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INFLUENCE OF HEAT TRANSFER ON MAGNETOHYDRODYNAMIC PERISTALTIC BLOOD FLOW WITH POROUS MEDIUM THROUGH A COAXIAL VERTICAL ASYMMETRIC TAPERED CHANNEL –AN ANALYSIS OF BLOOD FLOW STUDY

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ABSTRACT

Investigations concerning an influence of heat transfer on magnetohydrodynamic peristaltic blood flow with porous medium through coaxial vertical asymmetric tapered channel- an analysis of blood flow study. Exact analytical expressions of axial velocity, temperature, heat transfer coefficient at $y = h_1$ and $y = h_2$ and pressure gradient are obtained under the assumption of long wave length and low Reynolds number approximations. The influence of the physical parameters of the problem on these distributions are discussed numerically and explained graphically. We notice that the temperature distribution (θ) increases by increase in Prandtl number, heat generator operator and non porous parameter and also we observe that the heat transfer coefficient (at the wall y = h1) decreases in the portion of the channel $x\varepsilon[0, 0.55]$ and then it is increases in the rest of the channel $x\varepsilon[0.55,1]$ by increase in prandtl number and heat generator operator.

KEYWORDS: Heat transfer, peristaltic flow, porous medium, MHD, coaxial vertical asymmetric tapered channel.

INTRODUCTION

In view of its importance, numerous authors have studied peristalsis in both physiological and mechanical situations. LATHAM [1] made initial effort regarding peristaltic mechanism of viscous fluids. Afterward, this topic has been examined extensively for both non Newtonian and viscous. In another attempt, Jaffrin and Shapiro [2] investigated the basic principles of peristaltic pumping in a two dimensional channel. Mishra and Ramachandra Rao [3] whose results have been discussed the peristaltic flow of a Newtonian fluid in an asymmetric channel. Some important contributions beyond this, and of recent years, include the studies of S. Srinivas et al [4], T.Hayat et al [5], T.Hayat et al [6], M.H.Haroun [7], Kh.S. Mekheimer et al [8], S.Srinivas et al [9], T.Hayat et al et al [10], P. Hariharan [11], S. Nadeem et al [12] and T. Hayat et al [13].

The study of flow through porous medium has received much attention in recent years because of its application in industrial, bio-physical and hydrological problem, particularly in petroleum, chemical and nuclear industries. The role played by porous medium in the study of the flow of blood and other fluids and electro-osmosis, biological membranes and filters in bio-chemical engineering is more essential. This study is also useful to understand the mechanism of transfer heat from the deep interior of the earth to a shallow depth in the geothermal regions which is of vital importance in the present day grave power crisis. . In view of its considerable importance, Rapits et al.[14] studied a problem on free convection flow through a porous medium bounded by a vertical surface. Lukashave et al.[15] considered a mathematical model of the peristaltic transport of liquid initiated by the auto-wave process of mass transport through the porous capillary wall. In another attempt, Ravikumar et al [16, 17 & 18] whose results have been discussed on peristaltic fluid flows through the channels with porous medium.

The discussion on MHD flows is quite useful and attractive because it is used in magnetic wound or cancer tumor treatment causing hypothermia, targeted transport of drugs using magnetic particles as MRI (magnetic resonance imaging) to diagnose the disease. Some significant studies involving MHD flows were discussed by Srivastava and Agrawal [19] and Agrwal and Anwaruddin [20]. Some investigations on this topic have been directed through the Refs. (Hayat et al.[21 &22]. Subba Reddy et al. [23], Ravikumar [24, 25, 26&27].

The study of heat transfer on non-Newtonian/Newtonian fluids flow is also very important in many engineering applications, such as oil recovery, food processing, paper making and slurry transporting. Vajravelu *et al*., [28] have been analyzed the heat transfer characteristics on peristaltic flow in a porous annulus. Mekheimer and Abd Elmaboud [29] examined MHD and heat transfer effects on peristaltic transport of viscous fluid in a vertical annulus. Some of the important theoretical studies on peristalsis have been discussed by G. Radhakrishnamacharya [30], N. T.M. Eldabe [31], M. Kothandapani et al [32], Vasudev et al. [33] and F. M. Abbasi et al [34].

FORMULATION OF THE PROBLEM

Let us consider the peristaltic flow of an incompressible viscous fluid with porous medium through a coaxial vertical asymmetric tapered channel under the action of a magnetic field. Asymmetry in the flow is due to the propagation of peristaltic waves of different amplitudes and phase on the channel walls. The heat transfer in the channel is taken into account. The flow is generated by sinusoidal wave trains propagating with constant speed c along the tapered asymmetric channel walls.

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

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

Where b is the half-width of the channel, d is the wave amplitude, c is the phase speed of the wave and m' ($(m' << 1)$ 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 $0 \le \phi \le \pi$, $\phi = 0$ 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

$$d\cos\left(\frac{\phi}{2}\right) \le b$$

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

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad (3)$$

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

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

$$\rho C_p\left[\frac{\partial}{\partial t} + u\frac{\partial}{\partial x} + v\frac{\partial}{\partial y}\right]T = k\left[\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right]T + Q_0 \quad (6)$$

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.

