International Journal of Bio-Science and Bio-Technology
Vol.8, No.2 (2016), pp.395-408
http://dx.doi.org/10.14257/ijbsbt.2016.8.2.37

Analysis of Heat Transfer on MHD Peristaltic Blood Flow with Porous Medium through Coaxial Vertical Tapered Asymmetric Channel with Radiation – Blood Flow Study

S. Ravi Kumar

Assistant Professor
Department of Mathematics
NBKR Institute of Science and Technology (An Autonomous Institution, Accredited by NBA and 'A'- Grade of NAAC, ISO 9001:2008 Certified), Vidyanagar, SPSR Nellore, Andhra Pradesh, India.Pin-524413.
drsravikumar1979@gmail.com/drsravikumar1979@nbkrist.org

Abstract

We study the analysis of heat transfer on MHD peristaltic flow with porous medium through coaxial tapered asymmetric channel with radiation effect under the assumptions of long wavelength approximation with low Reynolds number. The expressions of the axial velocity, pressure gradient, volume flow rate, average volume flow rate, pressure rise, temperature and hear transfer coefficient at $y = h_1$*and* $y = h_2$ *are all obtained and the temperature and hear transfer coefficient at* $y = h_1$*and* $y = h_2$ *are discussed through the graphs. It is noted that the temperature increases with increase in radiation parameter and Prandtl number, heat generation parameter, non-uniform parameter and phase angle* φ*.*

Keywords*: Peristaltic fluid flow, MHD, Porous medium, tapered channel, radiation*

1. Introduction

Peristaltic pumping is a mechanism of the fluid transport in a flexible tube by a progressive wave of contraction or expansion from a region of lower pressure to higher pressure. This mechanism of fluid transport has received considerable attention in recent years in physiological sciences as well as in engineering. The physiological phenomena, like urine transport from kidney to bladder through the ureter, the movement of spermatozoa in the ducts afferents of the male reproductive tract and the ovum in the female fallopian tube, movement of chime in the gastrointestinal tract, transport of lymph in the lymphatic vessels and vasomotor of small blood vessels such as arterioles, the locomotion of some warms, venules and capillaries involves the peristaltic motion. In addition peristaltic pumping occurs in many practical applications involving biomechanical systems.

Biomechanical pumps are based on the same mechanism. Heat transfer involved many complicated processes in tissues such as heat conduction in tissues, metabolic heat generation and external interactions such as electromagnetic radiation emitted from cell phones, heat convection due to blood flow through pores of the tissues. These processes also involves mass transfer phenomenon. Heat and mass transfer are also important because oxygen and nutrients diffuse out of the blood vessels to the neighboring tissues. Magnetic field effects in the peristaltic transport are very important from the physiological point of view, such as the presence of hemoglobin molecule makes the blood a bio-magnetic fluid. Magnetic Resonance Imaging (MRI), magnetic devices and magnetic particles used as drug carriers have some applications of magnetic field in physiology.

ISSN: 2233-7849 IJBSBT

The peristaltic transport in mathematical point of view was first investigation reported by Latham [1]. The initial mathematical model of peristalsis obtained by train of sinusoidal waves in an infinitely long symmetric channel or tube has been investigated by Shapiro *et al*. [2] and Jaffrin and Shapiro [3] explained the basic principles of peristaltic pumping in a two dimensional channel and brought out clearly the significance of the various parameters governing the flow. A review of most of the theoretical and experimental investigations has been presented in Srivastava *et al* [4, 5]. Important contributions beyond this, and of recent years, include the studies of Srivastava and Srivastava [6], Mekheimer *et al*. [7], Misra and Pandey [8], Hayat *et al*. [9, 10, and 11], Medhavi *et al* [12], Ravikumar *et al*. [13-15].

The study of heat transfer analysis is another important area in connection with peristaltic motion, which has industrial applications like sanitary fluid transport, blood pumps in heart lungs machine and transport of corrosive fluids where the contact of fluid with the machinery parts are prohibited. There are only a limited number of researchers have been discussed the effects of magnetic field on the peristaltic flow (Mekheimer [16], Hayat, et.al. [17], Hayat, et.al. [18], Ravikumar *et al*. [19-21]). Flow through a porous medium has been of considerable interest in recent years; number of researchers employing Darcy, s law. However, the interaction of peristalsis with heat transfer has not received much attention. The thermo dynamical aspects of blood may not be important when blood is inside the body but they become significant when it is drawn out of the body. Keeping in view the significance of heat transfer in blood flow, (Victor and Shah [22]) studied the thermo dynamical aspects of blood flowing in a tube treating blood as Casson fluid. Agarwal [23] analyzed the heat transfer to pulsatile flow of a conducting fluid through a porous channel in the presence of magnetic field. Peristaltic phenomenon has discussed in the presence of heat transfer has been investigated in refs ([24-27]).

However, the influence of radiation on peristaltic flow of a viscous fluid in an asymmetric channel has received little interest. Radioactive convective flows are frequently encountered in many scientific and environmental processes, such as astrophysical flows, water evaporation from open reservoirs, heating and cooling of chambers, and solar power technology. Several researchers have investigated radioactive effects on heat transfer in nonporous and porous medium utilizing the Rosseland or other radioactive flux model, such as Hall *et al*. [28], Hakiem[29], Raptis [30], Bakier [31], Raptis and Perdikis [32], Sanyal and Adhikari [33], Rao [34], Prasad and Reddy [35].

2. Formulation of the Problem

We discussed the analysis of heat transfer on MHD peristaltic flow with porous medium through coaxial tapered asymmetric channel with radiation Asymmetry in the flow is due to the propagation of peristaltic waves of different amplitudes and phase on the channel walls. The flow is generated by sinusoidal wave trains propagating with constant speed c along the tapered asymmetric channel walls.

$$Y = H_2 = b + m'X + d\sin\left[\frac{2\pi}{\lambda}(X - ct)\right] \tag{1}$$

$$Y = H_1 = -b - m'X - d\sin\left[\frac{2\pi}{\lambda}(X - ct) + \phi\right] \tag{2}$$

Where b is the half-width of the channel, d is the wave amplitude, c is the phase speed of the wave and m' $((m' \ll 1)$ is the non-uniform parameter, λ is the wavelength, t is the time and X is the direction of wave propagation. The phase difference ϕ varies in the range $0 \leq \phi \leq \pi$, $\phi = 0$ corresponds to symmetric channel with waves out of phase and further b, d and ϕ satisfy the following conditions for the divergent channel at the inlet $d\cos(\frac{\phi}{2}) \le b$

It is assumed that the left wall of the channel is maintained at temperature T_0, while the right wall has temperature T_1.

