The Influence of Heat Transfer on Two Phase Visco –Elastic Fluid Model for MHD oscilliatory Blood Flow in Stenosed Arteries

M.Chitra[1] , R.Bhaskaran[2]

[1]Associate professor, [2]Research scholar, Department of Mathematics,

Thiruvalluar University, Vellore-632 115, Tamilnadu, India

Email: [1]chitratvu@gmail.com, [2]bhasswathi@yahoo.com

Abstract

The present study deals with a mathematical model describing the unsteady two phase visco-elastic blood flow in stenosed artery with heat transfer. The geometry of the stenosed arterial segment possessing constriction in two-phase appearing in the diseased arteries causing malfunction of the cardiovascular system is formulated mathematically. This model consists of a core surrounded by a peripheral layer. We assume that the value of the shear stress is high so that the nature of blood can be modelled as Newtonian in both erythrocytes suspended core region as well as RBC-depleted plasma region. The non linear unsteady flow phenomena is governed by the Navier-stokes equation while heat transfer is controlled by the heat conduction equation. All these equations together with the appropriate boundary conditions describing the biomechanical problem. We derive a mathematical model for the mixed conduction problem of two-phase visco elastic blood flow as non-linear partial differential equations are solved by Bessel equation and get the solutions for the velocity(u) , temperature(θ), volumetric flow rate (Q) and wall shear stress (τ)with various parameters like Peclet number , Grashof number . The influences of the stenosis, the arterial wall motion and the unsteady behaviour of the system in terms of the heat transfer on the blood flow in the entire arterial segment are highlighted through graphs.

Key words : Visco elastic fluid , Stenosed arteries ,Two-phase flow , Bessel function ,

Heat transfer, Peripheral plasma layer.

1.Introduction

The heat transfer on visco elastic blood flow behaviour in the stenosed artery is quite different than normal arteries. Body heat produced by the skeletal muscle is removed by the convection heat and transport of heat by the circulatory system makes heat transfer in the body through blood flow. The heat transfer on the motion of the blood in a stenosed artery can affects a man in different ways, by disturbing thermo regulation, it causes heat syncope, heat cramps, heat edema, heat stroke, confusion, some time unconsciousness and the body temperature increases very rapidly, the central nervous system and circulatory system are impacted. When fatty substance, cholesterols, cellular waste products, calcium, and fibrin build up in the inner lining of an artery which build up that results is called stenosis. The arteries narrowed by the development of atherosclerotic plaques that protrude into the lumen, resulting arterial stenosis. When an obstruction developed in artery, one of the most serious consequences is the increased resistance and associated reduction of the blood flow to the particular bed supplied by the artery. Thus, the presence of a stenosis leads to the serious circulatory disorder. The intimal thickening of an artery is the early process in the formation of atherosclerosis which is a one of the most wide spread diseases in human leading to the malfunction of the cardiovascular system and the present of a constriction in the artery disturbs the normal blood flow causes arterial diseases. Visco elastic blood flow through a stenosed artery results in the elastic deformation of the artery and in return the deformation affects the flow behaviour which affect cardiovascular system

Several researchers studied the existence of two phase fluid in the core region and peripheral region has some significance in the blood flow characteristics of the arterial system [6,9,13,14,15,16]. Ponalagusamy et al. [1] studied influence of magnetic field and heat transfer on two-phase fluid model for oscillatory blood flow in arterial stenosis. Bhavya Tripathi et al. [2] discussed the flow characteristics of MHD oscillatory two-phase blood flow through a stenosed artery with heat and mass transfer. Ogulu et al. [10] studied simulation of heat transfer on an oscillatory blood flow in an indented porous artery. Zaman et al. [11] discussed heat and mass transfer to blood flowing through a tapered overlapping stenosed artery. Misra et al [12] pointed out that The MHD oscillatory channel flow of heat and mass transfer in physiological fluid in presence of chemical reaction. Maithili Sharan et al. [4] discussed two-phase model for flow of blood in narrow tubes with increased effective viscosity near the wall. Ponalagusamy et al. [8] studied two-fluid model for blood flow through a tapered arterial stenosis: Effect of non-zero couple stress boundary condition at the interface. In the present analysis two-phase model for heat transfer of visco elastic blood flow through arteries with symmetric stenosis in core region and pheripheral region are discussed through graphs.

2.Mathematical formulation

Consider an axially symmetric, unsteady, incompressible, and oscillatory flow of two-phase blood flow through stenosed artery. The flow is fully developed laminar pulsatile flow of blood in the axial direction z through an stenosed artery with an axially symmetric. It is assumed that the visco-elastic blood flow in two-phase model with central core region and a peripheral layer of plasma region.

