

Pulsatile Flow of Blood with Volume Fraction of Micro-Organisms and Gravity Effect in The Presence of Transverse Magnetic Field.

Dr. Seema Jabeen

Department of Mathematics Khaja Bandanawaz University

DOI: <https://doi.org/10.51583/IJLTEMAS.2025.140500024>

Received: 17 May 2025; Accepted: 19 May 2025; Published: 03 June 2025

Abstract: The effect of static magnetic field on the pulsatile flow of blood with volume fraction of micro-organisms and gravity effect has been studied. The aim of the present investigation is to suggest how best the magnetic field can be applied in the treatment of cardio-vascular diseases, in healing of fractures, infections etc. it has been observed that the increase in magnetic field will decrease the velocities and in turn the flow-rate. In the absence of magnetic field, the results will coincide with the results of our earlier work and are in good agreement with theoretical and experimental results. As the magnetic effect increases, the velocities of blood and microorganisms decrease. Hence, the present model helps to control various types of cardio-vascular diseases with the application of magnetic field, which will help in deaccelerating the velocity of blood.

Keywords: dusty fluid, blood flow, pulsatile flow, magnetic field, volume fraction, Gravity, microorganisms.

I. Introduction:

It is known that blood is an electrically conducting fluid. So the flow of blood in human system can be deaccelerated 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 year 1936 Kolin [2] 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 [3] for the prevention and rational therapy of arterial hypertension apparently of no less importance is close study of hydromagnetics 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 (electromagnetic 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 at least 10hrs/day, effective magnetic field are all very much essential in acquiring good results Mathews [4], Bhatnagar and Rakesh [5] 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 [6] have studied the effect of transverse magnetic field on physiological type of flow in uniform circular pipe. Shastri and Seetaramaswamy [7] 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 [8] 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 periods. 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 [9]. Rathod and Shakera [14] 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.

The aim of the present investigation is to suggest how best the magnetic field can be applied in the treatment of cardio-vascular diseases, in healing of fractures, infections etc., through a mathematical model. Analytical expressions are obtained for velocity and flow rates for both blood and microorganisms.

Formulation of The Problem:

We have considered the one-dimensional motion for a dusty unsteady, viscous, incompressible, electrically conducting couple-stress fluid (we consider blood as a 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 dust particle (assuming dusty particles as microorganisms).

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

$$(1-\phi)\rho\left\{\frac{\partial U}{\partial t} + (U \cdot \nabla_1)U\right\} = (1-\phi)\left\{-gradP + \mu\nabla_1^2 U - n\nabla_1^4 U\right\} + KN(V-U) + g \sin \psi - \frac{\sigma B_0^2 U}{\rho} \quad (1)$$

$$\left\{\frac{\partial V}{\partial t} + (V \cdot \nabla_1)V\right\} = \phi\left\{-gradP + \mu\nabla_1^2 U - n\nabla_1^4 U\right\} + \frac{K}{m}(U-V) + g \sin \psi \quad (2)$$

$$divU = 0 \quad (3)$$

$$\frac{\partial N}{\partial t} + div(NV) = 0 \quad (4)$$

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 ($6\pi\mu\epsilon_1$, ϵ_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 $\nabla_1^2 = \left(\left(\frac{1}{r}\right)\frac{\partial}{\partial r}\right)\left(r\frac{\partial}{\partial r}\right)$

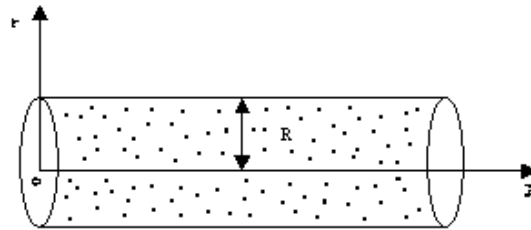


Figure 1. Schematic diagram for flow geometry

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) and (2) reduces to

$$(1-\phi)\rho\frac{\partial w_1}{\partial t} = (1-\phi)\left[-\frac{\partial p}{\partial z} + \mu\nabla_1^2 w_1 - \eta\nabla_1^4 w_1\right] + KN(w_2 - w_1) + g \sin \psi - \frac{\sigma B_0^2 w_1}{\rho} \quad (5)$$

$$\frac{\partial w_2}{\partial t} = \phi\left[-\frac{\partial p}{\partial z} + \mu\nabla_1^2 w_1 - \eta\nabla_1^4 w_1\right] + \frac{K}{m}(w_1 - w_2) + g \sin \psi \quad (6)$$