The equations governing the motion for the present problem are

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{3}$$

$$\rho\left[u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right] = -\frac{\partial p}{\partial x} + \mu\left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right] - \left[\sigma B_0^2\right](u+c) - \left[\frac{\mu}{k_1}\right](u+c) \tag{4}$$

$$\rho\left[u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y}\right] = -\frac{\partial p}{\partial y} + \mu\left[\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right] - \left[\sigma B_0^2\right]v - \left[\frac{\mu}{k_1}\right]v \tag{5}$$

$$\rho C_p\left[u\frac{\partial}{\partial x} + v\frac{\partial}{\partial y}\right]T = k\left[\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right]T + Q_0 - \frac{\partial q}{\partial y} \tag{6}$$

u and v are the velocity components in the corresponding coordinates, p is the fluid pressure, ρ is the density of the fluid, μ is the coefficient of the viscosity, k_1 is the permeability of the porous medium and k is the thermal conductivity, C_p is the specific heat at constant pressure, Q_0 is the constant heat addition/absorption and T is the temperature of the fluid.

Following Cogley *et al*. [36], it is assumed that the fluid is optically thin with a relatively low density and the radioactive heat flux is given by

$$\frac{\partial q}{\partial y} = 4\alpha^2(T_0 - T_1) \tag{7}$$

here α is the mean radiation absorption coefficient.

Introducing a wave frame (x, y) moving with velocity c away from the fixed frame (X, Y), the transformations

$$x = X - ct,\ y = Y,\ u = U - c,\ v = V \text{ and } p(x) = P(X, t) \tag{8}$$

Where u, v are the velocities in the x and y directions in the wave frame and p is the pressure in wave frame.

Introducing the following non-dimensional quantities:

$$\bar{x} = \frac{x}{\lambda} \quad \bar{y} = \frac{y}{b} \quad \bar{t} = \frac{ct}{\lambda} \quad \bar{u} = \frac{u}{c} \quad \bar{v} = \frac{v}{c} \quad h_1 = \frac{H_1}{b} \quad h_2 = \frac{H_2}{b} \quad p = \frac{b^2 p}{c\lambda\mu} \quad \theta = \frac{T - T_0}{T_1 - T_0}$$

$$\delta = \frac{b}{\lambda} \quad \mathrm{Re} = \frac{\rho c b}{\mu} \quad M = B_0 b\sqrt{\frac{\sigma}{\mu}} \quad \mathrm{Pr} = \frac{\mu C_p}{k} \quad \beta = \frac{Q_0 b^2}{\mu C_p (T_1 - T_0)} \quad N^2 = \frac{4\alpha^2 d_1^2}{k}$$

$$\varepsilon = \frac{d}{b} \tag{9}$$

where $\varepsilon = \frac{d}{b}$ is the non-dimensional amplitude of channel , $\delta = \frac{b}{\lambda}$ is the wave number, $k_1 = \frac{\lambda m'}{b}$ is the non - uniform parameter , Re is the Reynolds number, M is the Hartman number , $K = \frac{k}{b^2}$ Permeability parameter , Pr is the Prandtl number , β is the heat generation parameter and N^2 is the radiation parameter.

3. Solution of the Problem

In view of the above transformations (8) and non-dimensional variables (9), equations (3-6) are reduced to the following non-dimensional form after dropping the bars,

$$\mathrm{Re}\,\delta\left[u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right]=\left[-\frac{\partial p}{\partial x}+\delta^2\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}-Au-A\right] \quad (10)$$

$$\mathrm{Re}\,\delta^3\left[u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right]=\left[-\frac{\partial p}{\partial x}+\delta^4\frac{\partial^2 v}{\partial x^2}+\delta^2\frac{\partial^2 v}{\partial y^2}-M^2\delta^2 v-\delta^2\frac{1}{Da}v\right] \quad (11)$$

$$\mathrm{Re}\left[\delta u\frac{\partial \theta}{\partial x}+v\frac{\partial \theta}{\partial y}\right]=\frac{1}{\mathrm{Pr}}\left[\delta^2\frac{\partial^2\theta}{\partial x^2}+\frac{\partial^2\theta}{\partial y^2}\right]+\beta+\frac{N^2\theta}{P_r} \quad (12)$$

Where

$$A=\left(M^2+\frac{1}{Da}\right)$$

Applying long wave length approximation and neglecting the wave number along with low-Reynolds numbers. Equations (10-12) become

$$\frac{\partial^2 u}{\partial y^2}-Au=\frac{\partial p}{\partial x}+A \quad (13)$$

$$\frac{\partial p}{\partial y}=0 \quad (14)$$

$$\frac{1}{\mathrm{Pr}}\left(\frac{\partial^2\theta}{\partial y^2}\right)+\beta+\frac{N^2\theta}{P_r}=0 \quad (15)$$

The corresponding boundary conditions in dimensionless form are given by

$$u=-1,\ \theta=0 \text{ at } \quad y=h_1=-1-k_1x-\varepsilon\sin\left[2\pi(x-t)+\phi\right] \quad (16)$$

$$u=-1,\ \theta=1 \text{ at } \quad y=h_2=1+k_1x+\varepsilon\sin\left[2\pi(x-t)\right] \quad (17)$$

The closed form solutions for Equations (13 -15) with boundary conditions (16) and (17) are

$$u=b_1 Sin\ h[\alpha_1 y]+b_2 Cos\ h[\alpha_1 y]-\left(1+\frac{p}{A}\right) \quad (18)$$

Where

$$b_1=\left[\frac{-p}{A\ Sinh\ [\alpha_1 h_2]}\right]\left[\frac{Sinh\ [\alpha_1 h_2]\{Cosh\ [\alpha_1 h_1]-Cosh\ [\alpha_1 h_2]\}}{Sinh\ [\alpha_1 h_1]Cosh\ [\alpha_1 h_2]-Sinh\ [\alpha_1 h_2]Cosh\ [\alpha_1 h_1]}\right]$$

$$b_2=\left[\frac{p}{A}\right]\left[\frac{Sinh\ [\alpha_1 h_1]-Sinh\ [\alpha_1 h_2]}{Sinh\ [\alpha_1 h_1]Cosh\ [\alpha_1 h_2]-Sinh\ [\alpha_1 h_2]Cosh\ [\alpha_1 h_1]}\right] \qquad p=\frac{\partial p}{\partial x}$$

$$\theta=b_3 Cos\ [N\ y]+b_4 Sin\ [N\ y]-b_5 \quad (19)$$

Where

$$b_3=\left(\frac{1}{\cos\ N\ h_1}\right)\left(a_3+\left(\frac{\cos[N\ h_1]+a_3(\cos[N\ h_1]-\cos[N\ h_2])}{Sin[N\ h_1]\cos[N\ h_2]-Sin[N\ h_2]\cos[N\ h_1]}\right)\right)$$

$$b_4=\left(\frac{-\cos[N\ h_1]-a_3(\cos[N\ h_1]-\cos[N\ h_2])}{Sin[N\ h_1]\cos[N\ h_2]-Sin[N\ h_2]\cos[N\ h_1]}\right) \qquad b_5=\frac{\beta P_r}{N^2}$$

