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Influences of Heat Transfer in Peristaltic Transport of Two-Layer Model

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ABSTRACT

The two-layered peristaltic Transport and the heat transfer in the symmetric channel is analyzed. The core layer fluid satisfies the power-law fluid characterize and the peripheral layer is depicted as the Bingham flow model. The no-slip conditions at the walls are taken into consideration. For both zones, small Reynolds number and the long-wavelength approximations are used to simplify the governing equations. By using suitable methods, the interface equation between the two layers, the velocity, pressure gradient, temperature profile, and trapping phenomenon are studied. The influence of the physical parameters of the problem are debated and clarified graphically.

MSC..

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1. Introduction

Peristaltic transport is an essential mechanism used to characterize a progressive wave of area expansion or contraction which spreads over the length of the channel. Peristalsis is an ingrained property of numerous tubular body part of the human. Peristaltic transportation is also used for industrial applications such as corrosive and noxious fluids transport, blood pumps in heart-lung device and transport of sanitary fluid. The researches on peristaltic flow is now very wide and several researchers already described studies on the peristaltic flow [1–3].

A number of the famous biofluids are lymph, intestinal fluid, cerebrospinal fluids, saliva, mother's milk, perspiration, stomach juices. Not any Newtonian fluid models describe the features of these fluids in detail. Consequently they are exhibited as non-Newtonian fluids. Several of the non-Newtonian fluid which are recognized by investigators for the survey of these fluids are Casson fluid, Jeffrey fluid, Herschel–Bulkley fluid, Power-law fluid, Bingham fluid, etc.

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Some theoretical and experimental researches[4-7] have been made on the peristaltic motion of a non-Newtonian fluid and also as suspension of solid particles in a Newtonian fluid.

In several biological channels like the tiny blood vessels, ureter and esophagus, it is noticed that the shape of the wall pushing the fluid is covered with a fluid of various features than the fluid being pumped out. Some of the investigators [8,9] have displayed practically that for the blood flux in tight blood vessels, there be a peripheral stratum (outer) of plasma, as a Newtonian fluid and a core stratum (inner) of containing all the erythrocytes of blood, as a non-Newtonian fluid. This stratum owning a viscosity various to the viscosity of the core zone flowing in the channel. The fluid characteristics may vary in various channels of a living body. Motivated by this truth, numerous practical applications and studies have impart considerable interest in the peristaltic flow of double immiscible fluids. Peristaltic motion of Power-law fluid with a Jeffery fluid in an inclined channel with permeable wall was analyzed by Sreenadh et al.[10]. Goswami et al. [11] have investigated the impacts of electrokinetic peristaltic flow of power-law fluids in a cylindrical elastic tube. Goud et al.[12] analyzed the peristaltic motion of a Bingham Flow Model in Contact with a Newtonian fluid. Prasad et al. [13] investigated heat and mass transfer impacts of the peristaltic flow of a nanofluid in the peripheral layer in an axisymmetric tube. Vajravelu et al. [14] analyzed the two-layered fluid model consisting of a Jeffrey fluid in the core zone and a Newtonian fluid in the peripheral zone with the flow and heat transfer effects. Very recently, Ponalagusamy and Selvi [15] addressed the combined effects of plasma layer thickness, heat transfer and magnetic field on the flow of blood through stenosed arteries.

Stirred by the above studies, the study of the influence of the peripheral layer on the peristaltic movement of a power-law fluid with Bingham fluid in a symmetric horizontal channel under long wavelength and low Reynolds number assumptions has been done. Closed expression for interface, velocity, pressure gradient, heat and trapping phenomenon is attained. The impacts of different parameters on these flow are calculated and graphically displayed by applying Mathematica 11 program.

2. Problem Formulation Description

Consider the peristaltic motion of involving of two incompressible fluids of various viscosities occupying the core layer by a power-law fluid and peripheral layer by a Bingham fluid through the symmetric horizontal channel (Fig. (1)). The half-width of the channel is d. In the Cartesian coordinate system (X, Y), the channel walls are modeled as:

$$H(\bar{X},\bar{t}) = d + \bar{a}\,Sin\left[\frac{2\pi}{\lambda}(\bar{X} - c\bar{t})\right] \tag{1}$$

where $\bar{a}$ presents amplitude of peristaltic wave, λ is the wavelength, c is the velocity of the peristaltic wave, $\bar{t}$ is the time.

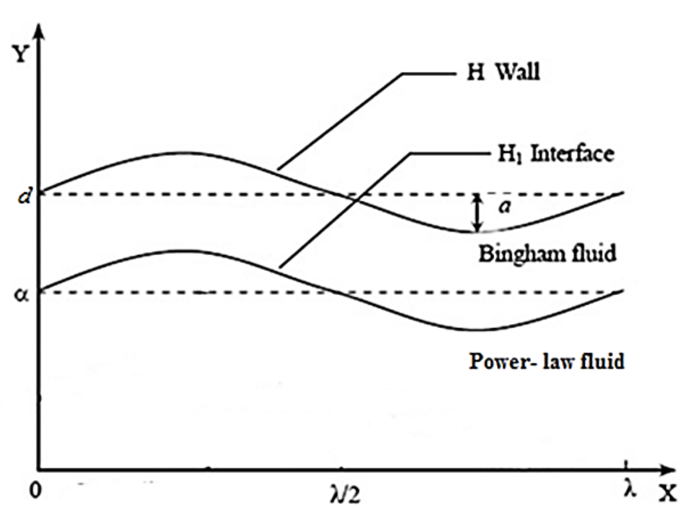

Fig. 1. Physical Model

3. Constitutive Equations

The equations governing the flow of power-law in the core zone and Bingham fluid in the peripheral zone are presented as follows:

$$\frac{\partial \bar{U}_1}{\partial \bar{X}} + \frac{\partial \bar{V}_1}{\partial \bar{Y}} = 0 \qquad 0 \le y \le H_1 \tag{2}$$

$$\rho\left[\frac{\partial \bar{U}_1}{\partial \bar{t}} + \bar{U}_1\frac{\partial \bar{U}_1}{\partial \bar{X}} + \bar{V}_1\frac{\partial \bar{U}_1}{\partial \bar{Y}}\right] = -\frac{\partial \bar{P}}{\partial \bar{X}} + \frac{\partial \tau_{\bar{X}\bar{X}}}{\partial \bar{X}} + \frac{\partial \tau_{\bar{X}\bar{Y}}}{\partial \bar{Y}} \qquad 0 \le y \le H_1 \tag{3}$$

$$\rho\left[\frac{\partial \bar{V}_1}{\partial \bar{t}} + \bar{U}_1\frac{\partial \bar{V}_1}{\partial \bar{X}} + \bar{V}_1\frac{\partial \bar{V}_1}{\partial \bar{Y}}\right] = -\frac{\partial \bar{P}}{\partial \bar{Y}} + \frac{\partial \tau_{\bar{Y}\bar{X}}}{\partial \bar{X}} + \frac{\partial \tau_{\bar{Y}\bar{Y}}}{\partial \bar{Y}} \qquad 0 \le y \le H_1 \tag{4}$$

$$\rho C_p\left[\frac{\partial \bar{T}_1}{\partial \bar{t}} + \bar{U}_1\frac{\partial \bar{T}_1}{\partial \bar{X}} + \bar{V}_1\frac{\partial \bar{T}_1}{\partial \bar{Y}}\right] = \kappa_1\left[\frac{\partial^2 \bar{T}_1}{\partial \bar{X}^2} + \frac{\partial^2 \bar{T}_1}{\partial \bar{Y}^2}\right] + \tau_{\bar{X}\bar{Y}}\left(\frac{\partial \bar{U}_1}{\partial \bar{Y}} + \frac{\partial \bar{V}_1}{\partial \bar{X}}\right) \qquad 0 \le y \le H_1 \tag{5}$$

where τ_{ij} , i, j ={X, Y} appoints the stress tensor for power-law fluid, it is described as[16]

$$\tau_{ij} = m_1(\dot{\gamma})^{n-1}\,\dot{\gamma}_{ij} \tag{6}$$

$$\dot{\gamma}_{ij} = \frac{\partial \bar{U}_i}{\partial \bar{x}_j} + \frac{\partial \bar{U}_j}{\partial \bar{x}_i} \tag{7}$$

$$\dot{\gamma} = \left[2\left(\frac{\partial \bar{U}_1}{\partial \bar{X}}\right)^2 + 2\left(\frac{\partial \bar{V}_1}{\partial \bar{Y}}\right)^2 + \left(\frac{\partial \bar{U}_1}{\partial \bar{Y}} + \frac{\partial \bar{V}_1}{\partial \bar{X}}\right)^2\right]^{\frac{1}{2}} \tag{8}$$

$$\frac{\partial \bar{U}_2}{\partial \bar{X}} + \frac{\partial \bar{V}_2}{\partial \bar{Y}} = 0 \qquad H_1 \le y \le H \tag{9}$$

$$\rho\left[\frac{\partial \bar{U}_2}{\partial \bar{t}} + \bar{U}_2\frac{\partial \bar{U}_2}{\partial \bar{X}} + \bar{V}_2\frac{\partial \bar{U}_2}{\partial \bar{Y}}\right] = -\frac{\partial \bar{P}}{\partial \bar{X}} + \frac{\partial \tau_{\bar{X}\bar{X}}}{\partial \bar{X}} + \frac{\partial \tau_{\bar{X}\bar{Y}}}{\partial \bar{Y}} \qquad H_1 \le y \le H \tag{10}$$

$$\rho\left[\frac{\partial \bar{V}_2}{\partial \bar{t}} + \bar{U}_2\frac{\partial \bar{V}_2}{\partial \bar{X}} + \bar{V}_2\frac{\partial \bar{V}_2}{\partial \bar{Y}}\right] = -\frac{\partial \bar{P}}{\partial \bar{Y}} + \frac{\partial \tau_{\bar{Y}\bar{X}}}{\partial \bar{X}} + \frac{\partial \tau_{\bar{Y}\bar{Y}}}{\partial \bar{Y}} \qquad H_1 \le y \le H \tag{11}$$

$$\rho c_p\left[\frac{\partial \bar{T}_2}{\partial \bar{t}} + \bar{U}_2\frac{\partial \bar{T}_2}{\partial \bar{X}} + \bar{V}_2\frac{\partial \bar{T}_2}{\partial \bar{Y}}\right] = \kappa_2\left[\frac{\partial^2 \bar{T}_2}{\partial \bar{X}^2} + \frac{\partial^2 \bar{T}_2}{\partial \bar{Y}^2}\right] + \tau_{\bar{X}\bar{Y}}\left(\frac{\partial \bar{U}_2}{\partial \bar{Y}} + \frac{\partial \bar{V}_2}{\partial \bar{X}}\right) \qquad H_1 \le y \le H \tag{12}$$

where τ_{ij} , i, j ={ X, Y} appoints the stress tensor for Bingham fluid, it is described as [17]

$$\tau_{ij} = \left(\frac{\tau_0}{\dot{\gamma}} + \mu_2\right)\dot{\gamma}_{ij} \qquad \tau \ge \tau_0 \tag{13}$$