The relative boundary conditions are

$$\bar{U} = 0, \bar{T} = T_0, \ \bar{C} = C_0 \text{ at } \bar{Y} = \bar{H}_1$$

$$\bar{U} = 0, \bar{T} = T_1, \ \bar{C} = C_1 \text{ at } \bar{Y} = \bar{H}_2$$

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

$$x = X - ct,\ y = Y,\ u = U - c,\ v = V \text{ and } p(x) = P(X, t) \tag{7}$$

Introducing the following non-dimensional quantities:

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

$$\delta = \frac{b}{\lambda} \quad \mathrm{Re} = \frac{\rho c b}{\mu} \quad M = B_0 b \sqrt{\frac{\sigma}{\mu}} \quad \Pr = \frac{\mu C_p}{k} \quad \beta = \frac{Q_0 b^2}{\mu C_p (T_1 - T_0)} \quad \varepsilon = \frac{d}{b} \tag{8}$$

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 and β is the heat generation parameter.

SOLUTION OF THE PROBLEM

In view of the above transformations (7) and non-dimensional variables (8), equations (3-6) are reduced to the following non-dimensional form after dropping the bars,

$$\mathrm{Re}\,\delta\left[\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right] = \left[-\frac{\partial p}{\partial x} + \delta^2\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} - Au - A\right] \tag{9}$$

$$\mathrm{Re}\,\delta^3\left[\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y}\right] = \left[-\frac{\partial p}{\partial x} + \delta^4\frac{\partial^2 v}{\partial x^2} + \delta^2\frac{\partial^2 v}{\partial y^2} - M^2\delta^2 v - \frac{1}{Da}v\right] \tag{10}$$

$$\mathrm{Re}\left[\delta\frac{\partial \theta}{\partial t} + \delta u\frac{\partial \theta}{\partial x} + v\delta\frac{\partial \theta}{\partial y}\right] = \frac{1}{\Pr}\left[\delta^2\frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2}\right] + \beta \tag{11}$$

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 (9-11) become

$$\frac{\partial^2 u}{\partial y^2} - Au = \left(\frac{\partial p}{\partial x} + A\right) \tag{12}$$

$$\frac{\partial p}{\partial y} = 0 \tag{13}$$

$$\frac{1}{\Pr}\left(\frac{\partial^2 \theta}{\partial y^2}\right) + \beta = 0 \tag{14}$$

The relative boundary conditions in dimensionless form are given by

u = -1, θ = 0 at $y = h_1 = 1 - k_1 x - \varepsilon \sin[2\pi(x-t)+\phi]$ (15)

u = -1, θ = 1 at $y = h_2 = 1 + k_1 x + \varepsilon \sin[2\pi(x-t)]$ (16)

The closed form solutions for Equations (12 -14) with boundary conditions (15) and (16) are given by

$$u = Q_1 Sinh[\alpha_1 y] + Q_2\, Cosh[\alpha_1 y] - \left(\frac{A+p}{A}\right) \tag{17}$$

$$\theta = Q_3 + Q_4 y - \beta \Pr y^2 \tag{18}$$

Where

$$Q_1 = \left(\frac{-p}{A\, Sinh[\alpha_1 h_2]}\right)\left(\frac{Sinh[\alpha_1 h_2]\,(Cosh[\alpha_1 h_1] - Cosh[\alpha_1 h_2])}{Sinh[\alpha_1 h_1]\, Cosh[\alpha_1 h_2] - Sinh[\alpha_1 h_2] Cosh[\alpha_1 h_1]}\right)$$

$$Q_2 = \left(\frac{p}{A}\right)\left(\frac{Sinh[\alpha_1 h_1] - Sinh[\alpha_1 h_2]}{Sinh[\alpha_1 h_1] Cosh[\alpha_1 h_2] - Sinh[\alpha_1 h_2] Cosh[\alpha_1 h_1]}\right)$$

$$Q_3 = [1 + \beta \Pr h_2^{\,2}] - \left[\frac{-h_2 + \beta \Pr h_2 [h_1^{\,2} - h_2^{\,2}]}{[h_1 - h_2]}\right] \quad Q_4 = \left(\frac{-1 + \beta \Pr [h_1^{\,2} - h_2^{\,2}]}{[h_1 - h_2]}\right)$$

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

$$Zh_1 = \theta_y h_{1x} \tag{19}$$

$$Zh_2 = \theta_y h_{2x} \tag{20}$$

The solutions of the coefficients of the heat transfer be

$$Zh_1 = \theta_y h_{1x} = [Q_4 - 2\beta \Pr y][-2\pi\varepsilon\, Cos\,[2\pi(x-t)+\phi] - k_1]$$

(21)

$$Zh_2 = \theta_y h_{2x} = [Q_4 - 2\beta \Pr y][2\pi\varepsilon Cos[2\pi(-t+x)] + k_1] \tag{22}$$