The coefficients of the heat transfer Zh_1 and Zh_2 at the walls $y = h_1$ and $y = h_2$ respectively, are given by

$$Zh_1=\theta_y h_{1x} \quad (20) \qquad Zh_2=\theta_y h_{2x} \quad (21)$$

The solutions of (20) and (21) be

$$Zh_1 = \theta_y h_{1x} = (-N b_3 Sin[N y] + N b_4 Cos[N y])(-2\pi\varepsilon Cos[2\pi(x-t)+\phi] - k_1)$$
(22)

$$Zh_2 = \theta_y h_{2x} = (-N b_3 Sin[N y] + N b_4 Cos[N y])(2\pi\varepsilon Cos[2\pi(-t+x)] + k_1) \quad (23)$$

The volumetric flow rate in the wave frame is defined by

$$q = \int_{h_1}^{h_2} u\, dy = p\left[-b_6 + b_7 - \frac{h}{A}\right] - h \quad (24)$$

Where

$$b_6 = \left[\frac{1}{\alpha_1 A\, Sinh[\alpha_1 h_2]}\right] * \left[\frac{Sinh[\alpha_1 h_2]\{Cosh[\alpha_1 h_1] - Cosh[\alpha_1 h_2]\}}{Sinh[\alpha_1 h_1]\, Cosh[\alpha_1 h_2] - Sinh[\alpha_1 h_2]\, Cosh[\alpha_1 h_1]}\right] * \left[\frac{[Cosh[\alpha_1 h_2] - Cosh[\alpha_1 h_1]]}{Sinh[\alpha_1 h_1]\, Cosh[\alpha_1 h_2] - Sinh[\alpha_1 h_2]\, Cosh[\alpha_1 h_1]}\right]$$

$$b_7 = \left[\frac{1}{A\alpha_1}\right] * \left[\frac{[Sinh[\alpha_1 h_1] - Sinh[\alpha_1 h_2]] * [Sinh[\alpha_1 h_2] - Sinh[\alpha_1 h_1]]}{Sinh[\alpha_1 h_1] Cosh[\alpha_1 h_2] - Sinh[\alpha_1 h_2] Cosh[\alpha_1 h_1]}\right]$$

$$h = h_2 - h_1$$

The pressure gradient obtained from equation (24) can be expressed as

$$\frac{dp}{dx} = \left[\frac{(q+h)}{-b_6 + b_7 - \frac{h}{A}}\right] \quad (25)$$

The instantaneous flux Q (x, t) in the laboratory frame is

$$Q = \int_{h_2}^{h_1} (u+1)\, dy = q - h \quad (26)$$

The average volume flow rate over one wave period (T=□□/ *c)* of the peristaltic wave is defined as

$$\overline{Q} = \frac{1}{T}\int_0^T Q\, dt = q + 1 + d \quad (27)$$

From the equations (25) and (27), the pressure gradient can be expressed as

$$\frac{dp}{dx} = \left(\frac{((\overline{Q} - 1 - d) + h)}{-b_6 + b_7 - \frac{h}{A}}\right) \quad (28)$$

4. Numerical Results and Discussion

The effects of Prandtl number (Pr), heat generation parameter (β), Non - uniform parameter (k_1), Radiation parameter (N) and Phase angle (ϕ) on temperature profiles and heat transfer coefficients (at y = h_1 and y = h_2) are presented and discussed in this section.

The influence of the radiation parameter N (N = 0.5, 0.7, 0.9) on temperature (θ) is depicted in Figure 1 with fixed values of Pr = 1, β = 2, k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6. It is notice that the temperature increases with an increase in radiation parameter. Figure 2 represents the flow structure of the temperature (θ) for different values of Prandtl number P_r (P_r = 1, 1.5, 2) with β = 2, N= 0.5, k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.Indeed, the temperature increases with an increase in Prandtl number in entire tapered channel. The influence of heat generator β (β = 2, 4, 6) with fixed Pr =1, N= 0.5, k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6 on temperature (θ) is shown in the Figure (3). This figure indicates that an increase in heat generation parameter, results in increase in the temperature of the fluid. Figure (4) shows that the effect of phase angle ϕ ($\phi = \pi, \frac{\pi}{2}, \frac{\pi}{6}$) on temperature (θ) with fixed Pr =1, N= 0.5, β = 2, k_1= 0.1, x =0.6, t =0. 4, ε = 0.2. It is observed that temperature is increases in the entire tapered channel with decreases the values of ϕ . Figure 5 presents the flow structure of temperature (θ) for different values of non- uniform parameter k_1 (k_1 =0.1, 0.2, 0.3) with Pr =1, N= 0.5, β = 2, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.This figure indicates that an increase in k_1, the results gradually increases in the temperature of the fluid. Hence we conclude that the temperature increases with an increase in radiation parameter, Prandtl number, heat generation parameter, non-uniform parameter and phase angle and also the temperature profile is found almost parabolic, significance variations in temperature lies near the center of the channel which is due to the viscous dissipation.

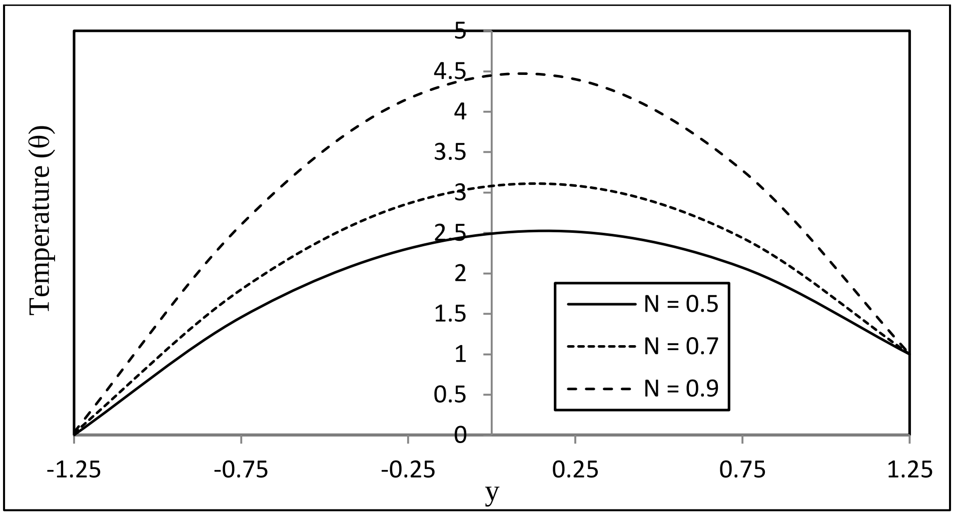

Figure 1. Effect of N on Temperature (θ) with Fixed Pr = 1, β = 2, k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6