$$\tau_{ij} = 0 \qquad \tau < \tau_0 \tag{14}$$

Where $\bar{U}i$ is the axial velocity, $\bar{V}_1$ is transverse velocity and $\bar{T}\,i$is the temperature. ρ is the density, and n is the fluid behavior index, m_1 is the consistency parameter $\bar{P}$ is the pressure and (κ_1, κ_2) thermal conductivity in core and peripheral layer respectively.
Actually, the flow is unsteady in the laboratory frame $(\bar{X}, \bar{Y})$. However, The flow becomes steady in a frame moving with the speed of the wave. Such a frame is famous as a wave frame $(\bar{x}, \bar{y})$. The conversions between the two frames are:

$$\bar{y} = \bar{Y}\ ,\ \bar{x} = \bar{X} - c\bar{t}\,, \bar{u} = \bar{U} - c\ \ ,\ \ \bar{v} = \bar{V},$$

$$\bar{p}(\bar{x}, \bar{y}) = \bar{P}(\bar{X}, \bar{Y}, \bar{T}),\ \ T = \bar{T}\,, \bar{Q} - 1 = q_1 + q_2 \tag{15}$$

In which $\bar{u}, \bar{v}, \bar{p}$, and T designate the velocity components, the pressure and the temperature in the wave frame, respectively.
To facilitate the mathematical problem, we consider the following dimensionless quantities:

$$\left.\begin{array}{l} x=\frac{\bar{x}}{\lambda}\ ,\ y=\frac{\bar{y}}{d}\ ,\ t=\frac{c\bar{t}}{\lambda},u_i=\frac{\bar{u}_i}{c}\ ,\ \ v_i=\frac{\lambda\,\bar{v}_i}{dc}\ ,\ \ p=\frac{d^{n+1}\bar{p}}{c^n\lambda m_1}\ ,\bar{q}=\ \frac{q}{dc} \\ \quad a=\frac{\bar{a}}{d},\delta=\frac{d}{\lambda},\ h=\frac{\bar{h}}{d}\ ,h_1=\frac{\bar{h}_1}{d},\ \ \tau_{ij}=\frac{d^n}{c^n\,m_1}\bar{\tau}_{ij},\ \ \theta_i=\frac{T_i-T_0}{\Delta T} \\ \quad\quad Re=\frac{\rho d^n}{m_1c^{n-2}},\quad \mu=\begin{cases}1 & 0\le y\le h_1\\ \frac{\mu_2}{m_1}\left(\frac{d}{c}\right)^{n-1} & h_1\le y\le h\end{cases} \\ \quad\quad\quad \tau_0=\frac{m_1c^n}{d^n}\bar{\tau}_0,\ \ Pr=\frac{c_pm_1}{\kappa_1}\left(\frac{c}{d}\right)^{n-1},Ec=\frac{c^2}{c_p\,\Delta T} \\ \quad\quad\quad Br=Pr.Ec\ \ ,\ \ \kappa=\begin{cases}1 & 0\le y\le h_1\\ \frac{\kappa_1}{\kappa_2} & h_1\le y\le h\end{cases}\end{array}\right\} \tag{16}$$

The quantities x,y are the components of the dimensionless coordinates, t the dimensionless time, u is dimensionless axial velocity, v is a dimensionless transverse component of velocity, p is dimensionless pressure, a is dimensionless the amplitude ratio, δ is the wavenumber, τ_0 is yield stress, T is the temperature, $\Delta T=(T_1-T_0)$ is temperature difference, C_p represents the specific heat at constant pressure, μ is the ratio of the viscosity, κ is the ratio of thermal conductivities, Re the Reynolds number, Ec the Eckert number, Pr the Prandtl number and Br the Brinkman number.

Stream function $\psi(x,y,t)$ and its relationship with velocity components are defined below

$$u=\frac{\partial\psi}{\partial y}\quad \text{and}\qquad v=-\frac{\partial\psi}{\partial x} \tag{17}$$

Since the flow is steady and using the shifts in Eq. (15) and by introducing non-dimensional quantities Eq.(16) and make use of Eq.(17) into constitutive relations (2)-(14), note that the mass balance represented by eq. (2) and eq. (9) are identically satisfied, yields

$$\frac{\partial p}{\partial x}=\frac{\partial}{\partial y}\left(\frac{\partial^2\psi_1}{\partial y^2}\right)^n \qquad 0\le y\le h_1 \tag{18}$$

$$\frac{\partial^2\theta_1}{\partial y^2}+Br\left(\frac{\partial^2\psi_1}{\partial y^2}\right)^{n+1}=0 \qquad 0\le y\le h_1 \tag{19}$$

$$\frac{\partial p}{\partial x}=\frac{\partial}{\partial y}\left(-\tau_0+\frac{\partial^2\psi_2}{\partial y^2}\right) \qquad h_1\le y\le h \tag{20}$$

$$\frac{\partial^2\theta_2}{\partial y}+\kappa.Br\left(-\tau_0+\frac{\partial^2\psi_2}{\partial y^2}\right)\frac{\partial^2\psi_2}{\partial y^2}=0 \qquad h_1\le y\le h \tag{21}$$

The non-dimensional no-slip conditions are

$$\psi_1=0 \qquad at \qquad y=0 \tag{22}$$

$$\frac{\partial^2\psi_1}{\partial y^2}=0 \qquad at \qquad y=0 \tag{23}$$

$$\psi_2=q \qquad at \qquad y=h \tag{24}$$

$$\frac{\partial\psi_2}{\partial y}=-1 \qquad at \qquad y=h \tag{25}$$

$$\psi_1=\psi_2=q_1 \qquad at \qquad y=h_1 \tag{26}$$

$$\frac{\partial\theta_1}{\partial y}=0 \qquad at \qquad y=0 \tag{27}$$

$$\theta_2=1 \qquad at \qquad y=h \tag{28}$$

$$\theta_1=\theta_2 \qquad at \qquad y=h_1 \tag{29}$$

$$\frac{\partial\theta_1}{\partial y} = \frac{1}{\kappa}\frac{\partial\theta_2}{\partial y} \qquad at \quad y = h_1 \tag{30}$$

