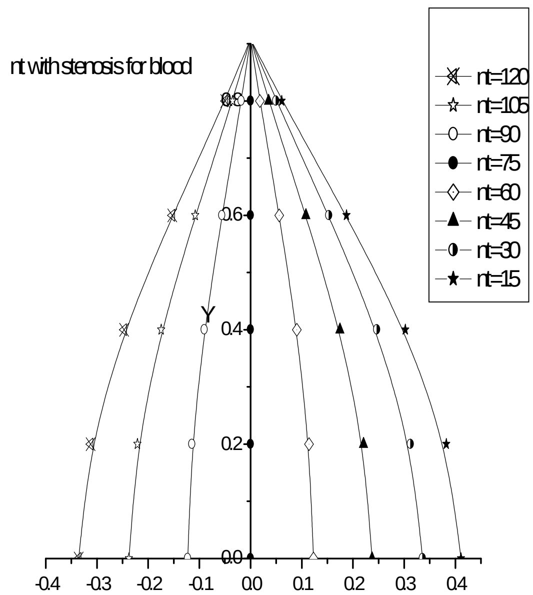


Fig6.1.2 Variation of velocity profile for different values of nt with M_1=5
δ=0.1,β=0.2,θ=15,k=2.4,J_1=0.5202,α=2.0,ϕ=0.5,α=sqrt[4]

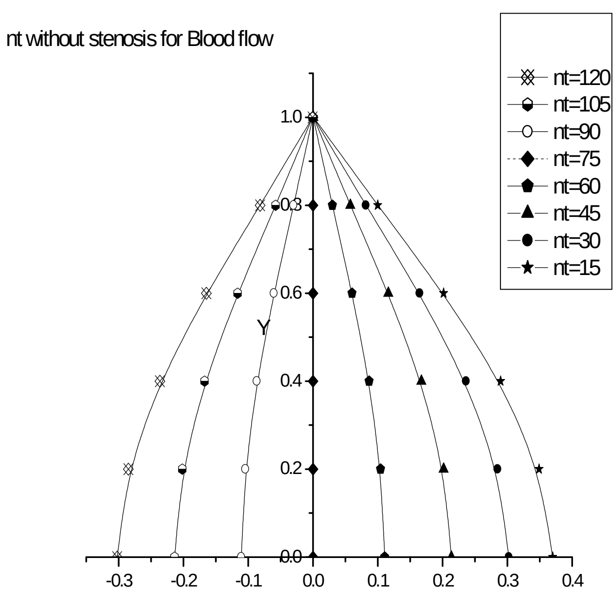


Fig6.1.1 Variation of velocity profile for different values of nt with M_1=5
β=0.2,θ=15,k=2.4,J_1=0.5202,α=2.0,ϕ=0.5,α=sqrt[4]

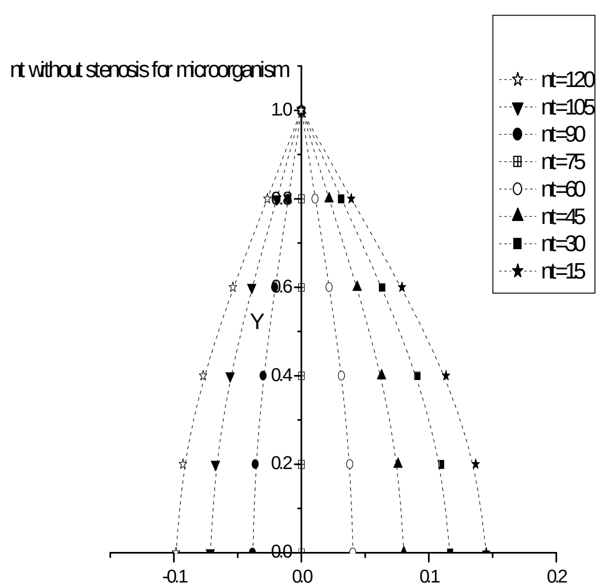


Fig6.1.3 Variation of velocity profile for different values of nt with M_1=5
β=0.2,nt=θ=15,k=2.4,J_1=0.5202,α=4.0,ϕ=0.5,α=sqrt[4]