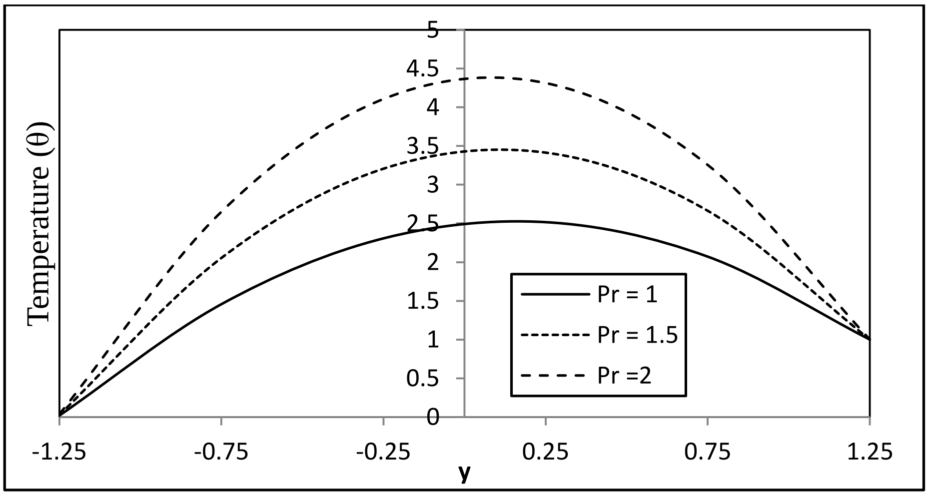

Figure 2. Effect of Pr on Temperature (θ) with Fixed β = 2, N= 0.5, k1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6

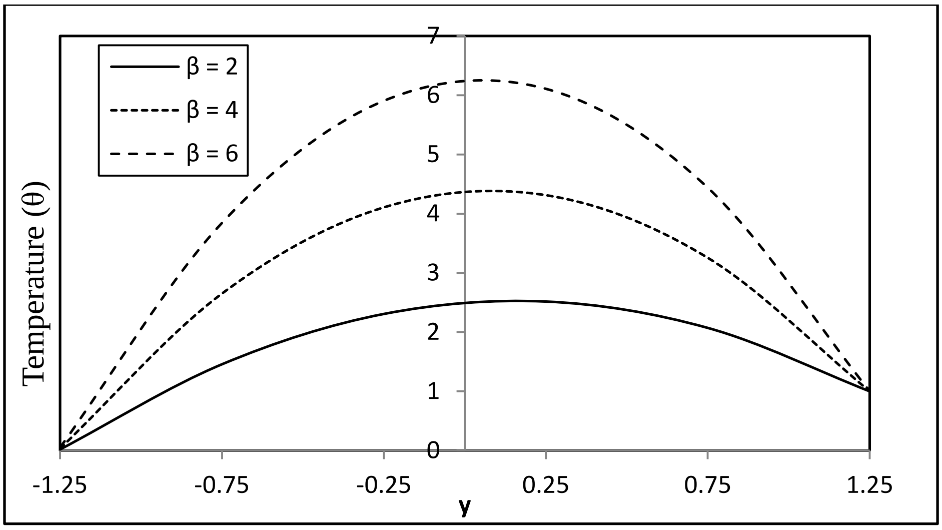

Figure 3. Effect of β on Temperature (θ) with Fixed Pr =1, N= 0.5, k1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.

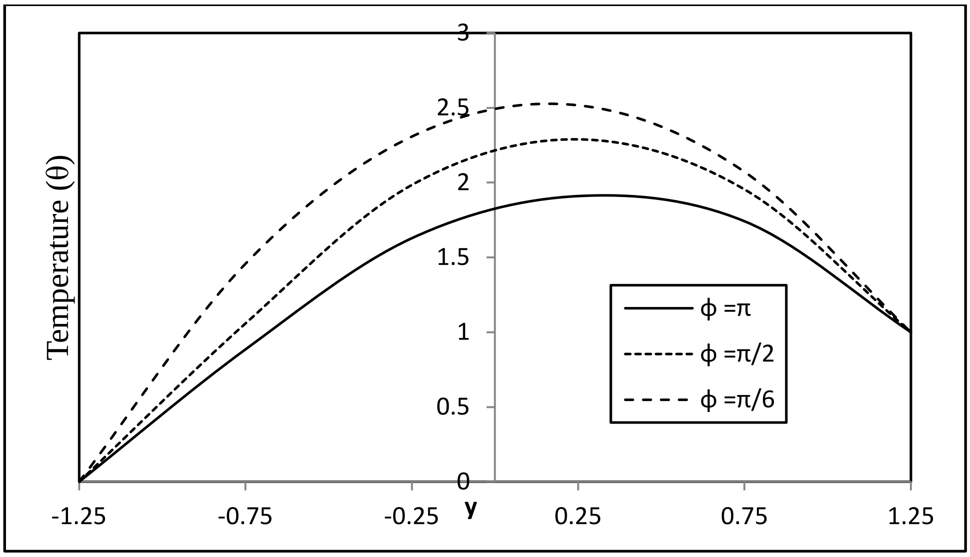

Figure 4. Effect of ϕ on Temperature (θ) with Fixed Pr =1, N= 0.5, β = 2, k1= 0.1, x = 0.6, t =0. 4, ε = 0.2

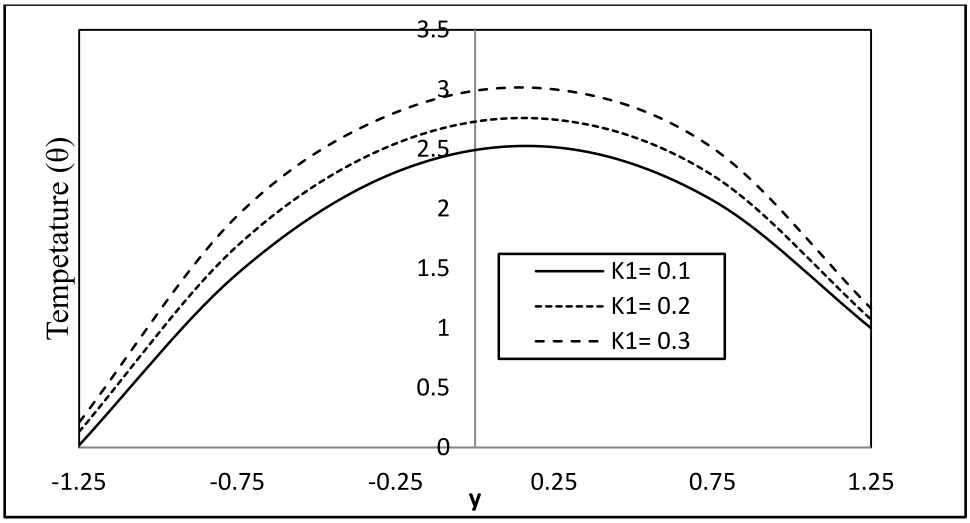

Figure 5. Effect of k1 on Temperature (θ) with Fixed Pr =1, N= 0.5, β = 2, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.