Here the flux q is the totality of core layer flux q_1 and peripheral layer flux q_2 a cross any cross-section in the wave frame ($q = q_1 + q_2$). Moreover, the shear stress and the velocity are continuous a cross the interface. It takes from the incompressibility of the fluids that the fluxes q, q_1 and q_2 are independent of x. The average dimensionless volume flow rate over one wavelength $T(=\frac{\lambda}{c})$ of the peristaltic wave is defined as

$$\bar{Q} = q + \frac{1}{T}\int_0^T h\, dt = q + 1 \tag{31}$$

4. Solution of the problem

Resolving Eqs. (18)-(21) together under boundary conditions (22) -(30), we get

$$\psi_1 = y\left[-1 + \frac{(P)^{\frac{1}{n}}}{\left(\frac{1}{n}+1\right)\left(\frac{1}{n}+2\right)}\left(y^{\frac{1}{n}+1} - \left(\frac{1}{n}+2\right)h_1^{\frac{1}{n}+1}\right) - \frac{P}{2\mu}(h^2 - h_1^2) - \frac{\tau_0}{\mu}(h_1 - h)\right] \tag{32}$$

$$\psi_2 = q + h - y + \frac{P}{6\mu}(y^3 + 2h^2 - 3h^2 y) + \frac{\tau_0}{2\mu}(y^2 + h^2 - 2hy) \tag{33}$$

$$\begin{aligned}\theta 1 = 1 + Br\frac{(P)^{\frac{1}{n}+1}}{\left(\frac{1}{n}+2\right)\left(\frac{1}{n}+3\right)}\left({h_1}^{\frac{1}{n}+3} - y^{\frac{1}{n}+3}\right) + \kappa * Br(\frac{(P)^2}{12\mu}(h^4 - {h_1}^4)\\ -\frac{\tau_0(P)}{6\mu}({h_1}^3 - h^3)) + (-Br\frac{(P)^{\frac{1}{n}+1}}{\kappa\left(\frac{1}{n}+2\right)}{h_1}^{2+\frac{1}{n}} + \kappa * Br(\frac{(P)^2}{3\mu}{h_1}^3 + \frac{\tau_0 P}{2\mu}{h_1}^2))(h_1 - h)\end{aligned} \tag{34}$$

$$\theta 2 = 1 + \frac{Brk_1 P\left(2(h^3-y^3)\tau_0 + (h^4-y^4)P\right)}{12\mu} + \frac{1}{6}Br{h_1}^2(-h+y)P])\left(-\frac{6{h_1}^{\frac{1}{n}}(P)^{\frac{1}{n}}}{\kappa\left(2+\frac{1}{n}\right)} + \frac{\kappa(2h_1 P + 3\tau_0)}{\mu}\right) \tag{35}$$

Where $P = \frac{\partial p}{\partial y}$

5. The interface solution

The interface equation $h_1(x)$ is acquired from the boundary condition (26). substituting in Eq.(32), we obtain the following equation

$$\mathrm{Q}_1 = \frac{h_1(-h+h_1)\tau_0}{\mu} - \frac{h_1(h^2-{h_1}^2)P}{2\mu} - \frac{{h_1}^{2+\frac{1}{n}}P^{\frac{1}{n}}}{(2+\frac{1}{n})} \tag{36}$$

Where $Q_1 = q_1 + h_1$ and $Q = q + h$. To find P in Eq. (36), we use the continuity of the stream function at the interface, which is given by $\psi_2 = q_1$.

$$Q_1 = Q - \frac{(h^2-2hh_1+{h_1}^2)\tau_0}{2\mu} + \frac{(2h^3-3h^2h_1+{h_1}^3)P}{6\mu} \tag{37}$$

or

$$P = \frac{3(-2Q\mu+2Q_1\mu-(h-h_1)^2\tau_0)}{(h-h_1)^2(2h+h_1)} \tag{38}$$

From Eqs. (36) and (37) after Eliminating P from these equations, we attain the equation governing the interface

$$Q+\frac{(h-h_1)^2\tau_0}{2\mu}-\frac{h_1(-h+h_1)\tau_0}{\mu}-\frac{-2Q\mu+2Q_1\mu+(h-h_1)^2}{2\mu}\tau_0+\frac{3h_1(h+h_1)\left(-2Q\mu+2Q_1\mu-(h-h_1)^2\tau_0\right)}{2(h-h_1)(2h+h_1)\mu}-\frac{3^{\frac{1}{n}}h_1{}^{2+\frac{1}{n}}\left(\frac{-2Q\mu+2Q_1\mu+(h-h_1)^2}{(h-h_1)^2(2h+h_1)}\tau_0\right)^{\frac{1}{n}}}{\left(2+\frac{1}{n}\right)}=0 \tag{39}$$

Eq. (39) reduces to fourth-order algebraic equation for Newtonian fluid when $n=1$ and $\tau_0=0$. The values of Q_1 is obtained by resolving Eq. (39) iteratively through the conditions $h_1=\alpha$ at $=0$. Following, the same equation is resolved iteratively for (h_1) at every axial station (x).

6. Results and discussions

The peristaltic motion of Power-Law fluid in touch with a Bingham Flow Model is studied under the influence of heat transfer. The impact of different parameters on the shape of the interface, the velocity profile, temperature profiles, pressure gradient and trapping phenomena are noticed.

6.1. Interface

The interface shape (h_1) for diverse values of (μ) is observed in Figure 2 We note that the deviation of (h_1) with increases value viscosity ratio cause to a thinner peripheral layer in the widened zone. From Figure 3, we infer that the increase in the amplitude ratio results in the thicker core layer in the widened zone. The shape of the interface for various yield stress value is shown in Figure 4, We observe that the increase in the (τ_0) increases the wideness of the peripheral layer in the widened zone.