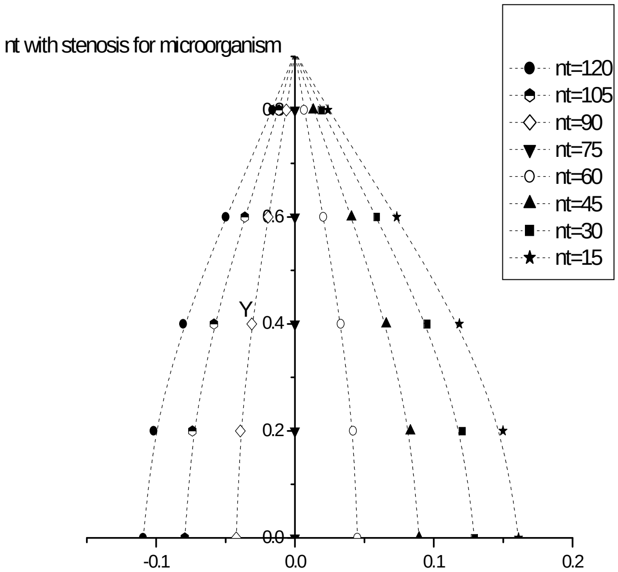


Fig6.1.4 Variation of velocity profile for different values of nt with M_1=5
β=0.2,θ=15,k=2.4,J_1=0.5202,α=4.0,ϕ=0.5,α=sqrt[4],δ=0.1,

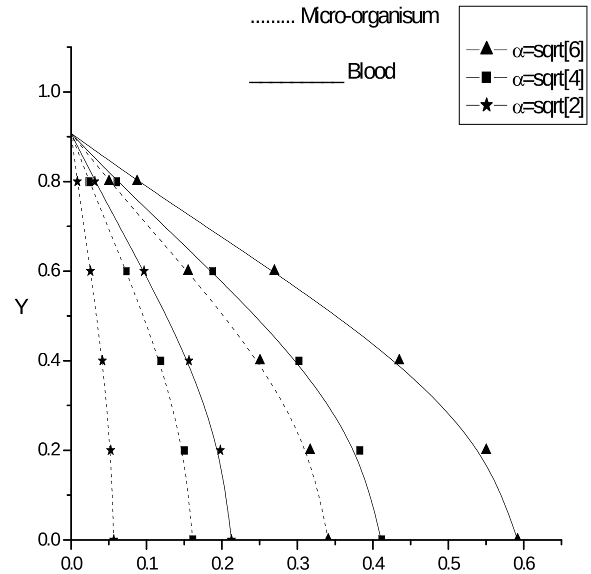


Fig1.3 Variation of velocity profile for different values of α with M_1=5
δ=0.1,β=0.2,nt=θ=15,k=2.4,J_1=0.5202,α=4.0,ϕ=0.5

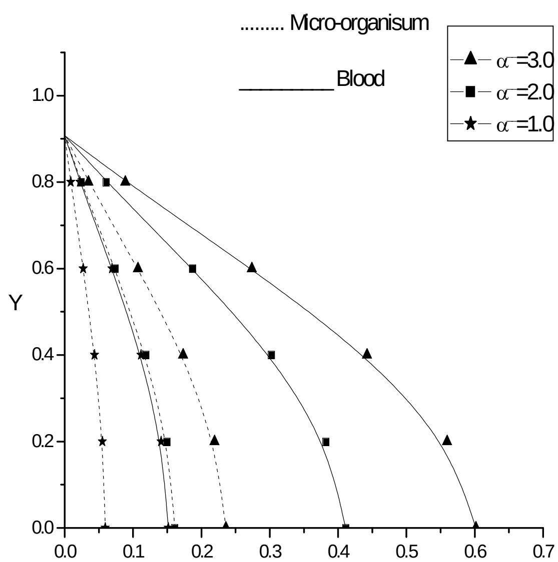


Fig1.2 Variation of velocity profile for different values of α & M_1=5
δ=0.1,β=0.2,nt=θ=15,k=2.4,J_1=0.5202,α=sqrt[4],ϕ=0.5