Figure 6 presents the flow structure of heat transfer coefficient at the wall y = h_1 for different values of N (N = 0.5, 0.7, 0.9) with β = 2, Pr = 1, k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.We notice that heat transfer coefficient decreases in the channel x ε [0, 0.6] and increases in the channel x ε [0.6, 1] with increasing the values of radiation parameter (N). Influence of Prandtl number Pr (Pr 1, 1.5, 2) on heat transfer coefficient at the wall y = h_1 with fixed N= 0.5, β = 2, k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6. It is shown that heat transfer coefficient profile decreases in x ε [0.1, 0.6] and increases in the range x ε [0, 0.1] ∪ [0.6, 1] with increasing the values of Pr. Figure 8 shows that the heat transfer coefficient profile for different values of heat generation parameter β (β = 2, 4, 6) with N= 0.5, Pr = 1, k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6. Indeed, heat transfer coefficient decreases in x ε [0.1, 0.6] and increases in the range x ε [0, 0.1] ∪ [0.6, 1] with increasing the values of β. Figure 9 reveals the influence of non-uniform parameter k_1 (k_1 = 0.1, 0.2, 0.3) on heat transfer coefficient with fixed N= 0.5, Pr = 1, β = 2, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6. It is interested to note that the heat transfer coefficient decreases in entire tapered channel at the wall y = h_1 with an increase in non- uniform parameter.

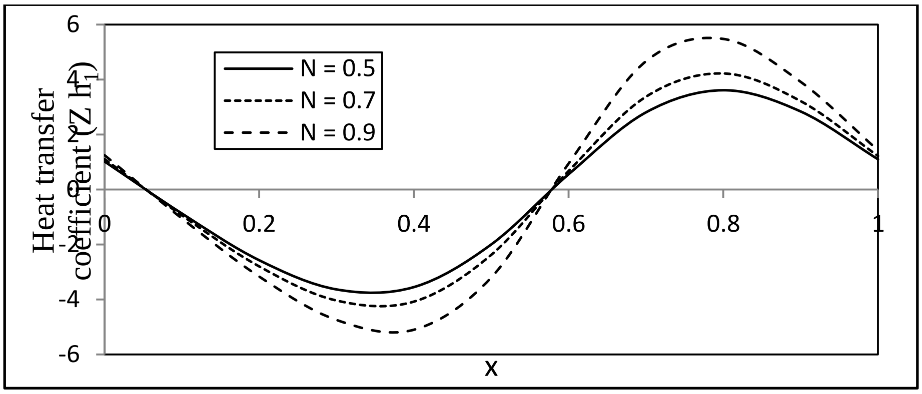

Figure 6. Effect of N on Heat Transfer Coefficient at the Wall y = h1 with Fixed β = 2, Pr = 1, k1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6

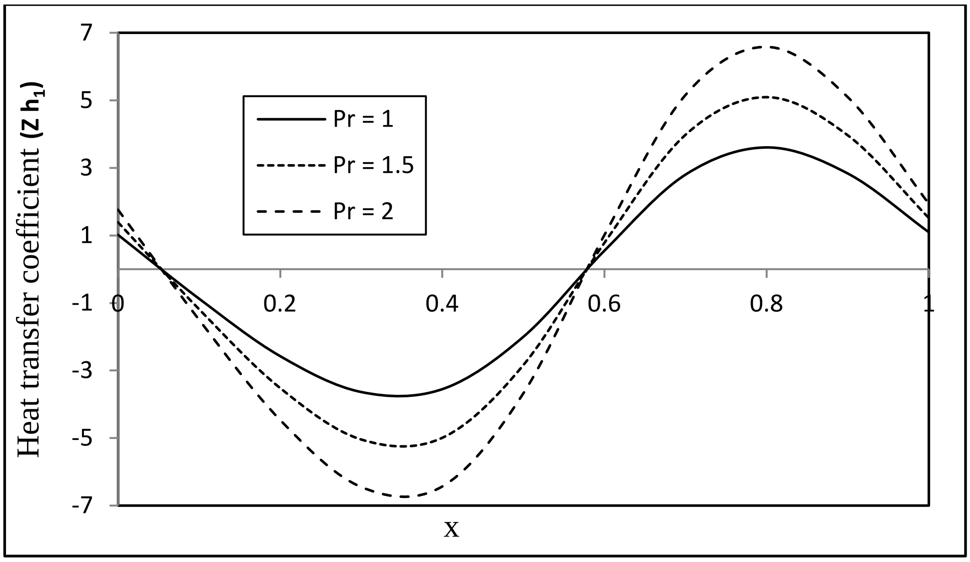

Figure 7. Effect of Pr on Heat Transfer Coefficient at the Wall y = h1 with Fixed N= 0.5, β = 2, k1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6

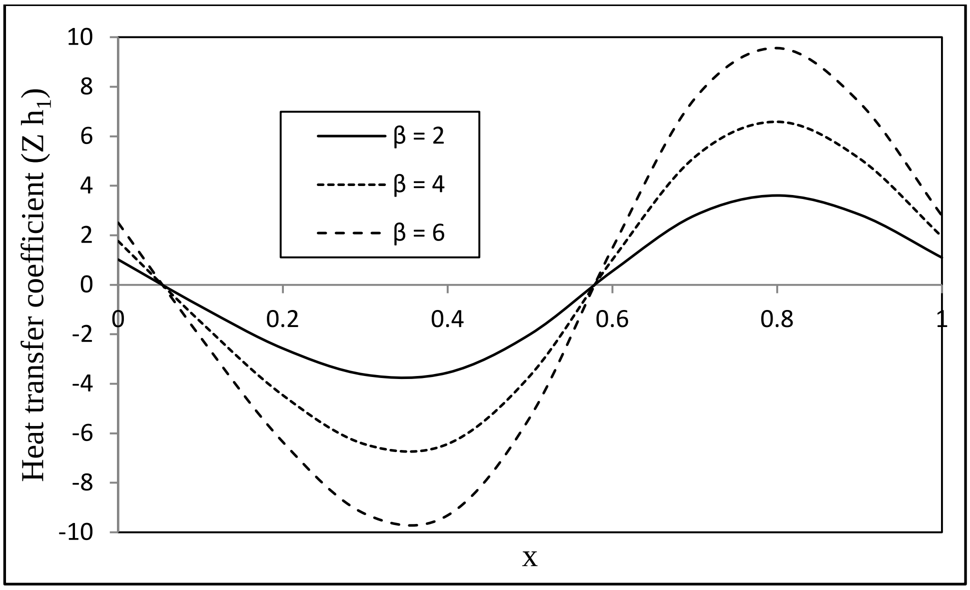

Figure 8. Effect of β Heat Transfer Coefficient at the Wall y = h1 with Fixed N= 0.5, Pr = 1, k1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6