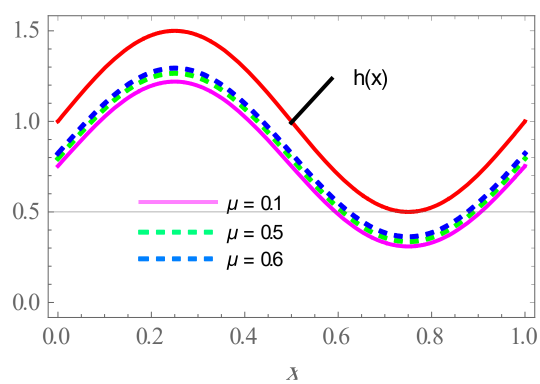

Fig. 2: showing the effect of (μ) on interface

at $n=0.5,\ \mu=Q=0.5, \alpha=0.7, \tau_0=0.1,$

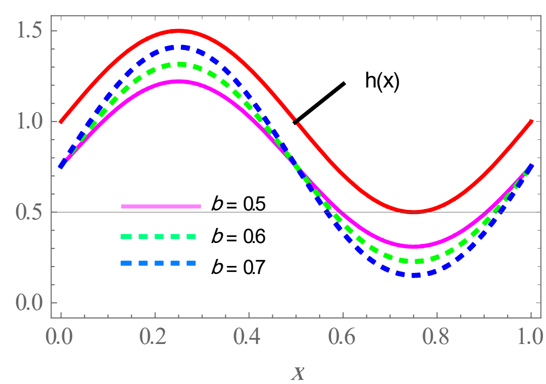

Fig. 3: showing the effect of (b) on interface

at $n=0.5,\ b=Q=0.5, \alpha=0.7, \tau_0=0.1,$

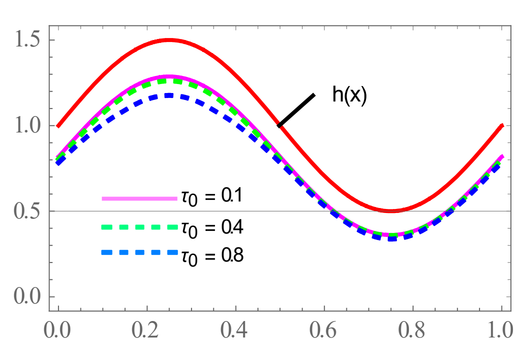

Fig. 4: showing the effect of (τ_0) on interface
at $n = 0.5,\ \mu = Q = 0.5, \alpha = 0.7, b = 0.5.$

6.2. Velocity profile

Axial velocity in core and peripheral layers are calculated from Eqs. (32) and (33) in terms of y. The behaviors of several parameters on velocity profiles at $(x = 0.2)$ and $(n = 0.5)$ are exhibited in Figures 5-7. Figure 5 is graphed to show the influence of viscosity ratio on velocity. A decrease in velocity is observed for an increase in the value of (μ). Physically, the viscosity ratio (μ) rises and offers more resistance to the flow. Hence, Figure 6 is sketched to show the variation of amplitude ratio on the velocity profile. Here velocity profile decreases in the center and increases close to channel boundaries with increases value of (b). It is observed from Figure 7 that the magnitude value of the velocity profile decreases with an increase in yield stress (τ_0) .

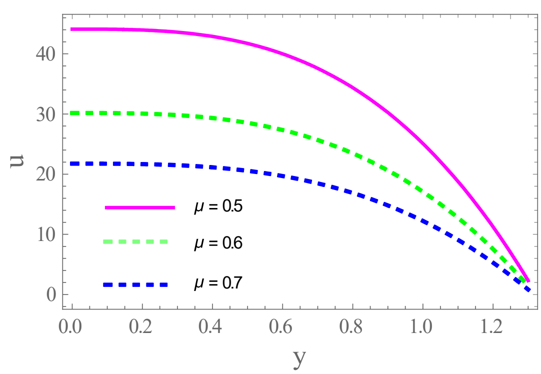

Fig.5: showing the effect of (μ) on velocity
at $b = 0.5, Q = 0.2, \alpha = 0.5, \tau_0 = 0.1.$

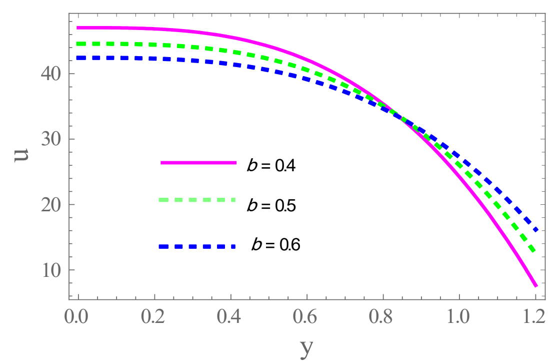

Fig.6: showing the effect of (b) on velocity
at $\mu = 0.5, Q = 0.2, \alpha = 0.5, \tau_0 = 0.2.$

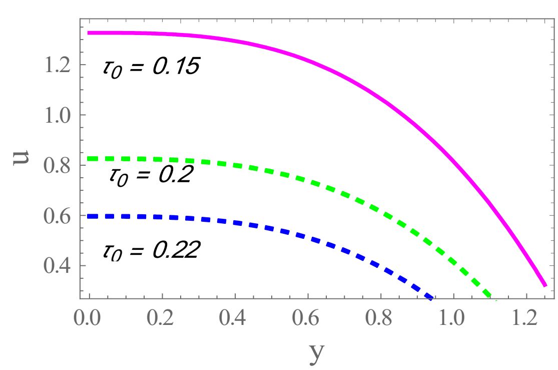

Fig.7: showing the effect of (τ_0) on velocity
at $\mu = 0.5, Q = 0.7, \alpha = 0.5, b = 0.5.$

6.3. Temperature profile

Temperature in core and peripheral regions is deliberate from Eqs. (34) and (35) in terms of y. Temperature profiles are calculated in Figures 8-9. Figures 8 and 9 are drawn to study the impact of Brinkman number and the ratio of thermal on the temperature distribution. We see that the temperature increases with increasing (Br) and (κ).