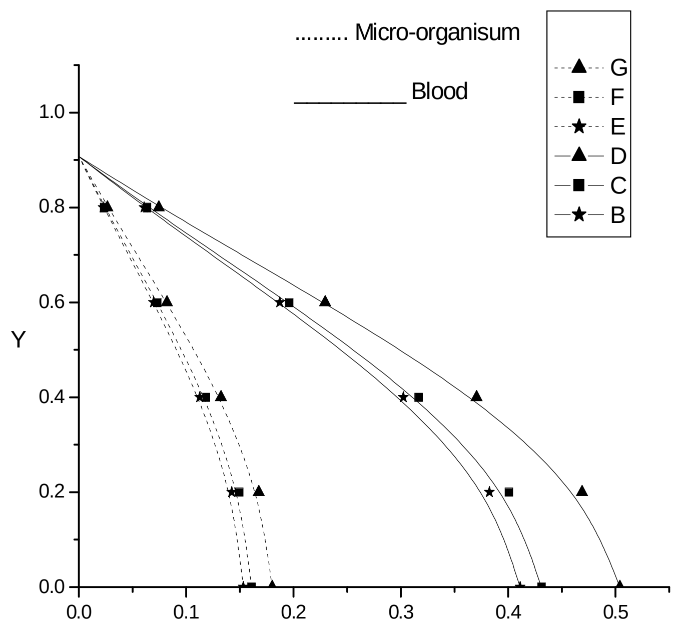


Fig1.4 Variation of velocity profile for different values of b with M_1=5
δ=0.1,α=sqrt[4],nt=θ=15,k=2.4,J_1=0.5202,α=4.0,ϕ=0.5

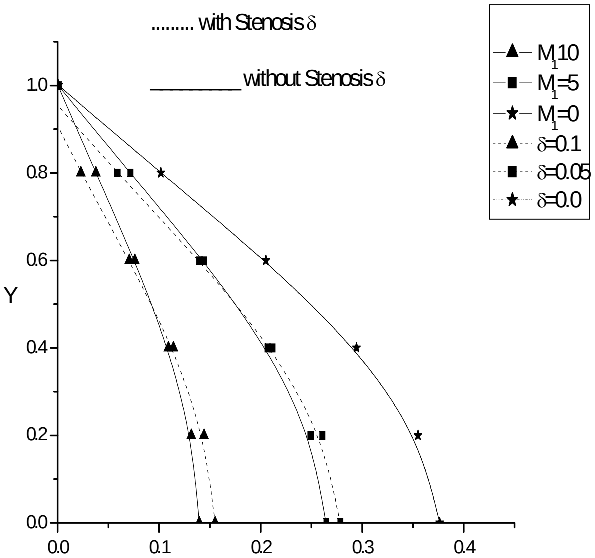
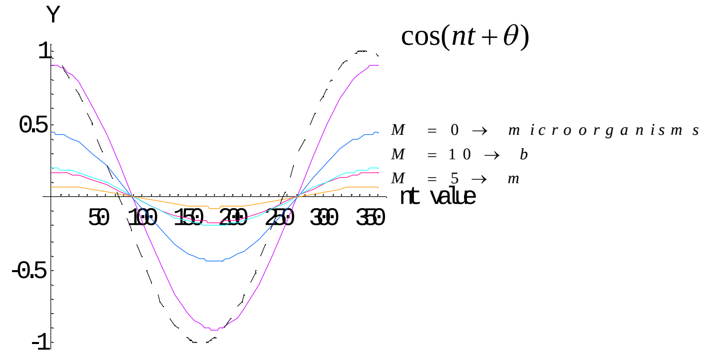


Fig 1.5.1 Variation of velocity profile for different values of δ and M_1

α=sqrt[4],β=0.2,nt=θ=15,k=2.4,J_1=0.5202,α=4.0,φ=0.5



(b=1, β =0.2, φ =15°, θ =15°, $\bar{\alpha}^2$ = 2, K=2.4, g= 9.8, ϕ =0.5, J_1=0.5202, α^2 =4)