VOLUMETRIC FLOW RATE

The volumetric flow rate in the wave frame is defined by

$$q = \int_{h_1}^{h_2} u\, dy = \quad p\left(-Q_5 + Q_6 - \frac{(h_2 - h_1)}{A}\right) - (h_{2.} - h_1) \tag{23}$$

$$Q_5 = \left(\frac{1}{\alpha_1 \, A Sinh\,[\alpha_1 h_2]}\right)\left(\frac{Sinh[\alpha_1 h_2]\,(Cosh[\alpha_1 h_1] - Cosh[\alpha_1 h_2])}{Sinh[\alpha_1 h_1]Cosh[\alpha_1 h_2] - Sinh[\alpha_1 h_2]Cosh[\alpha_1 h_1]}\right)$$

$$\left(\frac{[Cosh[\alpha_1 h_2] - Cosh[\alpha_1 h_1]]}{Sinh[\alpha_1 h_1]Cosh[\alpha_1 h_2] - Sinh[\alpha_1 h_2]Cosh[\alpha_1 h_1]}\right)$$

$$Q_6 = \left(\frac{1}{\alpha_1 \, A}\right)\left(\frac{(Sinh[\alpha_1 h_1] - Sinh[\alpha_1 h_2])(Sinh[\alpha_1 h_2] - Sinh[\alpha_1 h_1])}{Sinh[\alpha_1 h_1]Cosh[\alpha_1 h_2] - Sinh[\alpha_1 h_2]Cosh[\alpha_1 h_1]}\right)$$

The pressure gradient obtained from equation (23) and we can expressed as

$$\frac{dp}{dx} = \frac{q + (h_2 - h_1)}{\left(-Q_5 + Q_6 - \left(\frac{(h_2 - h_1)}{A}\right)\right)} \tag{24}$$

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

$$Q = \int_{h_2}^{h_1} (u+1)\,dy = q + (h_1 - h_2) \tag{25}$$

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

$$\overline{Q} = \frac{1}{T}\int_0^T Q\,dt = q + 1 + d \tag{26}$$

From the equations (24) and (26), the pressure gradient can be expressed as

$$\frac{dp}{dx} = \left(\frac{\left((\overline{Q} - 1 - d) + (h_2 - h_1)\right)}{-Q_5 + Q_6 - \frac{(h_2 - h_1)}{A}}\right) \tag{27}$$

NUMERICAL RESULTS AND DISCUSSION

Analytical expressions given by Equations (17), (18), (21), (22) and (27) represent the axial velocity, Temperature, the coefficients of heat transfer at y = h_1 and y = h_2 and pressure gradient.

The variation of axial velocity u with *y* for different values of Hartman number (M) with Da = 0.1, k_1= 0.2, x = 0.6, t = 0.4, ϕ = π/4, ε = 0.2, dp/dx = - 0.5 is presented in Fig. 1. It is clear that the axial velocity decreases by Hartman number M (M = 0.5, 1, 1.5) increased. From figure (2), it is obvious that the axial velocity (u) decreases with increase in Hartman number (M = 0.5, 1, 1.5) when Da = 0.5 with fixed other parameters. From the figures 1 to 2, we conclude that the axial velocity decreases with an increase in Hartman number (M) with Da ≥ 0.1.Figure (3) shows that the axial velocity with y for different values of porous parameter Da (Da = 0.1, 0.5, 1) with fixed M = 1, k_1= 0.2, x = 0.6, t = 0.4, ϕ = π/4, ε = 0.2, dp/dx = -0.5. This figure reveals that the axial velocity increases by increased in porous parameter. Figure (4) presents the various values of the porous parameter Da on the axial velocity u. It is clear that the axial velocity increases when porous parameter increased (Da) with M = 1.5 being other parameters fixed. We conclude that from figures (3) and (4), the axial velocity increases with an increased porous parameter with $M \geq 1$ being other parameters fixed.