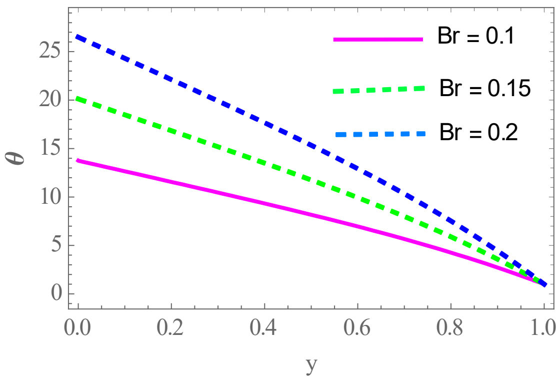

Fig. 8: showing the effect of (Br) on temperature at $x = n = 0.5, \mu = 0.7, Q = 0.5, \alpha = 0.4, \tau_0 = 0.1, b = 0.5, \kappa = 0.2$

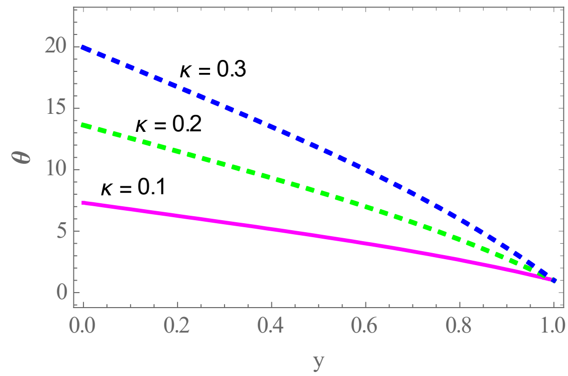

Fig. 9: showing the effect of (κ) on temperature at $x = n = 0.5, \mu = 0.7, Q = 0.5, \alpha = 0.43, \tau_0 = 0.1, b = 0.5, \varepsilon = \frac{\pi}{4}, Br = 0.2$

6.4. pressure gradient:

The impact of relevant parameters in the problem on the pressure gradient in the wave are investigated in Figures 10-11, where displayed that in the region (0≤ x ≤0.5) ∪ (1≤ x ≤1.5), influence these parameters on pressure gradient are small, which means that the flow can pass simply without imposing a big gradient pressure. Where, in the part of the channel (0.5≤ x ≤1), there must be a great pressure gradient to hold the same flow of fluid in the channel. Figure. 10 explains that a rise in the yield stress value decreases the pressure gradient. The behavior of pressure gradient against axial locations for changing the value of (b) is described in Figure 11. Growth in (b) rises the pressure gradient.

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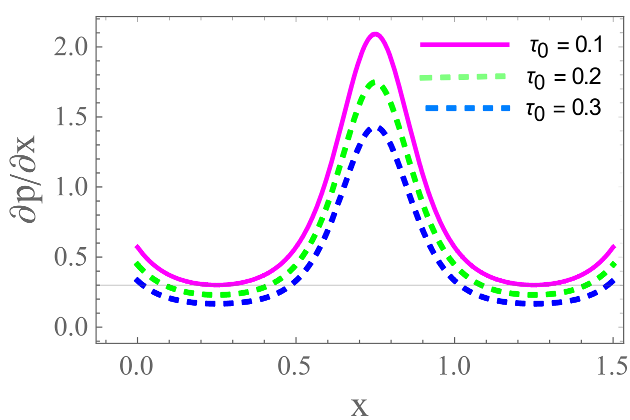


Fig. 10: showing the effect of (τ_0) on pressure gradient at $\mu = 0.4, Q = 0.7, \alpha = 0.9, b = 0.5, n = 0.5$

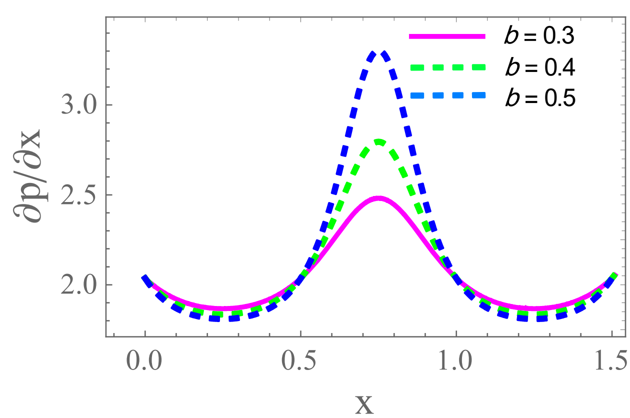
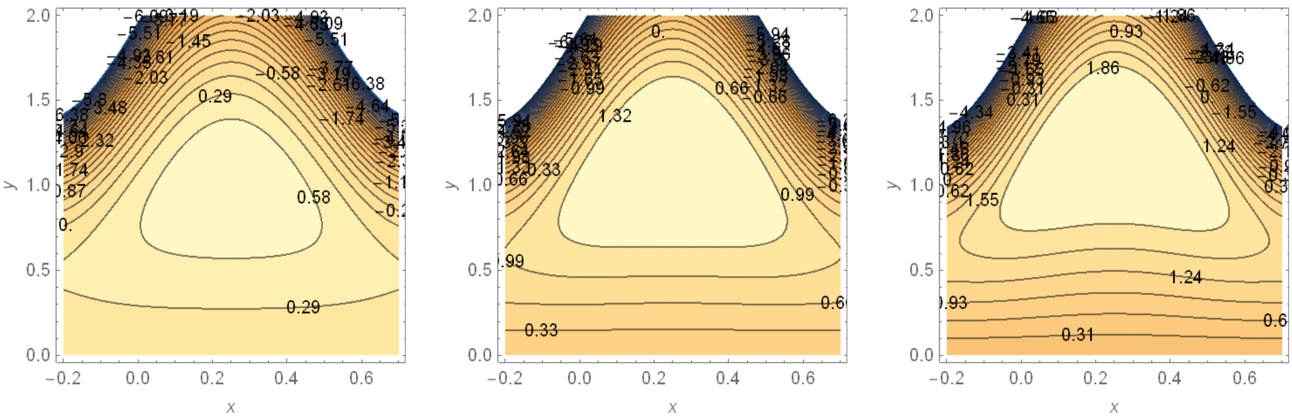