Fig 1.6 Variation of flow rate Q with nt and M for blood and Microorganism

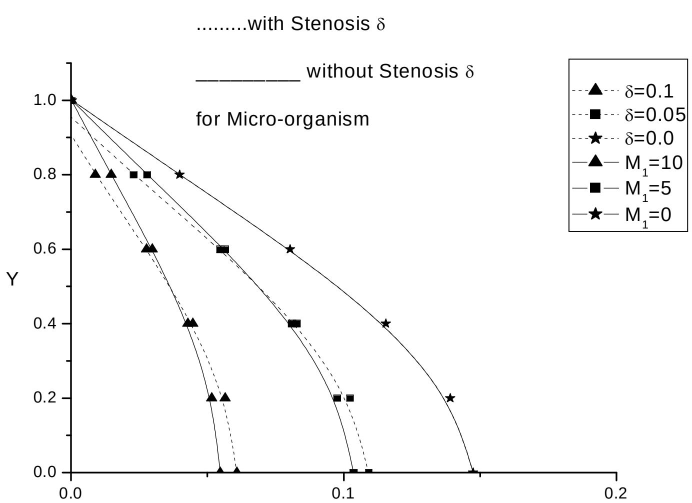
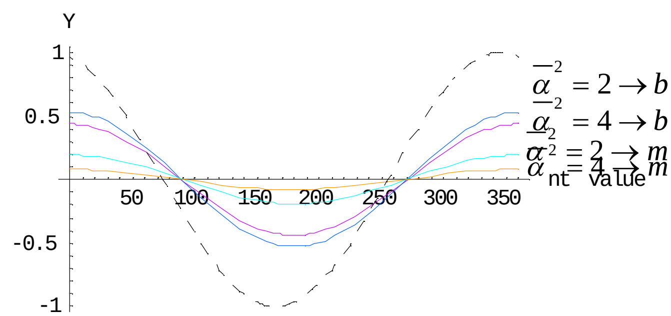


Fig 1.5.2 Variation of velocity profile for different values of δ & M_1

α=sqrt[4],β=0.2,nt=θ=15,k=2.4,J_1=0.5202,α=4.0,φ=0.5



(b=1, β =0.2, φ =15°, θ =15°, M=5, K=2.4, g= 9.8, ϕ =0.5, J_1=0.5202, α^2 =4)

Fig 1.7 Variation of flow rate Q with nt and $\bar{\alpha}$ for blood and Microorganism

Reference:

[1] Bali, R. and Awasthi, U. Effect of magnetic field on the resistance to blood flow through stenotic artery. Applied Mathematics and Computation, Vol. 188, pp. 1635-1641,2007.

[2] Chakravarty, S. Effects of stenosis on the flow behaviour of blood in an artery.International Journal of Engineering Science, Vol. 25, No. 8, pp. 1003-1016,1987.

[3] Buchanan Jr., J. R., Kleinstreuer, C. and Corner J. K. Rheological effects on pulsatile hemodynamics in a stenosed tube. Computers & Fluids, Vol. 29, pp. 695-724, 2000.

[4] Deplano, V. and Siouffi, M. Experimental and Numerical study of pulsatile flowthrough a tapered artery with stenosis. Journal of Biomechanics, Vol. 32, pp. 1081-1090, 1999.

[5] Haldar, K. Effects of the shape of stenosis on the resistance to blood flow through an artery. Bulletin of Mathematical Biology, Vol. 47, No.4, pp. 545-550, 1985.

[6] Mandal, P. K. An unsteady analysis of non-Newtonian blood flow through tapered arteries with a stenosis. International Journal of Non-Linear Mechanics, Vol. 40, pp.151-164, 2005.

[7] Chakravarty, S. and Mandal, P. K. Mathematical modeling of blood flow through an overlapping arterial stenosis. Mathl. Comput. Modelling, Vol. 19, No. 1, pp. 59-70, 1994.

[8] Ismail, Z., Abdullah, I., Mustapha, N. and Amin, N. A power-law model of blood flow through a tapered overlapping stenosed artery.Applied Mathematics and Computation, Vol. 195, No. 2, pp. 669-680, 2007.

[9] Hernan, A. and Gonzalez, R. Numerical implementation of viscoelastic blood flow in a simplified arterial geometry. Medical Engineering and Physics, Vol. 29, pp. 491-496,2007.

[10] Katiyar, V. K. and Basavarajappa, K.S. Blood flow in the cardiovsular system in the presence of magnetic field. International Journal of Applied Science and Computations, Vol. 9, No. 3, pp. 118-127, 2002.

[11] Liepsch, D. An introduction to biofluid mechanics – basic models and applications. Journal of Biomechanics, Vol. 35, pp. 415-435, 2002.

[12] Liu, G. T., Wang, X. J., Ai, B. Q. and Liu, L. G. Numerical study of pulsatile flow through a tapered artery with stenosis. Chinese Journal of Physics, Vol. 42, No. 4-I, pp. 401-409, 2004.