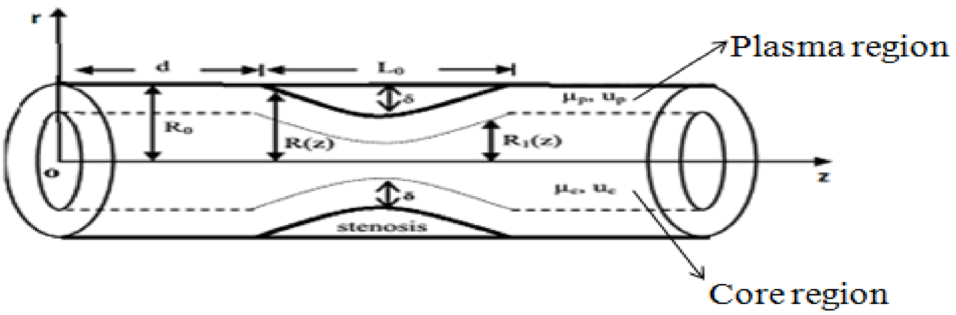

Fig.1.Geometry of stenosed artery

The geometry of the stenosis in the non-dimensional form in fig.1 is given by

$$R(z)=\begin{cases} R_0-\dfrac{\delta}{2}\left[1+\cos\dfrac{2\pi}{L_0}\left[z-d-\dfrac{L_0}{2}\right]\right], & d\le z\le d+L_0 \\ R_0, & otherwise \end{cases}$$

$$R_1(z)=\begin{cases} \gamma R_0-\dfrac{\delta}{2}\left[1+\cos\dfrac{2\pi}{L_0}\left[z-d-\dfrac{L_0}{2}\right]\right], & d\le z\le d+L_0 \\ \gamma R_0, & otherwise \end{cases}$$

Where R(z) and R_1(z) are the radii of the stenosed artery with the peripheral region and core region respectively. R_0 is the radius of normal artery, L_0 is the length of stenosis, d is the length of non-stenosis and δ is the maximum height of stenosis and γ is taken to the ratio of radii of core region and artery in the non-stenotic region.

The consistence viscosity μ may be written as

$$\mu=\begin{cases} \mu_c, & 0\le r\le R_1(z) \\ \mu_p, & R_1(z)\le r\le R(z) \end{cases}$$

Where μ_c and μ_p are the viscosities of core region and peripheral region respectively.

The momentum equations representing a Boussinesq incompressible fluid model discussed in Ponalagasamy et al. [35].

For the core region $0\le r\le R_1(z)$

Momentum equation

$$\frac{\partial u_c}{\partial t}=-\frac{1}{\rho_c}\frac{\partial P}{\partial z}+\frac{\mu_c}{\rho_c}\left[\frac{\partial^2 u_c}{\partial r^2}+\frac{1}{r}\frac{\partial u_c}{\partial r}\right]-\frac{\sigma B_0^2}{\rho_c}u_c-k_0^*\frac{\mu_c}{\rho_c}\frac{\partial}{\partial t}\left(\frac{1}{r}\left(\frac{r\partial u_c}{\partial r}\right)\right)+\beta g\left(T_c-T_0\right) \quad (1)$$

Energy equation

$$\frac{\partial T_c}{\partial t}=\frac{k_c}{\rho_c C_c}\left[\frac{\partial^2 T_c}{\partial r^2}+\frac{1}{r}\frac{\partial T_c}{\partial r}\right]-\frac{1}{\rho_c C_c}\frac{\partial q_c}{\partial r} \quad (2)$$

For the peripheral plasma region $R_1(z)\le r\le R(z)$

Momentum equation

$$\frac{\partial u_p}{\partial t}=-\frac{1}{\rho_p}\frac{\partial P}{\partial z}+\frac{\mu_p}{\rho_p}\left[\frac{\partial^2 u_p}{\partial r^2}+\frac{1}{r}\frac{\partial u_p}{\partial r}\right]-\frac{\sigma B_0^2}{\rho_p}u_p-k_0^*\frac{\mu_p}{\rho_p}\frac{\partial}{\partial t}\left(\frac{1}{r}\left(\frac{r\partial u_p}{\partial r}\right)\right)+\beta g\left(T_p-T_0\right) \quad (3)$$

Energy equation

$$\frac{\partial T_p}{\partial t}=\frac{k_p}{\rho_p C_p}\left[\frac{\partial^2 T_p}{\partial r^2}+\frac{1}{r}\frac{\partial T_p}{\partial r}\right]-\frac{1}{\rho_p C_p}\frac{\partial q_p}{\partial r} \qquad (4)$$

Where $\rho_c, u_c, T_c, k_c, q_c, C_c$ are density, velocity, temperature, thermal conductivity, heat radiative flux and the specific heat in core region respectively. $\rho_p, u_p, T_p, k_p, q_p, C_p$ are density, velocity, temperature, thermal conductivity, heat radiative flux and the specific heat in plasma region respectively and k_0^* is the coefficient of visco elasticity and β is the volume expansion due to temperature.

The boundary conditions are

$$\left.\begin{array}{lll} (i)\ \ u_p=0, T_p=T_B & at & r=R(z) \\ (ii)\ \ u_c=u_p, T_p=T_c & at & r=R_1(z) \\ (iii)\ \ \tau_c=\tau_p & at & r=R_1(z) \\ (iv)\ \dfrac{\partial u_c}{\partial r}=0, T_c=T_0 & at & r=0 \end{array}\right\} \qquad (5)$$

Where τ_c and τ_p are the shear stresses in the core region and plasma region.

The radiative heat fluxed in the core and peripheral plasma layer region expressed as

$$\frac{\partial q_c}{\partial r}=4\alpha_c^2\left(T_c-T_0\right)$$

$$\frac{\partial q_p}{\partial r}=4\alpha_p^2\left(T_p-T_0\right)$$

Where α_p and α_c are the mean radiation absorption coefficients.