Fig. 11: showing the effect of (b) on pressure gradient at $\mu = 0.4, Q = 0.7, \alpha = 0.9, \tau_0 = 0.1, n = 0.5$

6.5. Trapping phenomenon

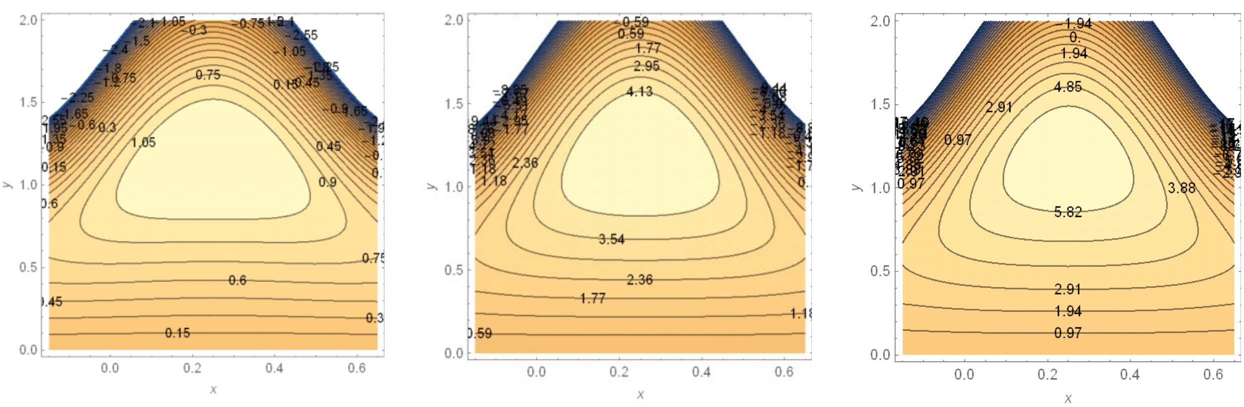
Other interesting phenomena of peristalsis is trapping, the shape of an internally circulating bolus of fluid which transmits along with the wave. Such a phenomenon has important consequences in engineering and physiological flow cases. ((The internal circulation of the trapped fluid may cause thrombosis of blood or obvious undesired chemical transformation in reactive fluids)). Figures 12-14 are drawn to observe the influences of different parameters on the streamline patterns. From figure 12. It is observed that a rise in the value of yield stress (τ_0) enhances the size of the trapped bolus and increases the number of bolus. The streamline shapes for various values of flow rate and viscosity ratio are displayed in Figures 13 and 14. it is noticed that the streamlines of the flow are influenced identically by growing either (Q) or (μ). It is noted that the trapped bolus seeming in the broader part of the channel declines by rising (Q) or (μ). Nonetheless, such a reduction is quicker by increasing (μ).



(a) (b) (c)

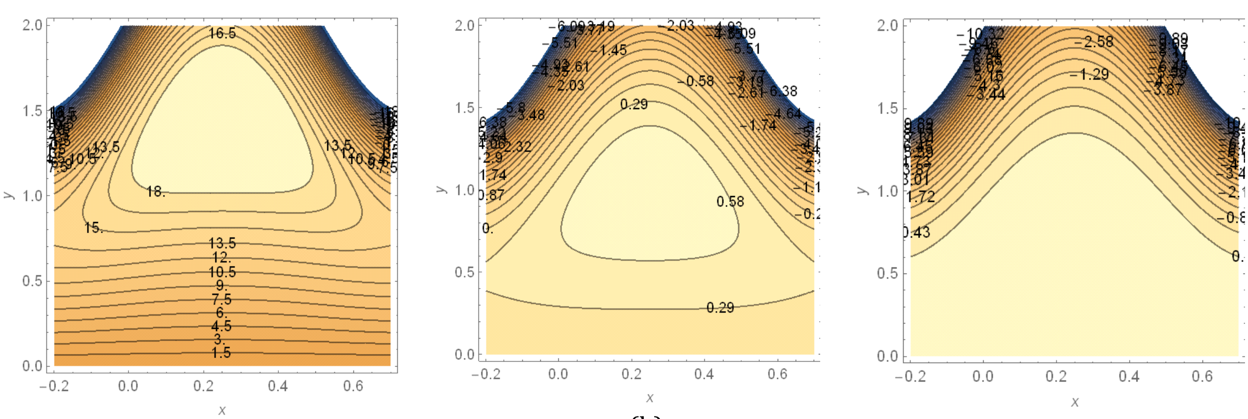
Fig. 12: showing the effect of (τ_0) on the streamlines at $\mu = 0.2, Q = 1, \alpha = 0.7, b = 0.3,$

$n = 0.5$. (a) $\tau_0 = 0.1$ (b) $\tau_0 = 0.5$ (c) $\tau_0 = 0.8$.