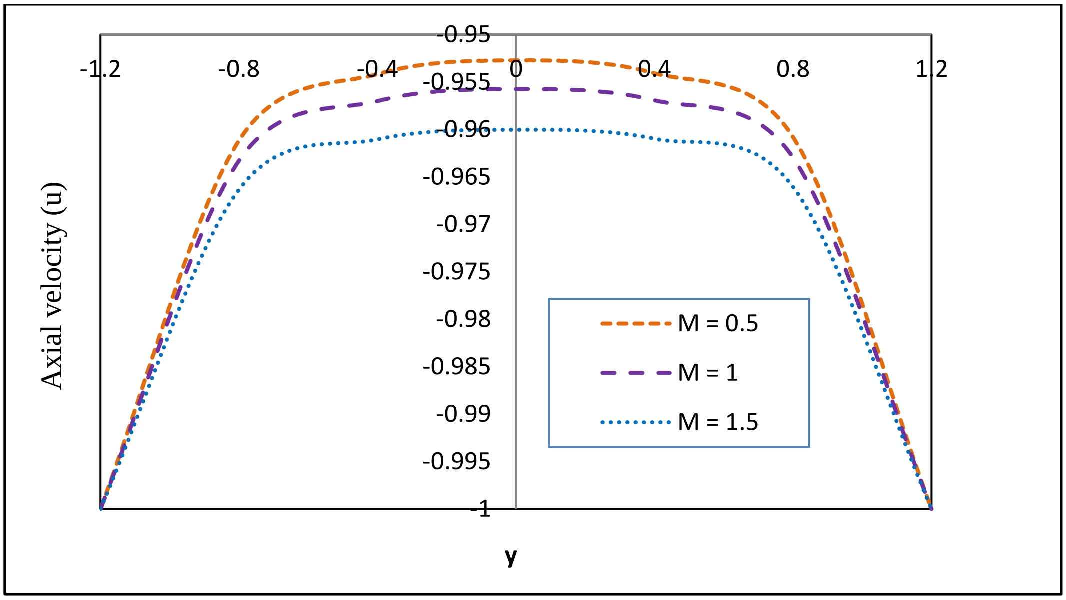

Figure (1): Velocity profile for different values of M with fixed Da = 0.1, k_1= 0.2, x = 0.6, t = 0.4, ϕ = π/4., ε = 0.2, dp/dx = -0.5.

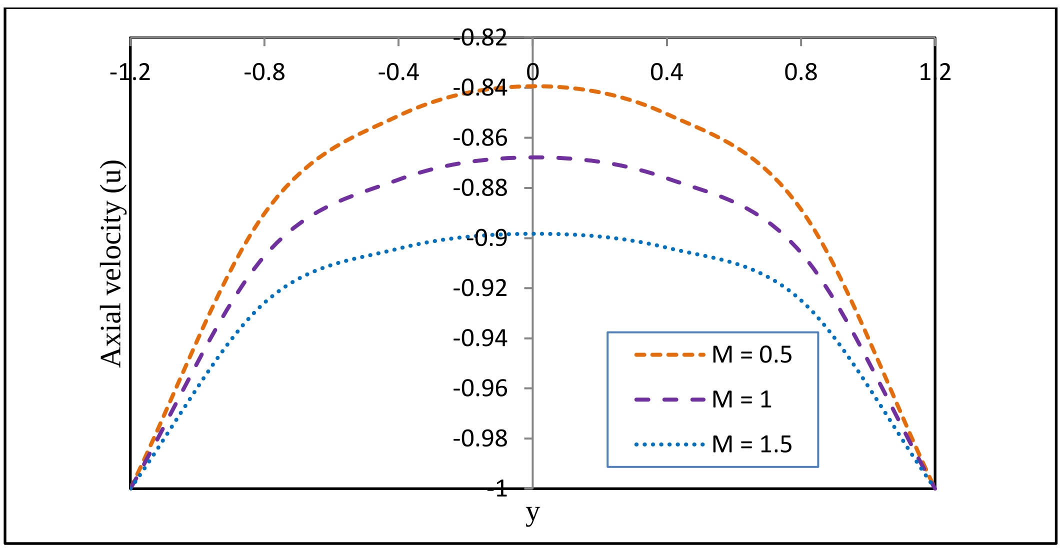

Figure (2): Velocity profile for different values of M with fixed Da = 0.5, k_1= 0.2, x = 0.6, t = 0.4,

ϕ = π/4, ε = 0.2, dp/dx = -0.5.

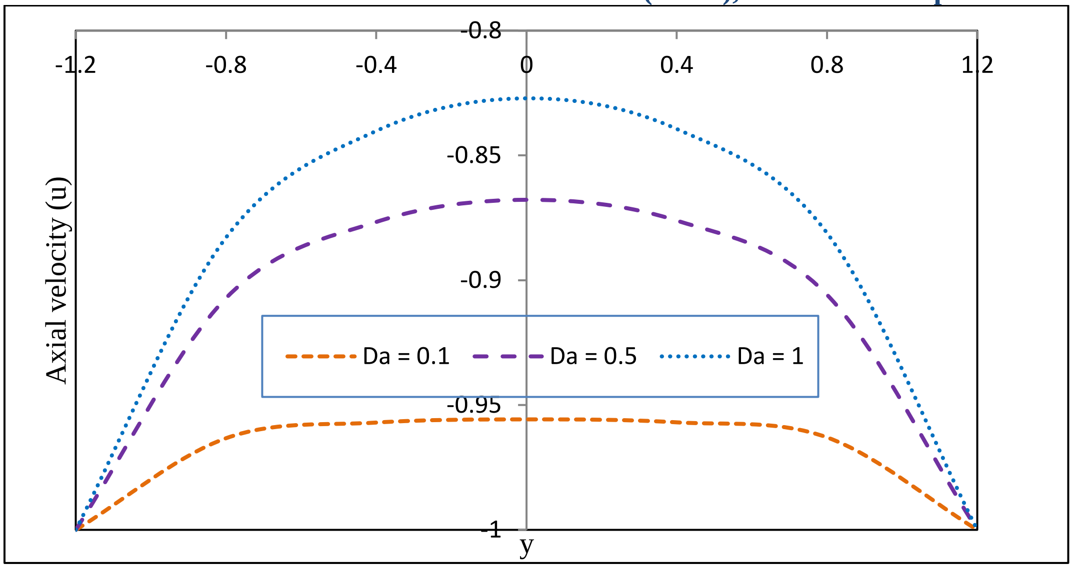

Figure (3): Velocity profile for different values of Da with fixed M = 1, k_1= 0.2, x = 0.6, t = 0.4, ϕ = π/4, ε = 0.2, dp/dx = -0.5.