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

The boundary conditions are

$$\begin{aligned} w_1, w_2 \text{ and } \nabla_1^2(w_1, w_2) & \text{ are all finite} & \text{at } r = 0 \\ w_1 = 0 = w_2 \text{ and } \nabla_1^2(w_1, w_2) & = 0 & \text{at } r = R \end{aligned} \quad (7)$$

Introduce the non-dimensional quantities,

$$u = \frac{w_1 n \rho}{M}, \quad v = \frac{w_2 n \rho}{M}, \quad y = \frac{r}{R}, \quad g^* = \frac{g \rho R^2 n}{\mu M}, \quad \phi^* = \frac{\phi}{b}$$

$$\frac{\partial^2}{\partial r^2} + \frac{1}{r} \frac{\partial}{\partial r} = \frac{1}{R^2} \left[\frac{\partial^2}{\partial y^2} + \frac{1}{y} \frac{\partial}{\partial y} \right] = \frac{1}{R^2} \nabla^2 \quad (8)$$

And assuming Womersley [10] type of pressure gradient of the form

$$-\frac{\partial p}{\partial z} = M \cos(nt + \theta) \quad (9)$$

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,

$$u = u_0(y)e^{int} \\ v = v_0(y)e^{int} \quad (10)$$

With the help of equations (8), (9),(10) the equations (5) and (6) reduce to

$$\nabla^4 u_0 - \bar{\alpha}^2 \nabla^2 u_0 + Xu_0 + \bar{\alpha}^2 M_1^2 u_0 = \frac{g \bar{\alpha}^2 \sin \psi (2 + i \alpha^2 \beta)}{1 + i \alpha^2 \beta (1 - \phi b)} + \bar{\alpha}^2 \alpha^2 e^{i\theta} \quad (11)$$

$$v_0 = \frac{-\phi \beta}{\bar{\alpha}^2 b (1 + i \alpha^2 \beta)} \left\{ \nabla^4 u_0 - \bar{\alpha}^2 \nabla^2 u_0 - \bar{\alpha}^2 \alpha^2 e^{i\theta} \right\} + \frac{u_0}{1 + i \alpha^2 \beta} + \frac{\beta g \sin \psi}{b (1 + i \alpha^2 \beta)} \quad (12)$$

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, $M_1 = B_0 R \sqrt{\frac{\sigma}{\mu}}$ Hartman number, $i = (-1)^{1/2}$, $\nu = \frac{\mu}{\rho}$ is kinematic viscosity.

The modified boundary conditions are

$$u_0, v_0 \text{ and } \nabla^2(u_0, v_0) \text{ are all finite at } y = 0 \\ u_0 = 0 = v_0 \text{ and } \nabla^2(u_0, v_0) = 0 \text{ at } y = 1 \quad (13)$$

$$\text{Where } \nabla_1^2 = \frac{1}{R^2} \left[\frac{1}{y} \frac{d}{dy} \left[y \frac{d}{dy} \right] \right] = \frac{1}{R^2} \nabla^2 \quad (14)$$

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

$$\bar{u}_0(k) = \int_0^1 u_0(y) y J_0(ky) dy \quad (15)$$

Where k's are the positive roots of the equation

$$J_0(k) = 0 \quad (16)$$

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

The Inverse transform is given by

$$\bar{u}_0(y) = 2 \sum_k \bar{u}_0(k) \frac{J_0(ky)}{J_1^2(k)} \quad (17)$$

The summation is taken over all the positive roots of (16). Applying the Hankel transform (15) and inverse transform (17) to the equation (11) and by using (10) and boundary conditions (13), we get the velocity of blood in non-dimensional form in the presence of microorganisms and magnetic effect as,