[13] Prakash, J., Makinde, O. D. and Ogulu, A. Magnetic effect on oscillary blood flow in a constricted tube. Botswana Journal of Technology April , pp. 45-50,2004.

[14] Tashtoush, B. and Magableh, A. Magnetic field effect on heat transfer and fluid flow charecteristics of blood flow in multi-stenotic arteries.Heat and Mass Transfer, Vol. 44, No. 3, pp. 297-304, 2008.

[15] Tzirtzilakis, E. E. A mathematical model for blood flow in magnetic field.Physics of Fluids, Vol. 17:077103, pp. 1-15, 2005.

[16] Sud, V. K. and Sekhon, G. S. Blood flow through the human arterial system in the presence of a steady magnetic field. Phys. Med. Biol.Vol. 34, No. 7, pp. 795-805,1989.

[17] Chester, W. The effect of a magnetic field on Stokes flow in a conducting fluid. J. Fluid Mech,.Vol. 3, pp. 304-308, 1957.

[18] Jauchem, J.R. Exposure to extremely-low-frequency electromagnetic fields and radiofrequency radiation: cardiovascular effects in humans,Review Int Arch Occup Environ Health, Vol. 70, pp. 9-21.1997.

[19] Kolin.A, Electromagnetic flow meter: principle of method and its applications to blood flow measurement. Proc. Soc. Exptl. Biol. Med. 35, 53 (1936).

[20] Korchevskii E.M and Marochnik L.S., Magneto hydrodynamic version of movement of blood. Biofizica, 10(2), 371-373 (1965).

[21] Mathews, P., Fracture healing by pulsating electromagnetic fields- a study. M.S.Dessertation G.U.G. (Nov. 1988).

[22] Bathnagar and Rakesh, Non-Newtonian fluid flow between co-axial rotating disks: effects of an externally applied magnetic field. Mat-Apl Compt. 2, 171-191 (1983).

[23] Ramachandrarao and Deshikachar K.S., Physiological type flows in a circular pipe in the presence of a transverse magnetic field. Indian Insti. Sci., 68, 247-260, (july-Aug 1988).

[24] Shastri, D.V.S and Seetaramaswamy R, MHD dustry viscous flow through a circular pipe. Indian J. Pure Appl. Math, 13:7, 811-817 (July 1982).
[25] Debnath and Ghosh, On unsteady hydromagnetic flows of a dusty fluid between two oscillating plates. Appl. Sc., Res., 45(4), 353-365 (1988).
[26] Kaur and Sharma: Unsteady MHD flow of a dusty viscous fluid in an annulus bounded by two co-axial cylinders under the influence of exponential pressure gradient when the outer cylinder is moving with time dependent velocity. J. Maulana Azad College Tech, 18, 73-82,(1985).
[27] V. P.Rathod and Shakera Tanveer Pulsatile Flow of Couple Stress Fluid through a Porous medium with Periodic Body Acceleration and Magnetic Field. Bull. Malays. Math. Sci. Soc. (2) 3 2(2) 245- 259,(2009).
[28] Kinouchi, Y., Yamaguchi, H., and Tenforde, T.S. Theoretical analysis of magnetic field interactions with aortic blood flow. Bioelectromagnetics, Vol. 17, pp. 21-32, 1996.
[29] Womersely, J.R, Method for the calculation of velocity, rate of flow and viscous drag in arteries when the pressure gradient is known, J. Physiol., 127, 553-563.
[30] Chaturani P and Rathod V.P., A theoretical model for pulsatile blood flow with application to cerebrovascular diseases. Jour. Neurological research, 3, 289-303, (1981).
[31] V. P. Rathod and Gayatri, , Effect of magnetic field on two layer model of Pulsatile blood flow with micro-organisms, Bull. Pure Appl. Sci. Sect. E Math. Stat. 19 no. 1 1–13, (2000).
[32] Bugliarello, G. and Sevilla, J. “Velocity distribution and other characteristics of steady and pulsatile blood flow in fine glass tubes”. Biorheology, **7**, 85-107 (1970).
[33] Bugliarello, G. and Hayden, J.W. “High speed micro cinematographic studies of blood flow in vitro”. Science, 138, 981-983(1962).