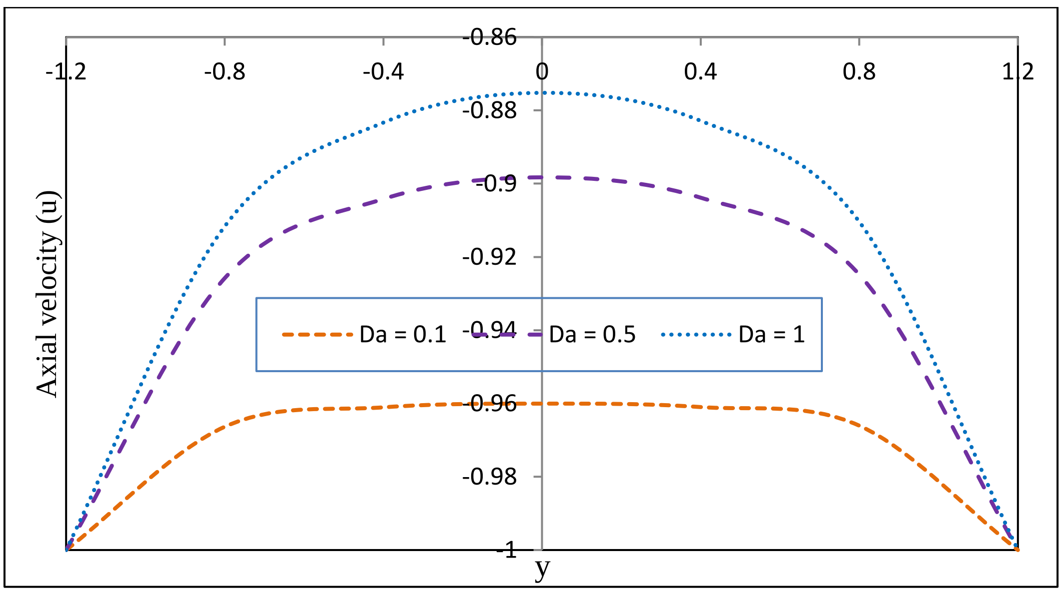

Figure (4): Velocity for different values of Da with fixed M = 1.5, k_1= 0.2, x = 0.6, t = 0.4, ϕ = π/4, ε = 0.2, dp/dx = -0.5.

Figure 5 reveals the pressure gradient verses x. This figure shows that the pressure gradient is maximum at the center of the channel (i.e. in the wider part of the channel) and it observed that the pressure gradient increases when Hartman number has higher values. Fig.6 reveals that an increase in Hartman number, the pressure gradient increases. We notice that form the figures (5) and (6), the results of pressure gradient increases with an increase in magnetic parameter with Da > 0.1. Figures 7 and 8 present the various values of volume flow rate ($\bar{Q}$) on the pressure gradient. It is obvious that the pressure gradient depreciates as volume flow rate increases when Da ≥ 0.1 being other parameters M = 0.5, k_1= 0.1, t = π/4, ϕ = π/4, ε = 0.2, d = 2 fixed. Figure 9 and 10 shows axial pressure gradient dp/dx is sketched via the dimensionless axial coordinate x for different values of ϕ. It is interested to notice that in both figures an axial pressure gradient increases in the in the portion of the channel xε [0, 0.5] and then it is decreasing in the rest of the channel xε [0.5, 1].