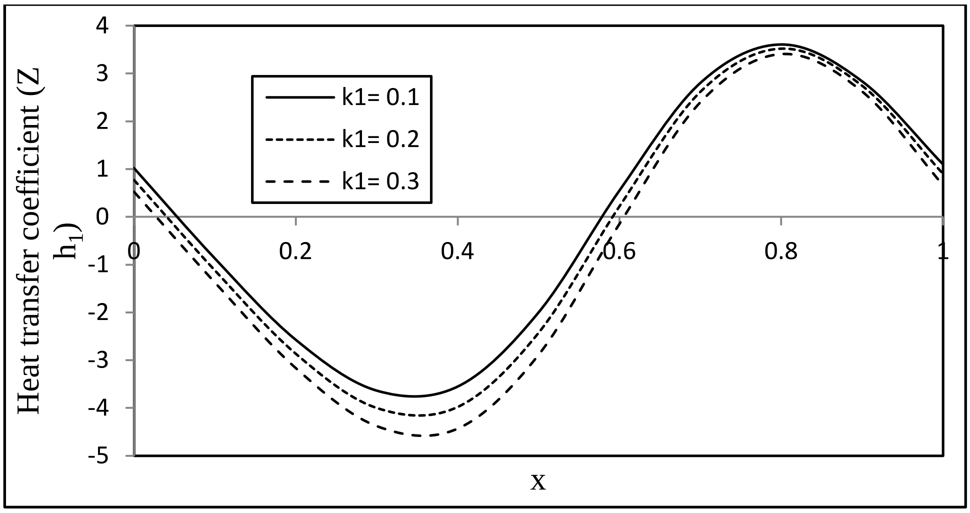

Figure 9. Effect of k1 on Heat Transfer Coefficient at the Wall y = h1 with Fixed N = 0.5, Pr = 1, β = 2, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6

Effect of radiation parameter N (N = 0.5, 0.7, 0.9) on heat transfer coefficient at the wall $y = h_2$ with

β = 2, Pr = 1, k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6 as depicted in figure (10). This figure indicates that the heat transfer coefficient profile decreases in x ε [0.1, 0.7] and increases in the range x ε [0, 0.1] ∪ [0.7, 1] with an increasing the values of N. Variations of the heat transfer coefficient at the wall $y = h_2$ have been presented in figure (11) for various values of Prandtl number with fixed other parameters N= 0.5, β = 2, k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.It can be seen that the heat transfer coefficient profile decreases in x ε [0.1, 0.7] and increases in the range x ε [0, 0.1] ∪ [0.7, 1] with an increasing the values of Pr. Figure 12, it may be notice that the heat transfer coefficient profile decreases in x ε [0.1, 0.7] and increases in the range x ε [0, 0.1] ∪ [0.7, 1] with an increasing the values of β. The influence of non – uniform parameter k_1 (k_1 = 0.1, 0.2, 0.3) on heat transfer coefficient as shown in figure 13.It is interested to noticed that the heat transfer coefficient decreases in x ε [0, 0.8] and increases in the range x ε [0.8, 1].

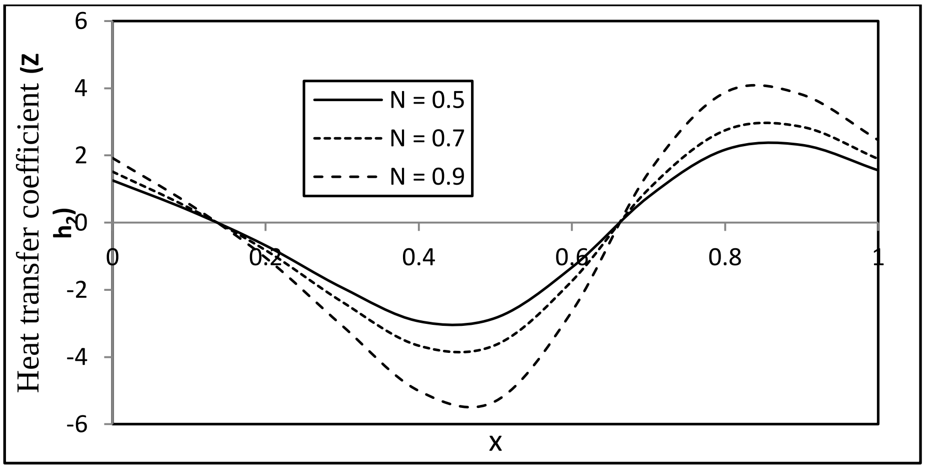

Figure 10. Effect of N on Heat Transfer Coefficient at the Wall y = h2 with Fixed β = 2, Pr = 1, k1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6

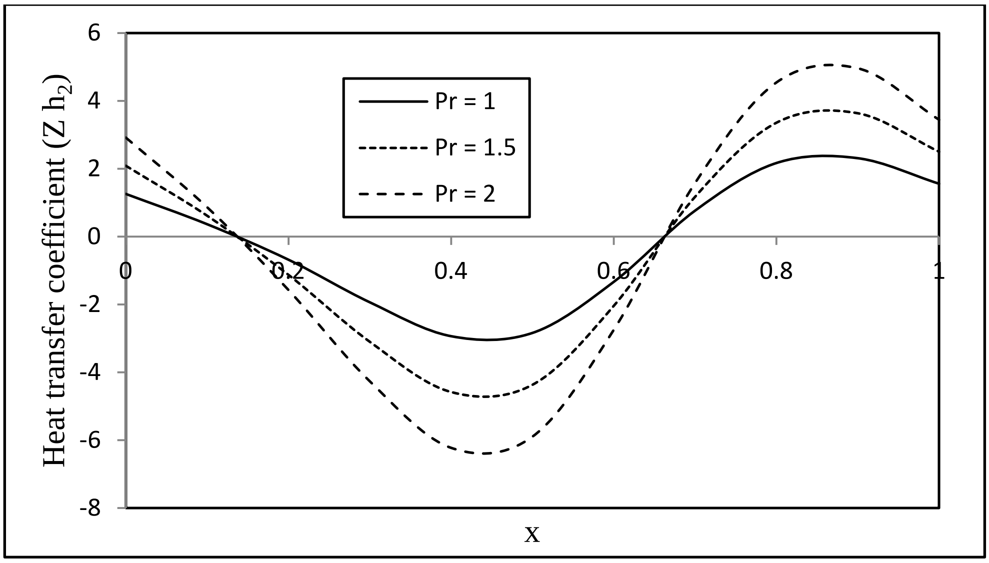

Figure 11. Effect of Pr on Heat Transfer Coefficient at the Wall y = h2 with Fixed N= 0.5, β = 2, k1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.