(a) (b) (c)

Fig. 13: showing the effect of (Q) on the streamlines at $\mu = 0.1, \tau_0 = 0.1, \alpha = 0.7, b = 0.3, n = 0.5$. (a) $Q = 0.5$ (b) $Q = 3$ (c) $Q = 5$.



(a) (b) (c)

Fig. 14: showing the effect of (μ) on the streamlines at $\tau_0 = 0.1, Q = 1, \alpha = 0.7, b = 0.3,$

$n = 0.5$. (a) $\mu = 0.01$ (b) $\mu = 0.2$ (c) $\mu = 0.4$.

7. Conclusions

The present problem deals with peristalsis and heat transfer impacts of a two-fluid model in an inclined symmetric channel with the approximations of lengthy wavelength and small Reynold's number. The obtained results are offered through graphs and are debated in detail. The results of the current study detect that the rise in the viscosity ratio and amplitude ratio increases the thickness of the core zone whereas it decreases with increases yield stress. The study shows that axial velocity has a decreasing behavior due to a rise in yield stress and viscosity ratio and the velocity decreases in the center of the channel while increases at a wall with an increase in the amplitude ratio. Brinkman number and the ratio of thermal conductivities. The trapped bolus size and number occurring rising with yield stress while its size and numbers decrease with the flow rate and viscosity ratio:

REFERENCES

[1] N. Ali, T. Hayat, "Peristaltic flow of a micropolar fluid in an asymmetric channel", *Computers and Mathematics with Applications*,55,(2008),p:589–608.

[2] K. Ramesh, M. Devakar, "Effect of Heat Transfer on the Peristaltic Transport of a MHD Second Grade fluid Through a Porous Medium in an Inclined a Symmetric Channel", *Chinese Journal of Physics*,55,(3),(2017),p:825-844.

[3] S. S. Hasen, A. M. Abdulhadi, "Influence of a Rotating Frame on the Peristaltic Flow of a Rabinowitsch Fluid Model in an Inclined Channel", *Journal of Al-Qadisiyah for Computer Science and Mathematics*,12,(1),(2020),p:21-33.

[4] G. C. Sankad1, A. Patil, "Impact of Permeable Lining of the Wall on the Peristaltic Flow of Herschel Bulkley Fluid. Applications and Applied Mathematics", *An International Journal (AAM)*,11,(2),(2016),p:663-679.

[5] K. Vajravelu, S. Sreenadh R. Saravana, "Combined influence of velocity slip, temperature and concentration jump conditions on MHD peristaltic transport of a Carreau fluid in a non-uniform channel", *Applied Mathematics and Computation*, 225,(2013),p: 656–676.

[6] H. A. Ali, A. M. Abdul Hadi, "Analysis of Heat Transfer on Peristaltic Transport of Powell-Eyring Fluid in an Inclined Tapered Symmetric Channel with Hall and Ohm's Heating Influences", Journal of al-Qadisiyah for Computer Science and Mathematics, 10,2,(2018).

[7] F. A. Adnan, A. M. Abdul Hadi, " Effect of a Magnetic Field on Peristaltic Transport of Bingham Plastic Fluid a Symmetric Channel, *Sci.Int.(Lahore)*,31(1) ,(2019), p:29-40.

[8] G. Bugliarello, J. Sevilla, "Velocity distribution and other characteristics of steady and pulsatile blood flow in fine glass tubes", *Biorheology* 1970.

[9] V. P. Srivastava, "A Theoretical Model for Blood Flow in Small Vessels", *Applications and Applied Mathematics (AAM): An International Journal*, 2,(1), (2007),p: 51 – 65.

[10] S. Sreenadh, K. Komal and A.N.S. Srinivas, "Peristaltic pumping of a power – Law fluid in contact with a Jeffrey fluid in an inclined channel with permeable walls", *Ain Shams Engineering Journal* 8,(2017), p:605–611.

[11] P. Goswami, J. Chakraborty, A. Bandopadhyay, S. Chakraborty, "Electrokinetically modulated peristaltic transport of power-law fluids", *Microvascular Research*,103 (2016),p: 41–54.

[12] J. S. Goud, R. H. Reddy, and R. Saravan, "Peristaltic Motion of a Bingham fluid in contact with a Newtonian fluid in a vertical channel", *IOP Conf. Series: Materials Science and Engineering*, 263, (2017),062005.

[13] K. Maruthi Prasad, N. Subadra and M. A. S. Srinivas, "Heat and Mass Transfer Effects of Peristaltic Transport of a Nano Fluid in Peripheral layer", *Applications and Applied Mathematics: An International Journal (AAM)*, 12,(2),(2017),p: 968 – 987.

[14] K. Vajravelu, S. Sreenadh and R. Saravana., "Influence of velocity slip and temperature jump conditions on the peristaltic flow of a Jeffrey fluid in contact with a Newtonian fluid", *Applied Mathematics and Nonlinear Sciences*,2,(2), (2017),p: 429–442.

[15] R. Ponalagusamy, R. T. Selvi, “Influence of magnetic field and heat transfer on a two-phase fluid model for oscillatory blood flow in an arterial stenosis”, *Meccanica*,50,(2015),p: 927-943.

[16] T. Hayat, M. Javed, S. Asghar and A. A. Hindi, “Wall properties and heat transfer analysis of the peristaltic motion in a power-law fluid”, Int. J. Numer. Meth. Fluids (2012).

[17] M.V. S. Reddy, B. J. Reddy, M. S. Reddy and N. Nagendra, “Long Wavelength Approximation to MHD Peristaltic Flow of a Bingham Fluid through a Porous Medium in an Inclined Channel”, *International Journal of Dynamics of Fluids,* 7, (2), (2011), pp:157-170.