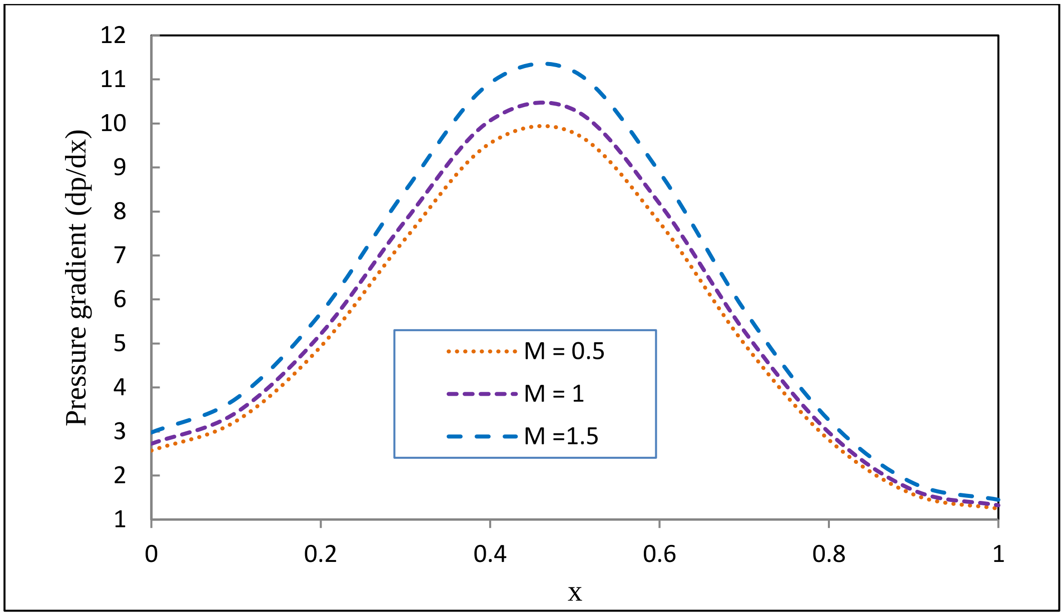

Figure (5): Pressure gradient (dp/dx) for different values of M with fixed Da = 0.1, k_1= 0.1, $t = \pi/4$, $\phi = \pi/4$, $\varepsilon = 0.2$, $\overline{Q} = 0.2$, d = 2.

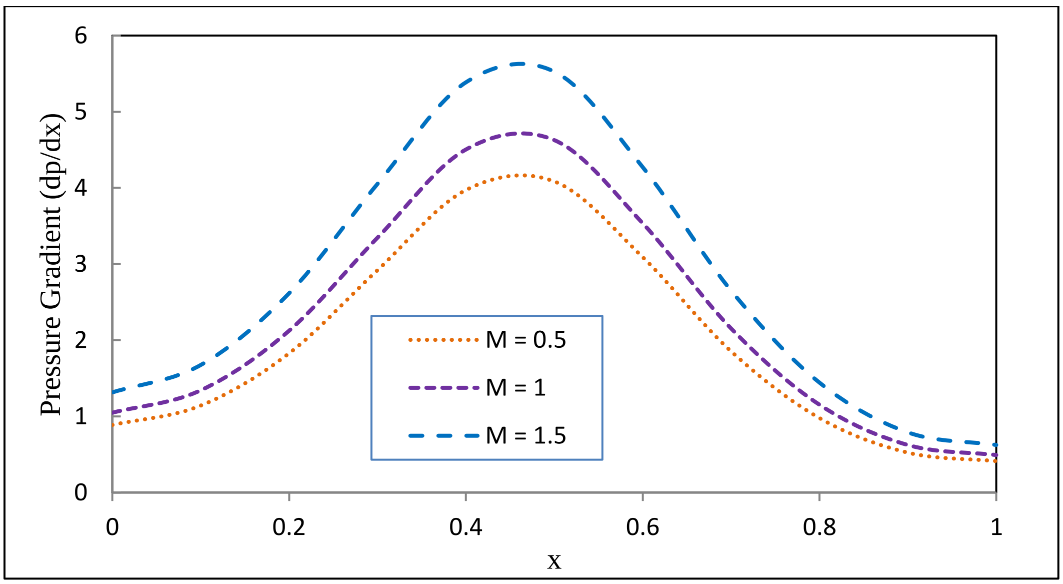

Figure (6): Pressure gradient (dp/dx) for different values of M with fixed Da = 0.5, k_1= 0.1, $t = \pi/4$, $\phi = \pi/4$, $\varepsilon = 0.2$, $\overline{Q} = 0.2$, d = 2.

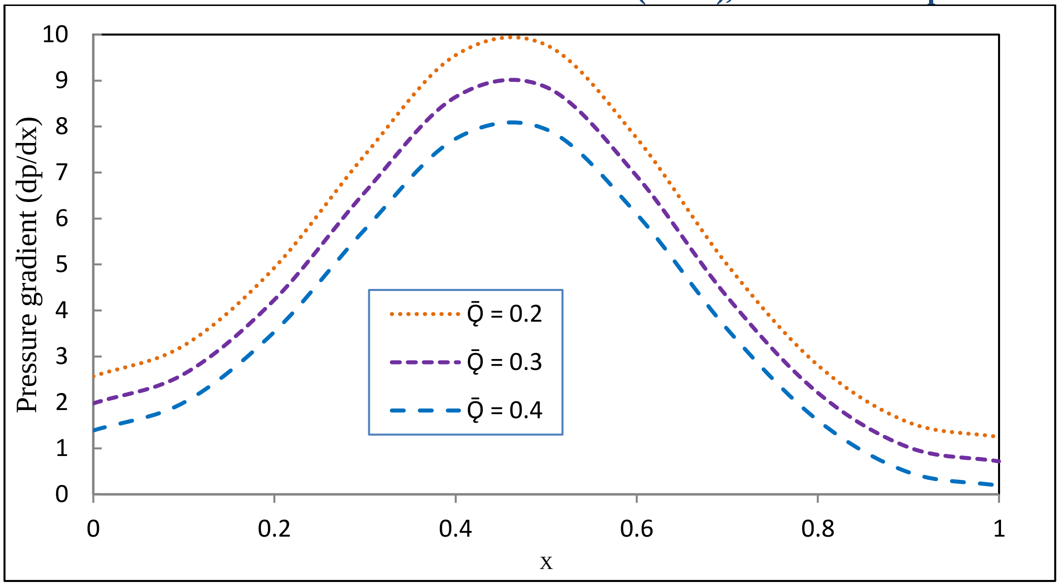

Figure (7): Pressure gradient (dp/dx) for different values of $\overline{Q}$ with fixed Da = 0.1, M = 0.5, k_1= 0.1, t = π/4, ϕ = π/4, ε = 0.2, d = 2.