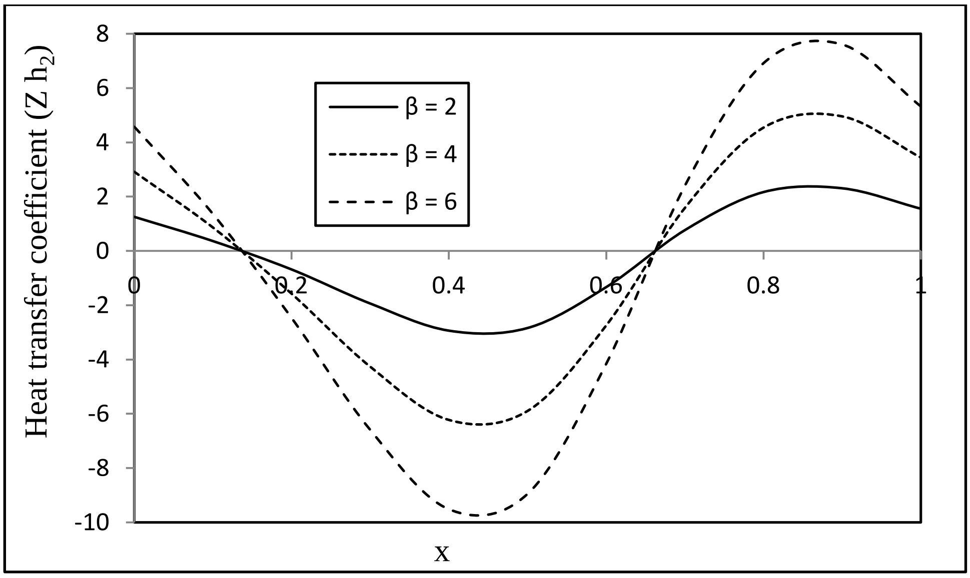

Figure 12. Effect of β on Heat Transfer Coefficient at the Wall y = h2 with Fixed N= 0.5, Pr = 1, k1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.

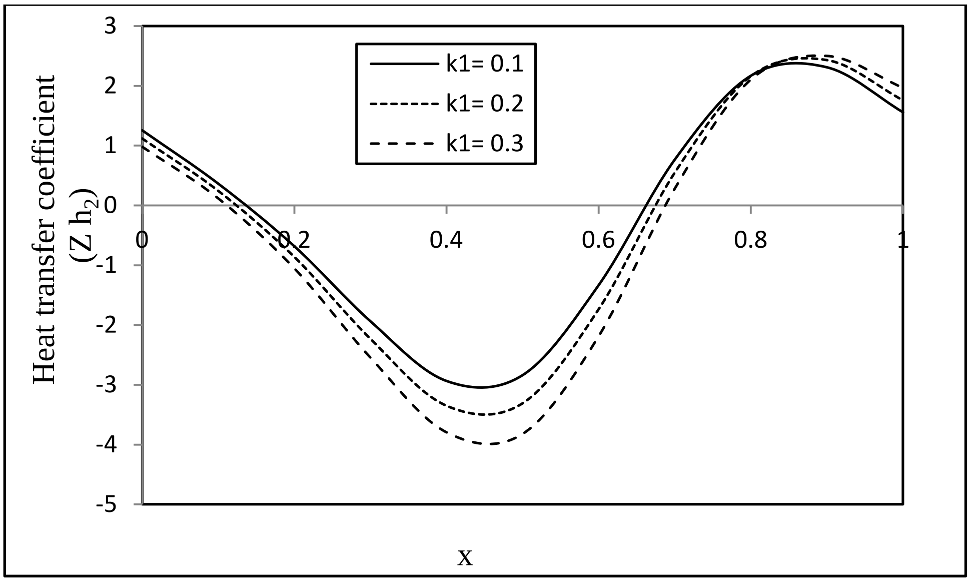

Figure 13. Effect of k1on Heat Transfer Coefficient at the Wall y = h2 with Fixed N= 0.5, Pr = 1, β = 2, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6

5. Conclusions

In this paper, we study the analysis of heat transfer on MHD peristaltic flow with porous medium through coaxial tapered asymmetric channel with radiation under the assumptions of long wavelength approximation with low Reynolds number.

1. The temperature increases with increase in the values of radiation parameter (N), Prandtl number (Pr), heat generation parameter (β), non-porous parameter (k_1) and phase angle (ϕ) .
2. The heat transfer coefficient decreases in the channel x ε [0.1, 0.6] and increases in the channel x ε [0, 0.1] ∪ [0.6, 1] with an increasing the values of N, Pr, β.
3. The heat transfer coefficient decreases in entire tapered channel with an increase in non-porous parameter.
4. The heat transfer coefficient profile decreases in x ε [0.1, 0.7] and increases in the range x ε [0, 0.1] ∪ [0.7, 1] with an increasing the values of N, Pr, β.
5. The heat transfer coefficient decreases in x ε [0, 0.8] and increases in the range x ε [0.8, 1] with an increase in non-uniform parameter.

References

[1] T. W. Lathem, “Fluid motion in a peristaltic pump”. Master’s thesis, Massachusetts, MIT, Cambridge, **(1966)**.
[2] A. H. Shapiro, M. Y. Jaffrin and S. L. Weinberg, “Peristaltic pumping with long wavelengths at low Reynolds number”, Fluid Mech., vol. 37, **(1969)**, pp. 799-825.
[3] M.Y. Jaffrin and A.H. Shapiro, “Peristaltic pumping”, Ann. Rev. Fluid Mech., vol. 3, **(1971)** ,pp.13-36.
[4] L.M. Srivastava and V.P. Srivastava, “Peristaltic transport of blood: Casson model II”, J. Biomech., vol17, **(1984)**, pp. 821-829.
[5] V.P. Srivastava and M. Saxena, “A Two-fluid model of non-Newtonian blood flow induced by peristaltic waves”, Rheol. Acta, vol 34, **(1995)**, pp. 406-414.
[6] L.M. Srivastava and V.P. Srivastava, “Influence of wall elasticity and Poiseuille flow on peristaltic induced flow of a particle-fluid mixture”. Int. J. Engng. Sci., vol. 35, **(1997)**, pp. 1359-1361.
[7] Kh.S. Mekheimer, F.E. El-Shehawey and A. A. Elaw, “Peristaltic motion of a particle fluid suspension in a planar channel”, Int. J. Theo. Phys., vol. 37, **(1998)**, pp. 2895- 2920.
[8] J.C. Misra and S.K. Pandey, “Peristaltic transport of blood in small vessels: study of a mathematical model”, Computers and Mathematics with Applications, vol. 43, **(2002)**, pp. 1183-1193