$$u(y, t) = 2 \sum_k \left\{ \frac{\bar{\alpha}^2 \alpha^2 e^{i(nt+\theta)} + L}{\left[k(k^4 + \bar{\alpha}^2 k^2 + X + \bar{\alpha}^2 M_1^2) \right]} \right\} \frac{J_0(ky)}{J_1(k)} \quad (18)$$

$$\text{Where } L = \frac{g \bar{\alpha}^2 \sin \psi e^{\text{int}} (2 + i \alpha^2 \beta)}{1 + i \alpha^2 \beta (1 - \phi b)} \quad \& \quad X = \frac{i \bar{\alpha}^2 \alpha^2 [(1 - \phi)(1 + i \alpha^2 \beta) + b]}{1 + i \alpha^2 \beta (1 - \phi b)} \quad (19)$$

Using the equation (18) and (10) in (12), we get the velocity for microorganisms in non-dimensional form as

$$v(y, t) = 2 \sum_k \left[\left(\frac{\beta g \sin \psi}{b(1 + i \alpha^2 \beta)} - M^* L \right) \frac{J_0(ky)}{kJ_1(k)} + u(y, t) \left(M^* X + \frac{1}{1 + i \alpha^2 \beta} \right) \right] \quad (20)$$

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

Expression for flow rate Q is defined as,

$$Q = 2\pi \int_0^1 y(u(y, t), v(y, t)) dy \quad (21)$$

Expressions for flow rate for blood and microorganisms respectively are obtained from expressions (18), (20) and (21)

$$Q_u = 4\pi \sum_k \left\{ \frac{(\bar{\alpha}^2 \alpha^2 e^{i(nt+\theta)} + L)}{\left\{ k^2 (k^4 + \alpha^2 k^2 + X + \bar{\alpha}^2 M_1^2) \right\}} \right\} \quad (22)$$

$$Q_v = 4\pi \left[\sum_k \frac{1}{k} \left\{ \left(\frac{\beta g \sin \psi}{b(1 + i \alpha^2 \beta)} - M^* L \right) + \frac{\bar{\alpha}^2 \alpha^2 e^{i(nt+\theta)} + L}{k(k^4 + \bar{\alpha}^2 k^2 + X + \bar{\alpha}^2 M_1^2)} \left(M^* X + \frac{1}{1 + i \alpha^2 \beta} \right) \right\} \right] \quad (23)$$

The general apparent viscosity is defined by,

$$\mu = \frac{\pi R^4 M e^{i(nt+\theta)}}{8Q} \quad (24)$$

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

$$\mu_b = \frac{\mu e^{i\theta}}{32(\bar{\alpha}^2 \alpha^2 e^{i\theta} + L)} \sum_k k^2 (k^4 + \bar{\alpha}^2 k^2 + X + \bar{\alpha}^2 M_1^2) \quad (25)$$

$$\mu_m = \frac{\mu e^{i\theta}}{32 \sum_k \frac{1}{k} \left[\left(\frac{\beta g \sin \psi}{b(1+i\alpha^2 \beta)} - M^* L \right) + \frac{\bar{\alpha}^2 \alpha^2 e^{i\theta} + L}{k(k^4 + \bar{\alpha}^2 k^2 + X + \bar{\alpha}^2 M_1^2)} \left(M^* X + \frac{1}{1+i\alpha^2 \beta} \right) \right]} \quad (26)$$

II. 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-Newtonian fluid i.e., blood

Newtonian fluid

In the presence and absence of microorganisms with or without magnetic effect by simple and proper substitutions.