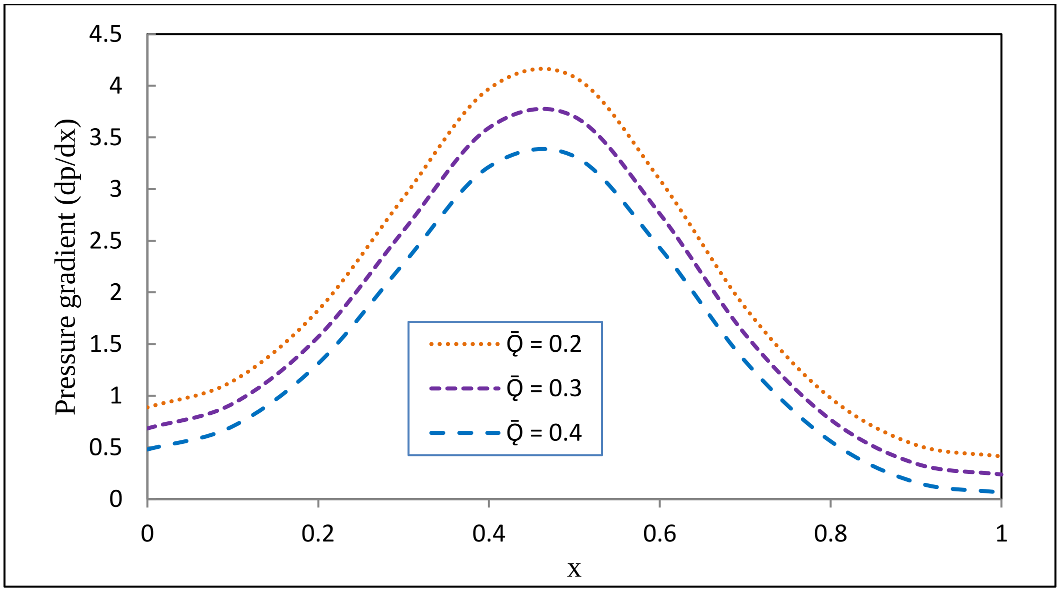

Figure (8): Pressure gradient (dp/dx) for different values of $\overline{Q}$ with Da = 0.5, M = 0.5, k_1= 0.1, t = π/4, ϕ = π/4, ε = 0.2, d = 2.

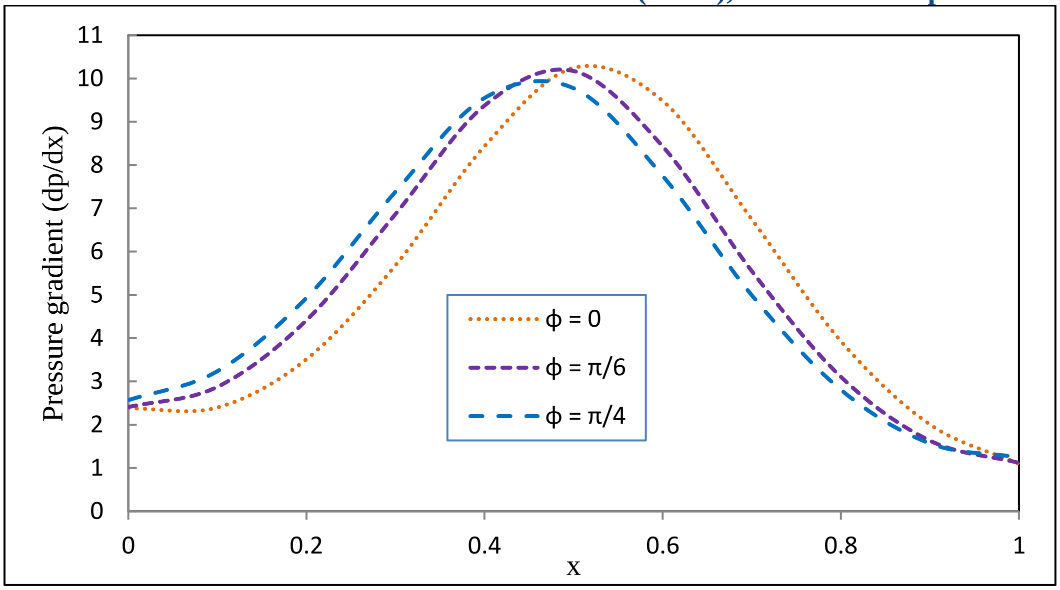

Figure (9): Pressure gradient (dp/dx) for different values of ϕ with Da = 0.1, M = 0.5, k_1=0.1, t = π/4, $\overline{Q}$ = 0.2, ε = 0.2, d = 2.