[9] T. Hayat, Y. Wang, A.M. Siddiqui and K. Hutter, "Peristaltic motion of a third order fluid in a circular cylindrical tube", Mathematical Models and Methods in Applied Sciences, vol. 12, **(2002)**, pp. 1671-1706.
[10] T. Hayat and N. Ali, "On mechanism of peristaltic flows for power-law fluid", Physica Acta, vol. 371, **(2006)**, pp. 188-194.
[11] T. Hayat and N. Ali, "Peristaltic induced motion of a MHD third grade fluid- in a deformable tube", Physica Acta, vol. 370, **(2006)**, pp. 225-239.
[12] Medhavi, Amit, "Peristaltic pumping of a particulate suspension in a catheterized tube", E. Journal of Sci. and Tech., vol. 5, **(2010)**, pp. 77-93.
[13] S. Ravikumar, G. P. Rao and R. S. Prasad, "Peristaltic flow of a couple stress fluid flows in a flexible channel under an oscillatory flux", Int. J. of Appl. Math and Mech., vol. 6, no. 13, **(2010)**, pp. 58-71.
[14] S. Ravikumar and R. S. Prasad, "Interaction of pulsatile flow on the peristaltic motion of couple stress fluid through porous medium in a flexible channel", Eur. J. Pure Appl. Math, vol. 3, **(2010)**, pp. 213-226.
[15] S. Ravikumar, G. P. Rao and R. S. Prasad, "Peristaltic flow of a second order fluid in a flexible channel", Int. J. of Appl. Math and Mech., vol. 6, no. 18, **(2010)**, pp. 13-32.
[16] Kh.S. Mekheimer, "Non linear peristaltic transport of magnetohydrodynamic flow an inclined planner channel" Arab J.Sci Eng., vol. 28, **(2003)**, pp. 183-201.
[17] T. Hayat and N. Ali, "Slip effects on peristaltic transport of MHD fluid with variable viscosity" Physics Letters A, vol. 372, **(2008)**, pp. 1477-1489.
[18] T. Hayat, Afsar Ambreen, M. Khan and S. Asghar, "Peristaltic transport of a third order fluid under the effect of a magnetic field", Appl Math Comput., vol. 53, **(2007)**, pp. 1074-87.
[19] S. Ravikumar, "Effect of couple stress fluid flow on magnetohydrodynamic peristaltic blood flow with porous medium trough inclined channel in the presence of slip effect-Blood flow study", International Journal of Bio-Science and Bio-Technology, vol. 7, no. 5, **(2015)**, pp. 65-84.
[20] S. Ravikumar, "The effects of the couple stress fluid flow on the magneto hydrodynamic peristaltic motion with a uniform porous medium in the presence of slip effect", Jordan Journal of Mechanical and Industrial Engineering (JJMIE), vol. 9, no. 4, **(2015)** , pp. 269-278.
[21] S. Ravikumar, "MHD Peristaltic Transportation of a Conducting Blood Flow with Porous Medium through Inclined Coaxial Vertical Channel", International Journal of Bio-Science and Bio-Technology, vol. 8, no. 1, **(2016)**, pp. 11-26.
[22] S. A. Victor and V. L. Shah, Int. J. of heat and mass transfer, vol. 19, **(1976)**, pp. 777.
[23] R. P. Agarwal, "Heat transfer to pulsatile flow of conducting fluid in a porous channel", PhD Thesis, **(1989)**, Allahabad.
[24] S. Hina, T. Hayat, S. Asghar and A. A. Hendi, "Influence of compliant walls on peristaltic motion with heat/mass transfer and chemical reaction", International Journal of Heat and Mass Transfer, vol 55, **(2012)**, pp.3386−3394.
[25] T. Hayat, S. Noreen, M. Alhothuali S. Asghar and A. Alhomaidan, "Peristaltic flow under the effects of an induced magnetic field and heat and mass transfer", International Journal of Heat and Mass Transfer, vol 55, **(2002)**, pp.443−452.
[26] F. M. Abbasi, T. Hayat, A. Alsaedi and B. Ahmed, "Soret and Dufour effects on peristaltic transport of MHD fluid with variable viscosity", Appl Math Inf Sci, vol 8, **(2014)**, pp.211−219.
[27] T. Hayat, F.M. Abbasi and S. Obaidat, "Peristaltic motion with Soret and Dufour effects", Magnetohydrodynamics, vol 47, **(2011)**, pp.295−302.
[28] D. Hall, G.C.Vliet and T.L. Bergman, "Natural convection cooling of vertical rectangular channels in air considering radiation and wall conduction", J. Electron. Pack, vol 121, **(1999)**, pp.75-84.
[29] EI. M. A. Hakiem, "MHD oscillatory flow on free convection radiation through a porous medium with constant suction velocity", J. Magnetism and Magnetic Materials, vol 220, **(2000)**, pp.271-276.
[30] A. Raptis, "Radiation and flow through a porous medium", J. Porous Media, vol 4, **(2001)**, pp.271-273.
[31] A.Y. Bakier, "Thermal radiation effects on mixed convection from vertical surfaces in saturated porous media", Int. Comm. Heat and Mass Transfer, vol 28, **(2001)**, pp.243-248.
[32] A. Raptis and C. Perdikis, "Unsteady flow through a highly porous medium in the presence of radiation", Transport in Porous Media, vol 57, **(2004)**, 171-179.
[33] D.C. Sanyal and A. Adhikari, "Effects of radiation on MHD vertical channel flow", Bull. Cal. Math. Soc., vol 98, No 5, **(2006)**, pp. 487-497.
[34] C.G. Rao, "Interaction of surface radiation with conduction and convection from a vertical channel with multiple discrete heat sources in the left wall", Numer. Heat Transfer Part A: Appl., vol 52, **(2007)**, pp.831-848.
[35] V.R. Prasad and N.B. Reddy, "Radiation effects on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium", J. Energy, Heat and Mass Transfer, vol 30, **(2008)**, pp.57-78.
[36] A.C.L. Cogley, W.G.Vinvent and E.S. Giles, "Differential approximation for radiative heat transfer in non-linear equations-grey gas near equilibrium", American Institute of Aeronautics and Astronautics, vol 6, **(1968)**, pp.551–553.

Author

S. Ravi Kumar has done B. Sc. (Mathematics) from Sri Krishna Devaraya University, Anantapur, India in 1999, M.Sc (Mathematics) from Sri Venkateswara University, Tirupati, India in 2002, M. Phil (Fluid Mechanics) from Sri Krishna Devaraya University, Anantapur, India in 2006 and PhD (Fluid Mechanics) from Sri Krishna Devaraya University, Anantapur, India in 2009. He has published more than 25 papers in International / National Journals. His research areas of interest are Peristaltic fluid flows, Couple stress fluid flows, Heat and Mass Transfer, MHD fluid flows and Fluid Dynamics.