Using the following non-dimensional parameters

$$\left.\begin{array}{l} r^*=\dfrac{r}{R_0},\ z^*=\dfrac{z}{R_0},\ t^*=\omega t,\ u_c^*=\dfrac{u_c}{u_0},\ u_p^*=\dfrac{u_p}{u_0} \\ P^*=\dfrac{PR_0}{u_0\mu_p},\ \theta_c^*=\dfrac{T_c-T_0}{T_B-T_0},\ \theta_p^*=\dfrac{T_p-T_0}{T_B-T_0} \\ P_e=\dfrac{\rho_p C_p R_0^2\omega}{k_p},\ N^2=\dfrac{4R_0^2\alpha_p^2}{k_p},\ M^2=\dfrac{B_0^2\sigma R_0^2}{\mu_p} \\ G_r=\dfrac{g\rho_p\beta R_0^2\left(T_B-T_0\right)}{u_0\mu_p},\ \tau_c^*=\dfrac{\tau_c R_0}{u_0\mu_p},\ \tau_p^*=\dfrac{\tau_p R_0}{u_0\mu_p} \end{array}\right\} \qquad (6)$$

Substituting equation (6) into the equations (1) to (4), we get the dimensionless form in core region and plasma region with dropping (*) as follows for the core region

The velocity of the blood flow in the stenosed artery of the core region is

$$\frac{\alpha^2}{\rho_0}\frac{\partial u_c}{\partial t} = -\frac{\partial P}{\partial z} + \frac{1}{\mu_0}\left[\frac{\partial^2 u_c}{\partial r^2} + \frac{1}{r}\frac{\partial u_c}{\partial r}\right] - k_2\left[\frac{\partial^2 u_c}{\partial r^2} + \frac{1}{r}\frac{\partial u_c}{\partial r}\right] - M^2 u_c + \frac{G_r}{\rho_0}\theta_c \qquad (7)$$

Where $k_2 = \frac{k_0^*}{\mu_0}$

The temperature distribution of the core region is

$$\frac{P_e k_0}{\rho_0 C_0}\frac{\partial \theta_c}{\partial t} = \left[\frac{\partial^2 \theta_c}{\partial r^2} + \frac{1}{r}\frac{\partial \theta_c}{\partial r}\right] - \frac{k_0}{\alpha_0}N^2\theta_c \qquad (8)$$

The velocity of the blood flow in the stenosed artery of peripheral plasma layer region is

$$\alpha^2\frac{\partial u_p}{\partial t} = -\frac{\partial P}{\partial z} + \left[\frac{\partial^2 u_p}{\partial r^2} + \frac{1}{r}\frac{\partial u_p}{\partial r}\right] - M^2 u_p + G_r\theta_p - k_1\left[\frac{\partial^2 u_p}{\partial r^2} + \frac{1}{r}\frac{\partial u_p}{\partial r}\right] \qquad (9)$$

The temperature distribution of the peripheral plasma layer region is

$$P_e\frac{\partial \theta_p}{\partial t} = \left[\frac{\partial^2 \theta_p}{\partial r^2} + \frac{1}{r}\frac{\partial \theta_p}{\partial r}\right] - N^2\theta_p \qquad (10)$$

Where $\alpha^2 = \frac{\rho_p \omega R_0^2}{\mu_p}$, $\rho_0 = \frac{\rho_p}{\rho_c}$, $\mu_0 = \frac{\mu_p}{\mu_c}$, $C_0 = \frac{C_c}{C_p}$ and k_0 is the ratio of thermal conductivity in the plasma region to thermal conductivity in core region. α_0 is the ratio of mean radiation absorption coefficient in the plasma region to mean radiation absorption coefficient in the core region. P_e is Peclet number, N^2 is radiation parameter, M^2 is magnetic parameter, ω is the frequency of oscillation, α^2 is mean radiation absorption parameter and G_r is Grashof number.

Non-dimensional boundary conditions are

$$\left.\begin{array}{lll} u_p = 0,\ \theta_p = 1 & at & r = R(z) \\ u_c = u_p,\ \theta_c = \theta_p & at & r = R_1(z) \\ \tau_c = \tau_p & at & r = R_1(z) \\ \frac{\partial u_c}{\partial r} = 0,\ \frac{\partial u_p}{\partial r} = 0 & at & r = 0 \end{array}\right\} \qquad (11)$$

The geometry of the stenosis in the non-dimensional form in fig.1 is given by

$$\frac{R(z)}{R_0}=\begin{cases}1-\dfrac{\delta}{2R_0}\left[1+\cos\dfrac{2\pi}{L_0}\left[z-d-\dfrac{l_0}{2}\right]\right], & d\le z\le d+l_0\\ 1, & otherwise\end{cases} \tag{12}$$

$$\frac{R_1(z)}{R_0}=\begin{cases}\gamma-\dfrac{\delta}{2}\left[1+\cos\dfrac{2\pi}{L_0}\left[z-d-\dfrac{L_0}{2}\right]\right], & d\le z\le d+L_0\\ \gamma, & otherwise\end{cases} \tag{13}$$

Where $R(z)$ is the radius of the stenotic region, R_0 is the radius of normal artery, L_0 is the length of stenosis, d is the length of non-stenosis and δ is the maximum height of stenosis and $R_1(z)$ is the radius of the central core region of constricted artery.