The expression (18) 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 (19)).

$$u(y) = 2 \sum_k \left\{ \frac{\bar{\alpha}^2 \alpha^2 e^{i(nt+\theta)} + 2g\bar{\alpha}^2 \sin \psi e^{\text{int}}}{\left[k(k^4 + \bar{\alpha}^2 k^2 + i\bar{\alpha}^2 \alpha^2 + \bar{\alpha}^2 M_1^2) \right]} \right\} \frac{J_0(ky)}{J_1(k)} \quad (27)$$

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

$$w(y) = \sum_k \frac{2MR^2 \bar{\alpha}^2 e^{i\theta}}{\mu k(k^4 + \bar{\alpha}^2 k^2 + \bar{\alpha}^2 M_1^2)} \frac{J_0(ky)}{J_1(k)} \quad (28)$$

In equation (18), if $\bar{\alpha} \rightarrow \infty$, then it reduces to the velocity for pulsatile Newtonian fluid with microorganisms and magnetic effect as follow.

$$u(y) = 2 \sum_k \left\{ \frac{\alpha^2 e^{i(nt+\theta)} + L}{\left[k(k^2 + X + M_1^2) \right]} \right\} \frac{J_0(ky)}{J_1(k)} \quad (29)$$

By substituting $n = 0$ in the above expression (29), it reduces to the expression of steady Newtonian fluid in the dimensional form, without microorganisms under magnetic effect as,

$$w(y) = \sum_k \frac{2MR^2 e^{i\theta}}{\mu k(k^2 + M_1^2)} \frac{J_0(ky)}{J_1(k)} \quad (30)$$

With $m = 0$, the expression (29) will reduces to the pulsatile flow of Newtonian fluid in te absence of microorganisms along with magnetic effect as,

$$u(y) = 2 \sum_k \left\{ \frac{\alpha^2 e^{i(nt+\theta)} + 2g \sin \psi e^{\text{int}}}{\left[k(k^2 + i\alpha^2 + M_1^2) \right]} \right\} \frac{J_0(ky)}{J_1(k)} \quad (31)$$

When the Hartmann number M_1 is zero in all the above expressions, we get the earlier results (Ref [1]), 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 [12] 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 (31), which gives

$$u(y) = 2 \sum_k \left\{ \frac{\alpha^2 e^{i(nt+\theta)} + 2g \sin \psi e^{\text{int}}}{[k(k^2 + i\alpha^2)]} \right\} \frac{J_0(ky)}{J_1(k)} \quad (32)$$

Further the expression (32) will reduce to the expression for Newtonian fluid in the dimensional form and is given by the equation

$$w(y) = \sum_k \frac{2MR^2 e^{i\theta}}{\mu k^3} \frac{J_0(ky)}{J_1(k)} \quad (33)$$

The velocity expression (33) is exactly the same as that of Ref [1] (equation (31)). The velocity profiles obtained from this expression are in good agreement with the experimental results of Bugliarello and Sevilla [13].

Table-1: 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	0	0	0

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 (28) as,

$$w(y) = \sum_k \frac{2MR^2 \bar{\alpha}^2 e^{i\theta}}{\mu k(k^4 + \bar{\alpha}^2 k^2)} \frac{J_0(ky)}{J_1(k)} \quad (34)$$

The velocity profiles obtained from expressions (34) are in good agreement with the experimental velocity profiles of Ref [1] and Bugliarello et al [13] respectively. The comparison of these velocity profiles has been shown through Table.1 and figure 6 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, $\beta=0.2$, $\varphi=15^\circ$, $\theta=15^\circ$, **K=2.4, $g=0.5$, $\phi=0.5$**) have been shown through figure 1, 2 and 3 for both blood and microorganisms. From figure 1 it is clear that the velocity profile for blood and microorganisms is parabolic upto 75° and the reverse flow start as nt increases. Where as for $M_1 = 5$, the velocity profile for blood and microorganisms is parabolic upto 75° and but there is no reverse flow for microorganisms as nt increases. It is observed that for different values of M_1 ($M_1 = 0, 5$) there is much difference in both velocities.**

From figure 2 it is observed that the velocity of blood and microorganisms decreases as the Hartmann number is increased. Here the couple-stress parameter $\bar{\alpha}$ is increased from $\bar{\alpha} = 2$ to 4. The velocity of blood is parabolic upto 75° , the reverse flow start from 90° onwards. For smaller value of couple-stress parameter and higher value (≥ 8) of Reynolds' number, the velocity is independent of magnetic effect. It has been found that there is a sudden increase in velocity as $\bar{\alpha}$ increased from 2 to 4.

In figure 3 the velocity curve are drawn for fixed value of couple-stress parameter and for different values of Reynolds' number and Hartmann number. The back flow for blood and microorganisms starts from 90° onwards. It is confirmed from figures 4, 5 and 6 that the flow rate is directly proportional to pulsatile Reynolds number and also the couple-stress parameter. The flow rate

is directly proportional to the Hartmann number, but for smaller value of couple-stress parameter ($\alpha = 2$) 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 also wider phase difference between the flow rate curves of microorganisms with pressure gradient curve.

References:

1. V.P.Rathod and Gayatri, pulsatile flow of blood with effect of microorganisms, Application to cardiovascular diseases and its AIDS.
2. Kolin.A, Electromagnetic flow meter: principle of method and its applications to blood flow measurement. Proc. Soc. Exptl. Biol. Med. 35, 53 (1936).
3. Korchevskii E.M and Marochnik L.S., Magneto hydrodynamic version of movement of blood. Biofizika, 10(2), 371-373 (1965).
4. Mathews, P., Fracture healing by pulsating electromagnetic fields- a study. M.S.Dessertation G.U.G. (Nov. 1988).
5. 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).
6. 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).
7. Shastri, D.V.S and Seetaramaswamy R, MHD dusty viscous flow through a circular pipe. Indian J. Pure Appl. Math, 13:7, 811-817 (July 1982).
8. Debnath and Ghosh, On unsteady hydromagnetic flows of a dusty fluid between two oscillating plates. Appl. Sc., Res., 45(4), 353-365 (1988).
9. 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).
10. Womersley, J.R., Method for the calculation of velocity, rate of flow and viscous drag in arteries when the pressure gradient is known. J. Physio, 127, 553-563, (1955).
11. Tranter, Editor B.L. Wornship, Integral transforms in mathematical physics, infinite transforms 88, 2nd edition, London, 1856.