Method of solution

The non-dimensional form of pressure gradient can be taken as $-\frac{\partial P}{\partial z}=Pe^{it}$ (14)

Let us take oscillatory flow variables in core and plasma region in non-dimensional form

$$\left.\begin{aligned}u_c(r,t)&=u_c(r)e^{it}\\ u_p(r,t)&=u_p(r)e^{it}\\ \theta_c(r,t)&=\theta_c(r)e^{it}\\ \theta_p(r,t)&=\theta_p(r)e^{it}\end{aligned}\right\} \tag{15}$$

Solution of temperature profile in plasma region is obtained as follows.

Substitute equation (15) in equation (10), we get

$$\frac{\partial^2\theta_p}{\partial r^2}+\frac{1}{r}\frac{\partial\theta_p}{\partial r}+\beta_1^2\theta_p=0 \tag{16}$$

Where $\beta_1^2=-\left[N^2+iP_e\right]$

This is the form of Bessel equation, solving Bessel equation (16), we get $\theta_p=AJ_0(\beta_1 r)$

boundary condition equation (11), we get $A=\frac{1}{J_0(\beta_1 R)}$

The temperature distribution in plasma region is

$$\theta_p(r,t)=\frac{J_0(\beta_1 r)}{J_0(\beta_1 R)}e^{it} \tag{17}$$

Solution of temperature profile in core region is obtained as follows.

Substitute equation (15) in equation (8), we get

$$\frac{\partial^2\theta_c}{\partial r^2}+\frac{1}{r}\frac{\partial\theta_c}{\partial r}+\beta_2^2\theta_c=0 \qquad (18)$$

Where $\beta_2^2=-\left[\frac{k_0N^2}{\alpha_0}+\frac{ik_0P_e}{\rho_0C_0}\right]$

It is a form of Bessel equation and by solving we get $\theta_c=BJ_0\left(\beta_2 r\right)$

Using boundary condition equation (11), we get $B=\frac{J_0\left(\beta_1R_1\right)}{J_0\left(\beta_1R\right)J_0\left(\beta_1R_1\right)}$

The solution of temperature distribution in core region is $\theta_c\left(r,t\right)=\frac{J_0\left(\beta_1R_1\right)J_0\left(\beta_2 r\right)}{J_0\left(\beta_2R_1\right)J_0\left(\beta_1R\right)}$ (19)

The solution of velocity in plasma region is obtained as follows.

Substitute the equation (15) in the equation (9) ,we get

$$\frac{\partial^2u_p}{\partial r^2}+\frac{1}{r}\frac{\partial\theta_p}{\partial r}+\beta_3^2u_p=-\frac{P}{\left(1-ik_1\right)}-\frac{G_rJ_o\left(\beta_1 r\right)}{\left(1-ik_1\right)J_o\left(\beta_1R\right)} \qquad (20)$$

where $\beta_3^2=-\frac{\left[M^2+i\alpha^2\right]}{\left[1-ik_1\right]}$, $k_1=k_0^*$

Solving the equation (20) by using the boundary conditions given in equation (11), we get

the solution of axial velocity in plasma region is as follows.

$$u_p\left(r,t\right)=\left[\frac{-P}{\left(1-ik_1\right)\beta_3^2}+\frac{PJ_o\left(\beta_3 r\right)}{\left(1-ik_1\right)\beta_2^2J_o\left(\beta_3R\right)}+\frac{\beta_3G_r}{\left(1-ik_1\right)\left(\beta_1^2-\beta_3^2\right)}\left[\frac{J_o\left(\beta_3 r\right)}{J_o\left(\beta_3R\right)}-\frac{J_o\left(\beta_1 r\right)}{J_o\left(\beta_1R\right)}\right]\right]e^{it} \qquad (21)$$

The solution of velocity in core region is obtained as follows.

Substituting the equation (15) in the equation (7), we get

$$\frac{\partial^2u_c}{\partial r^2}+\frac{1}{r}\frac{\partial u_c}{\partial r}+\beta_4^2u_c=\frac{-P\mu_0}{\left(1-ik_2\right)}-\frac{G_r\mu_o}{\left(1-ik_2\right)}\theta_c \qquad (22)$$

Where $k_2=\frac{k_0^*}{\mu_0}$, $\beta_4^2=-\left[\mu_0M^2+\frac{i\alpha^2\mu_0}{\rho_0}\right]$

Solving the equation (22) by using boundary condition given in equation (11), we get the solution of the axial velocity in core region is as follows.

$$u_c(r,t)=\left[\begin{array}{l}\dfrac{u_p(R_1,t)J_0(\beta_4 r)}{J_0(\beta_4 R_1)}-\dfrac{P\mu_0}{(1-ik_2)\beta_4^2}+\dfrac{P\mu_0 J_o(\beta_4 r)}{(1-ik_2)\beta_4 J_o(\beta_4 R_1)}\\ +\dfrac{\beta_4 G_r \mu_0}{\rho_0(\beta_2^2-\beta_4^2)}\left[\dfrac{J_o(\beta_4 r)}{J_o(\beta_4 R)}-\dfrac{J_o(\beta_2 r)}{J_o(\beta_2 R)}\right]\end{array}\right]e^{it} \tag{23}$$

Volumetric flow rate in plasma region defined as

$$Q_p=\int_{R_1(z)}^{R(z)} r\cdot u_p dr = R_0^2 u_0\int_{\gamma R}^{R} ru_p dr \tag{24}$$

Where γ is taken to the ratio of radii of core region and artery in the non-stenotic region.

Substituting the equation (21) in equation (24), we get

$$Q_p=R_0^2u_0\left[\begin{array}{l}\dfrac{P}{(1-ik_1)\beta_3^3}\left[\dfrac{R/R_0\, J_1\left(\beta_3 R/R_0\right)}{J_0\left(\beta_3 R/R_0\right)}-\dfrac{\left(R/R_0\right)^2}{2}\beta_3-\dfrac{\left(\gamma R/R_0\right)J_1\left(\beta_3\left(\dfrac{\gamma R}{R_0}\right)\right)}{J_0\left(\beta_3 R/R_0\right)}+\dfrac{\left(\dfrac{\gamma R}{R_0}\right)^2}{2}\beta_3\right]\\ +\dfrac{G_r}{(1-ik_1)(\beta_1^2-\beta_3^2)}\left[\dfrac{R/R_0\, J_1\left(\beta_3 R/R_0\right)}{J_0\left(\beta_3 R/R_0\right)}-\dfrac{R/R_0\,\beta_3}{\beta_1}\dfrac{J_1\left(\beta_1 R/R_0\right)}{J_0\left(\beta_1 R/R_0\right)}-\dfrac{\left(\gamma R/R_0\right)J_1\left(\beta_3\left(\dfrac{\gamma R}{R_0}\right)\right)}{J_0\left(\beta_3 R/R_0\right)}+\dfrac{\left(\gamma R/R_0\right)\beta_3}{\beta_1}\dfrac{J_1\left(\dfrac{\beta_1 R}{R_0}\right)}{J_0\left(\beta_1 R/R_0\right)}\right]\end{array}\right]e^{it} \tag{25}$$

Volumetric flow rate in core region is

$$Q_c=\int_0^{R_1(z)} ru_c dr = R_0^2u_0\int_0^{R_1(z)/R_0} r^* u_c^* dr^*$$

By dropping (*), we get

$$Q_c=R_0^2u_0\int_0^{\gamma R/R_0} ru_c dr \tag{26}$$

Substituting the equation (21) in the equation (24), we get

$$Q_c = \frac{R_0^2 u_0}{\beta_4^2}\left[\begin{array}{l}\dfrac{\left(\dfrac{\gamma R}{R_0}\right)\beta_4 J_1\left(\beta_4 \dfrac{\gamma R}{R_0}\right)u_p\left(\dfrac{\gamma R}{R_0},t\right)}{J_0\left(\beta_4\left(\dfrac{\gamma R}{R_0}\right)\right)} \\ -\dfrac{P\mu_0\left(\dfrac{\gamma R}{R_0}\right)^2}{2(1-ik_2)}+\dfrac{(\gamma R)P\mu_0 J_1\left(\beta_4\dfrac{\gamma R}{R_0}\right)}{\beta_4(1-ik_2)J_0\left(\beta_4\left(\dfrac{\gamma R}{R_0}\right)\right)}\end{array}\right]e^{it} \tag{27}$$

Total volumetric flow rate is $Q = Q_c + Q_p$

The shear stress τ_p in the plasma region is defined as

$$\tau_p = \left[-\frac{\partial u_p}{\partial r}\right]$$

By dropping (*), we get

$$= \frac{u_0}{R_0}\left[-\frac{\partial u_p}{\partial r}\right] \tag{28}$$

$$\tau_p = \frac{u_0}{R_0}\left[\frac{PJ_1(\beta_3 r)}{\beta_3(1-ik_1)J_o(\beta_3 R)}+\frac{\beta_3 G_r}{(1-ik_1)\left(\beta_3^2-\beta_1^2\right)}\left[\frac{\beta_3 J_1(\beta_3 r)}{J_o(\beta_3 R)}-\frac{\beta_1 J_1(\beta_1 r)}{J_o(\beta_1 R)}\right]\right]e^{it} \tag{29}$$

The shear stress τ_c in the core region is defined as

$$\tau_c = \left[-\frac{1}{\mu_0}\left(\frac{\partial u_c}{\partial r}\right)\right]$$

By dropping (*), we get

$$\tau_c = -\frac{1}{\mu_0}\frac{u_0}{R_0}\left[\frac{\partial u_c}{\partial r}\right] \tag{30}$$

Where γ is taken to be the ratio of core region and artery in the non-stenotic region.

$$\tau_c = \frac{u_0}{R_0}\left[\begin{array}{l}\dfrac{\beta_4 u_p(\gamma R)J_1(\beta_4 r)}{J_o(\beta_4(\gamma R))}+\dfrac{P\mu_0 J_1(\beta_4 r)}{(1-ik_2)\beta_4 J_o(\beta_4(\gamma R))} \\ +\dfrac{G_r\beta_4\mu_0}{\rho_0\left(\beta_2^2-\beta_4^2\right)}\left[\dfrac{\beta_4 J_1(\beta_4 r)}{J_o(\beta_4 R)}-\dfrac{\beta_2 J_1(\beta_2 r)}{J_o(\beta_2 R)}\right]\end{array}\right]e^{it} \tag{31}$$