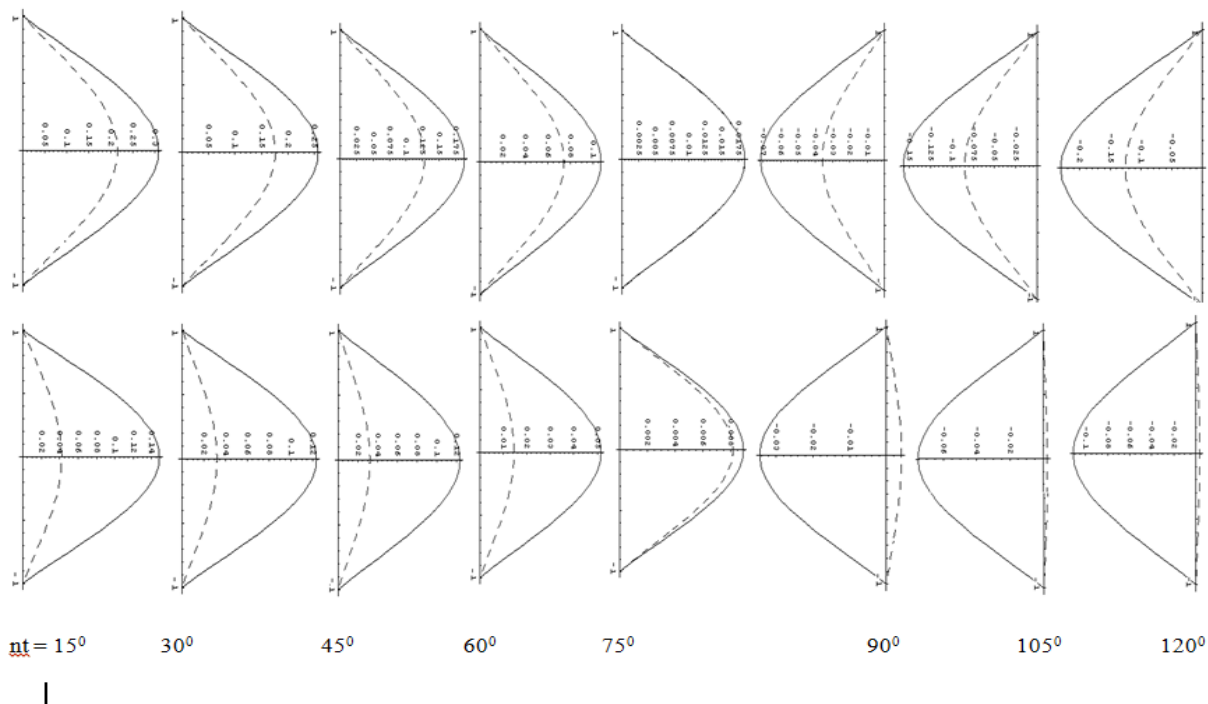


Fig 1. Velocity variation with nt , $M=0, 5$
($b=1, \beta=0.2, \varphi=15^\circ, \theta=15^\circ, \alpha^2=4, K=2.4, g=0.5, \phi=0.5, \alpha^2=2$)
————— Blood - - - - - Microorganisms

12. 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).

13. Bugliarello, G. and Sevilla, J., Velocity distribution and other characteristics of steady and pulsatile blood flow in fine glass tubes. Jour Biorheology, 7, 85-107, (1970).
14. Rathod and Shakera, Pulsatile flow of couple stress fluid through a porous medium with a periodic body acceleration and magnetic field. Bull. Malays. Math. Sci. Soc. (2) 32(2), 245-259, (2009).

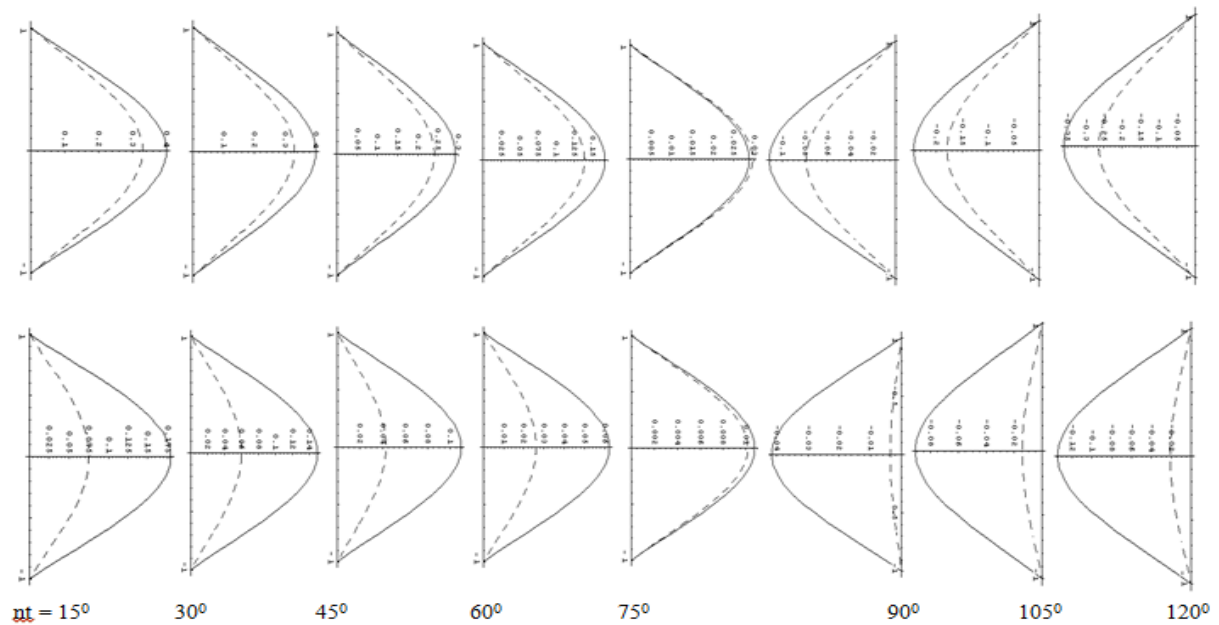


Fig 2. Velocity variation with nt , $M=0.5$
($b=1$, $\beta=0.2$, $\varphi=15^\circ$, $\theta=15^\circ$, $\alpha^2=4$, $K=2.4$, $g=0.5$, $\phi=0.5$, $\bar{\alpha}^2=4$)
—— Blood - - - - - Microorganisms