4. Results and discussions

The present two-phase mathematical model sheds some light on investigating the effects of peripheral region and core region with heat transfer on the flow of blood through stenosed arteries. Figure 2 depicts the variation of temperature distribution with radial direction; it is observed that the temperature increases as Pecklet number values increases. It is pertinent to point out here that the percentage of increase in the temperature with an increase in the radial distance. The heat transfer on the blood flow is lower near the axis of the blood vessels and this is higher near the wall of the blood vessel. Figure 3 illustrates that the axial velocity increases as the Grashof number values increase. Figure 4 shows that axial velocity decreases as the Pecklet number values increase. It is noted that the velocity of the blood flow is maximum at the middle of stenosed arteries and minimum at the unobstructed position of the tube. Figure 5 shows that the volumetric flow rate decreases as the Pecklet number values increase. Figure 6 depicts that the volumetric flow rate increases as the Grashof number values increase. It is clear that the volumetric flow rate in peripheral region and core region increases in stenosed artery due to Grashof number and it decreases due to Pecklet number. Figures 7, 8, 9 and 10 point out that the shear stress increases as the Pecklet number and Grashof number increases in core region and peripheral region. It is noted that the high wall shear stress not only damaged the vessel walls and it affect the entire circulation of the blood flow in arteries.

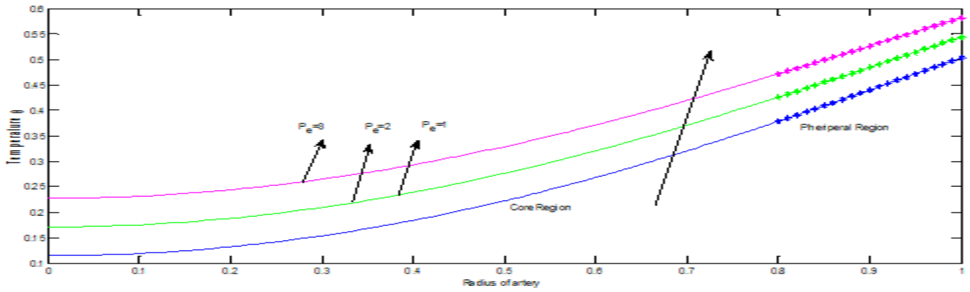

Fig.2.Temperature distribution verses radius of artery with different values of Peclet number with $t = 2, N = 5, \alpha_0 = 0.7, \rho_0 = 1, k_0 = 1, e = 0.2, d = 0.25, l_0 = 0.5, R_0 = 1$

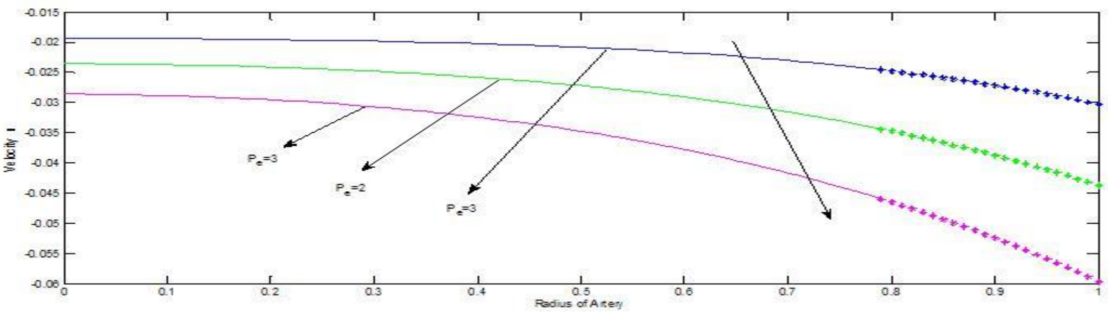

Fig.3.velocity distribution verses radius of artery with differert values of
Peclet number number with $t = 2, N = 5, \alpha_0 = 0.7, \rho_0 = 1, k_0 = 1,, M = 0.5, K_1 = 0.8, K_2 = 0.2$

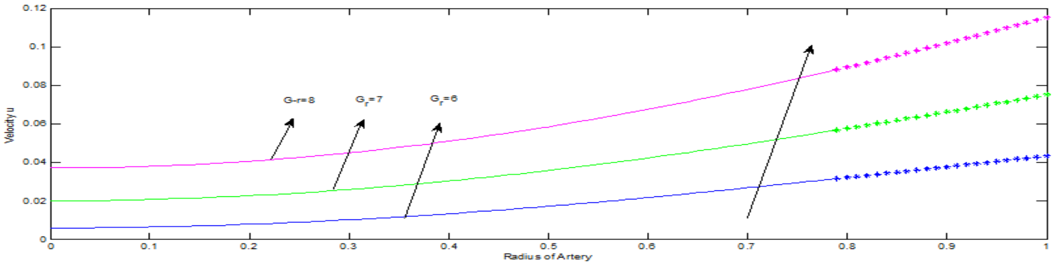

Fig.4.velocity distribution verses radius of artery with differert values of Grashof number with $t = 2, N = 5, \alpha_0 = 0.7, \rho_0 = 1, k_0 = 1,, M = 0.5, K_1 = 0.8, K_2 = 0.2$.