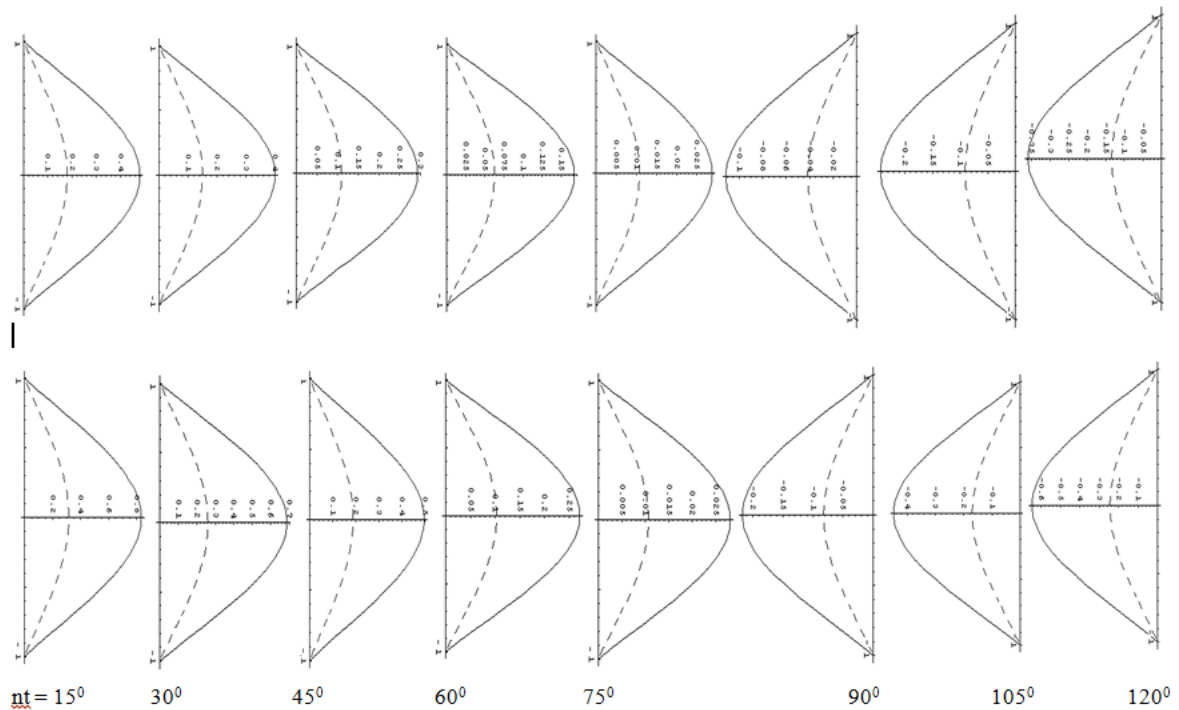


Fig 3 Velocity variation of blood with nt , $\alpha^2=4, 8$
($b=1$, $\beta=0.2$, $\varphi=15^\circ$, $\theta=15^\circ$, $K=2.4$, $g=0.5$, $\phi=0.5$, $\bar{\alpha}^2=4$)
—— $M_1=0$ - - - - - $M_1=5$