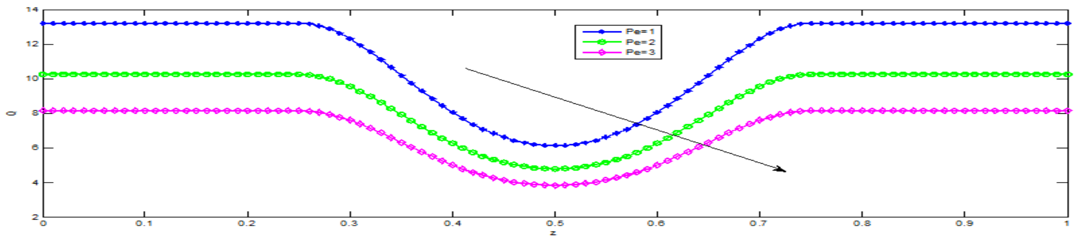

Fig.5.Volumetric flow rate versus axial direction z for different values of Peclet number with $t = 2, N = 5, \alpha_0 = 0.7, M = 0.5$, e=0.2,d=0.25,P=0.5

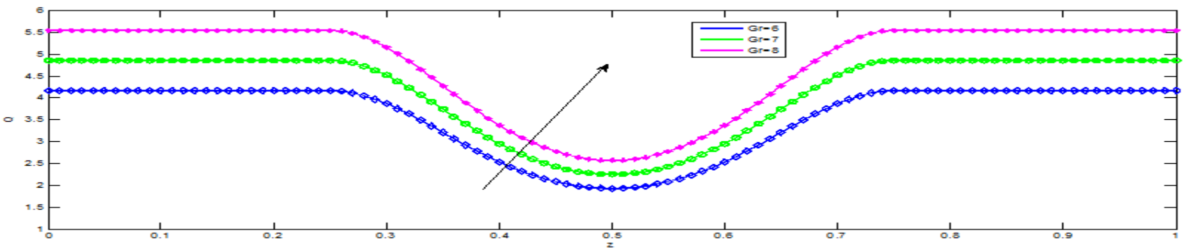

Fig.6.Volumetric flow rate versus axial direction z for different values of Grashof number with $t = 2, N = 5, \alpha_0 = 0.7, M = 0.5$, e=0.2,d=0.25,P=0.5, $l_0 = 0.5$

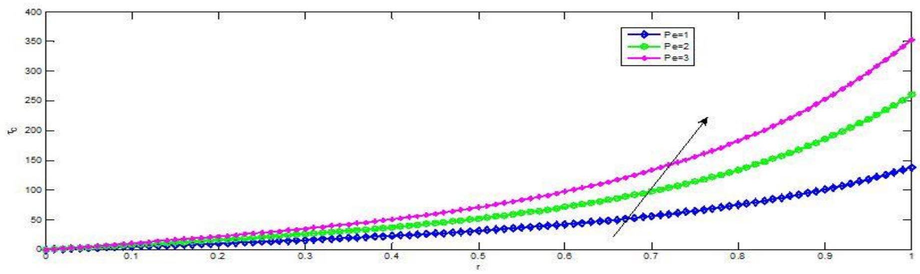

Fig.7.Shear stress versus radial direction in core region for different values of Peclet number with $t = 2, N = 5, \alpha_0 = 0.7, M = 0.5$, e=0.2,d=0.25,P=0.5,z=0.5

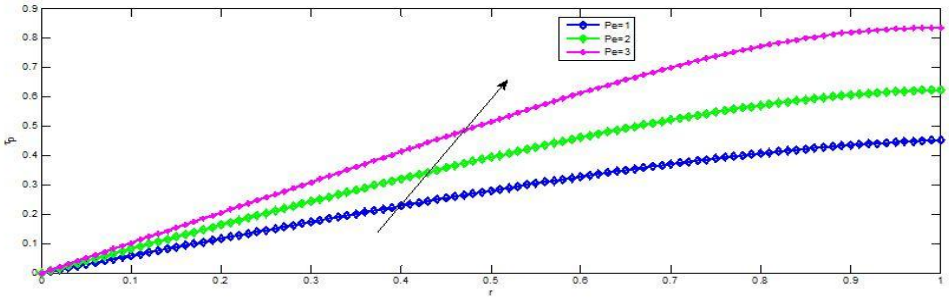

Fig.8.Shear stress versus radial direction in pheripheral region for different values of Peclet number with $t=2, N=5, \alpha_0=0.7,\ M=0.5$,e=0.2,d=0.25,P=0.5,z=0.5

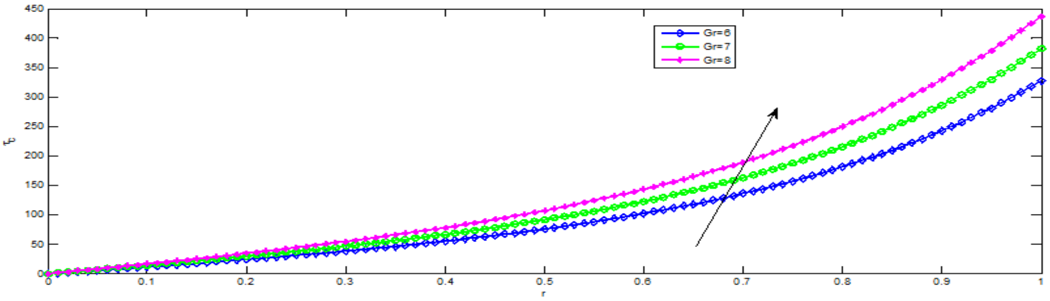

Fig.9. Shear stress versus radial direction in core region for different values of Grashof number with $t=2, N=5, \alpha_0=0.7,\ M=0.5$,e=0.2,d=0.25,P=0.5,z=0.5