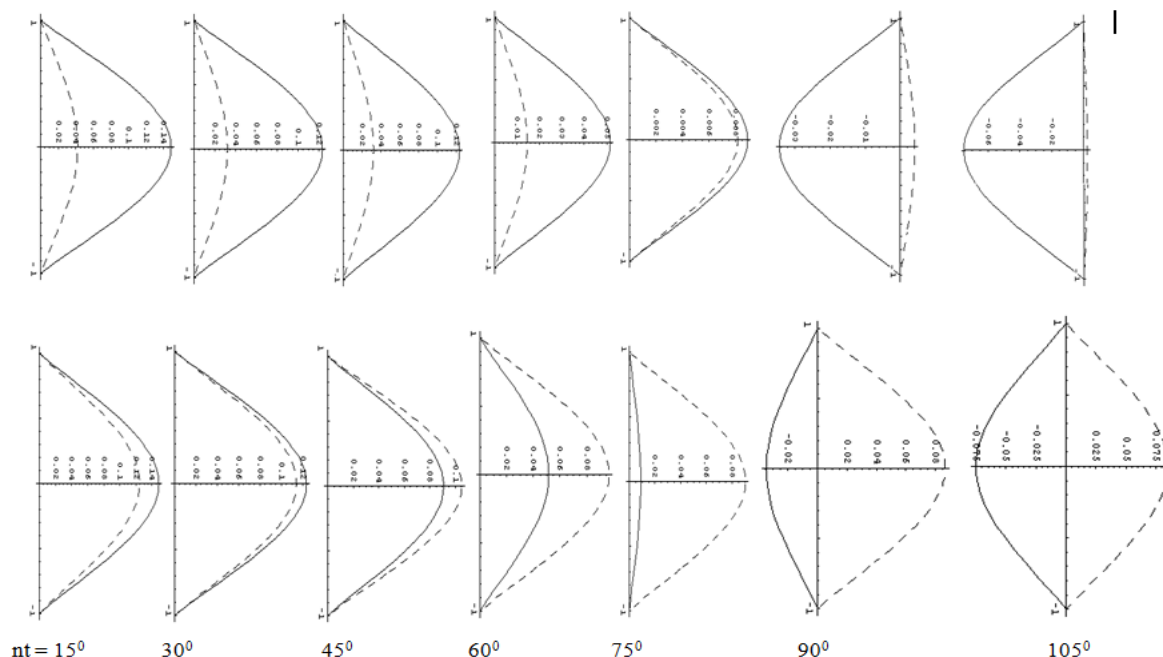


Fig 4. Velocity variation with nt , $g = 0, 1.5$
($b=1, \beta=0.2, \phi=15^\circ, \theta=15^\circ, \alpha^2=4, K=2.4, M=5, \phi=0.5, \bar{\alpha}^2=2$)
—— Blood - - - - - Microorganisms

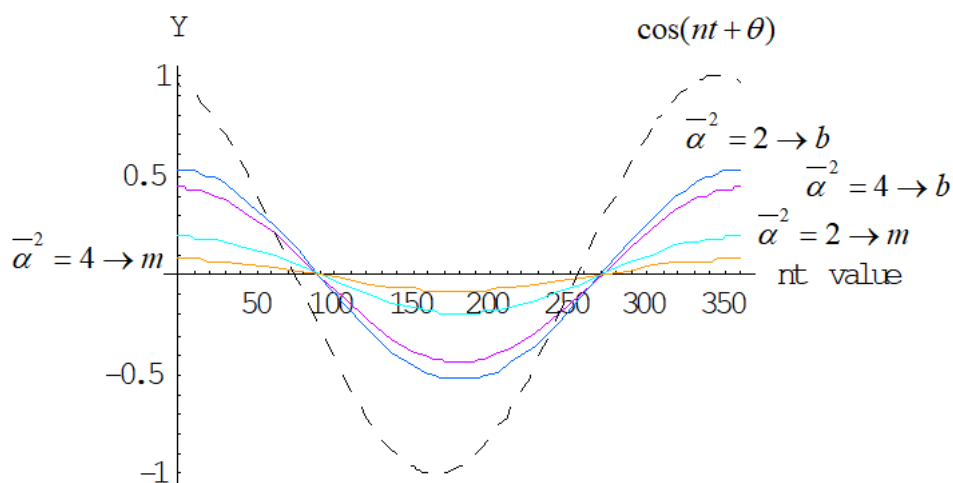


Fig 6 Variation of flow rate Q with nt and $\bar{\alpha}$ for blood and Microorganism
($b=1, \beta=0.2, \phi=15^\circ, \theta=15^\circ, M=5, K=2.4, g=9.8, \phi=0.5, J_1=0.5202, \alpha^2=4$)
($b=1, \beta=0.2, \phi=15^\circ, \theta=15^\circ, \bar{\alpha}^2=2, K=2.4, g=9.8, \phi=0.5, J_1=0.5202, \alpha^2=4$)