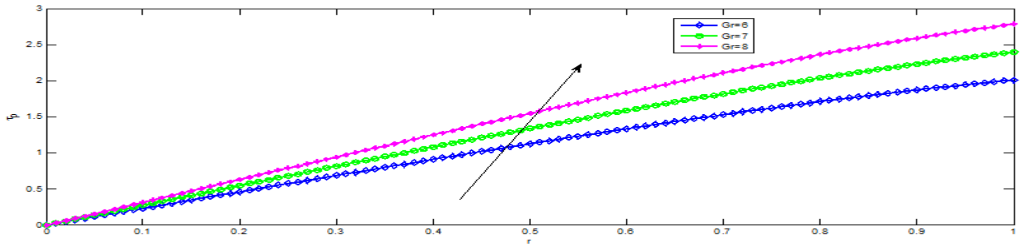

Fig.10.Shear stress versus radial direction in the peripheral region for different values of Grashof number with z=0.5,e=0.2,d=0.25,P=0.5,mp=0.3,$l_0=0.5, B_0=0.2$

5. Conclusion

The present study is investigated as a two-layered visco-elastic fluid model for blood flow through a stenosed artery with heat transfer in peripheral region and core region has been considered. The model consists of a core region surrounded by a peripheral plasma layer. The temperature increases as Pecklet number increases. It is noted that the body temperature increases very rapidly, the circulatory system is impacted. The axial velocity profile increases when the Grashof number increases and it decreases as the Pecklet number increases. It is found that the volumetric flow rate increases as Grashof number increases and it is decreases as Pecklet number increases and shear stress increases as the Pecklet number, Grashof number increases in core region and peripharal region.

In view of these arguments, the present study could be useful for analysing the blood flow in the diseased arteries. From this study, peripheral layer helps in the functioning on the diseased arterial system. It is noted that the heat transfer on the blood flow in stenosed artery affect the circulatory of the system and the body temperature increases which affect central nervous system.

6. References

[1] Ponalagusamy R,Tamilselvi R,2014,*Influence of magnetic field and heat transfer on two-phase fluid model for oscillatory blood flow in arterial stenosis*,Meccanica,10.1007/S 11012-014-9990-1

[2] Bhavya Tripathi,Bhupendra kumar Sharma,2017, *Flow characteristics of MHD oscillatory to space blood flow through a stenosed artery with heat and mass transfer*.ARX IV-1705-0979V2[Physics-flu-dyn]

[3] Verma SR,2014,*Analytical study of a two-phase model for steady flow of blood in a circular tube.* International Journal of engineering Research and Application,*1(4):1-10*.

[4] Maithili Sharan and Aleksander Popel S,2001,*A two-phase model for flow of blood in narrow tubes with increased effective viscosity near the wall.* Biorheology, 38(5,6):415-428.

[5] Ponalagusamy R,2016,*Two-fluid model for blood flow through a tapered arterial stenosis: Effect of non-zero couple stress boundary condition at the interface.* International Journal of Applied and Computational Mathemathics Pages 1-18.

[6] Sankar DS,2011,*Two-phase non-linear model for blood flow in asymmetric and axisymmetric stenosed stenosed arteries*. International Journal of Non-Linear Mechanics,46(1):296-305.

[7] Ponalagusamy R, Priyadharshini S, 2009,*Numerical investigation on two-fluid model(micropolar-newtonian) for pulsatile flow of blood in a tapered arterial stenosis with radially variable magnetic field and core fluid viscosity*. Computation and Applied Mathematics,1-25.

[8] Sanker DS,Usik Lee,2007,*Two-phase non-linear model for the flow through stenosed blood vessels.* Journal Of Mechanical Science and Technology,21(4):678-689.

[9] Ogulu A and Abbey TM,2005, *Simulation of heat transfer on an oscillatory blood flow in an indented porous artery.* International communication in heat and mass transfer,32(7):983-989.

[10] Zaman A, Ali N, Anwar Beg O, and Sajid M,2009, *Heat and mass transfer to blood flowing through a tapered overlapping stenosed artery.* International Journal of Heat and Mass Transfer,95:1084-1095.

[11] Misra JC and Adhikary SD,2016, *MHD oscillatory channel flow, Heat and mass transfer in physiological fluid in presence of chemical reaction.* Alexandria Engineering Journal,55(1):287-297.

[12] Maithili Sharan, Balbir Singh and Pawan Kumar,1997, *A two-layer model for studying the effect of plasma layer on the delivery of oxygen to tissue using a finite element method.* Applied Mathematical Modelling,21(7):419-426.

[13] Chaturani P, Kaloni PN,1976, *Two-fluid poiseuille flow model foe blood flow through arteries of small diameter and arterioles.*Biorheology 13:243-250.

[14] Ikbal M, Chakravarty AS, Mandal PK,2009, *Two-fluid micropolar fluid flow through stenosed artery: effect of peripheral layer thickness*,Comput Math Appl 58:1338-1339.

[15] Ponalagusamy R,2007, *Blood flow through an artery with mild stenosis: a two-layered model,different shapes of stenosis and slip velocity at the wall.*J Appl Sci 7:107-1077.