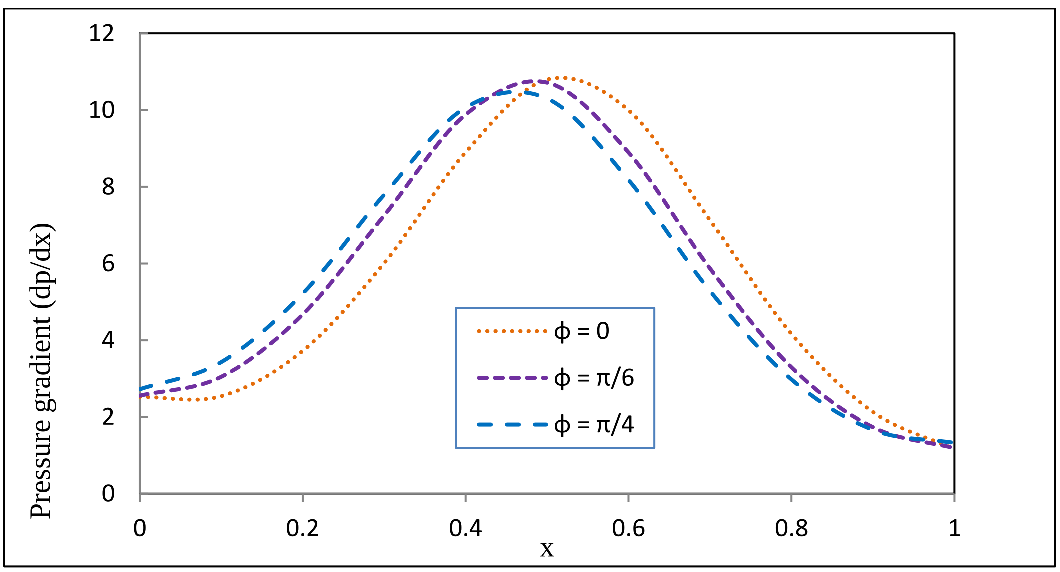

Figure (10): Pressure gradient (dp/dx) for different values of ϕ with fixed Da = 0.1, M = 1, k_1= 0.1, t = π/4, $\overline{Q}$ = 0.2, ε = 0.2, d = 2.

Temperature distribution (θ) verses y as depicted in figures 11 and 12. We notice from these figures (11) and (12), the temperature distribution increases when the Prandtl number Pr (Pr =0.5, 1, 1.5) increased with β ≥ 1 being other parameters k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6 fixed. Influence of heat generator operator on temperature distribution (θ) was depicted in figures 13 and 14. Indeed, the temperature distribution (θ) increases in the entire tapered as heat generator operator increased (β = 1, 2, 3) with Pr ≥ 1 and other parameters fixed. Figures 15 and 16 indicated temperature distribution verses y. We observe from the figures the temperature gradually increases by increasing the values of non-uniform parameter k_1 (k_1 = 0.1, 0.2, 0.3) when Pr ≥ 1 with fixed β = 1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6. Hence we conclude from the figures the temperature increases in the entire tapered channel by increased in Pr, β and k_1.

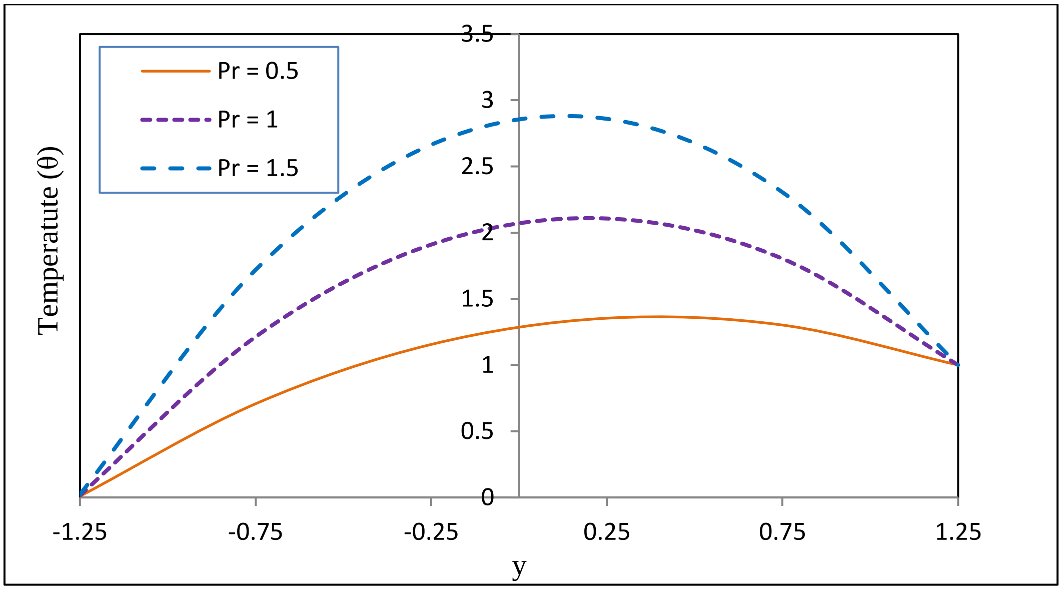

Figure (11): Temperature profile (θ) for different values of Pr with fixed β = 1, k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.

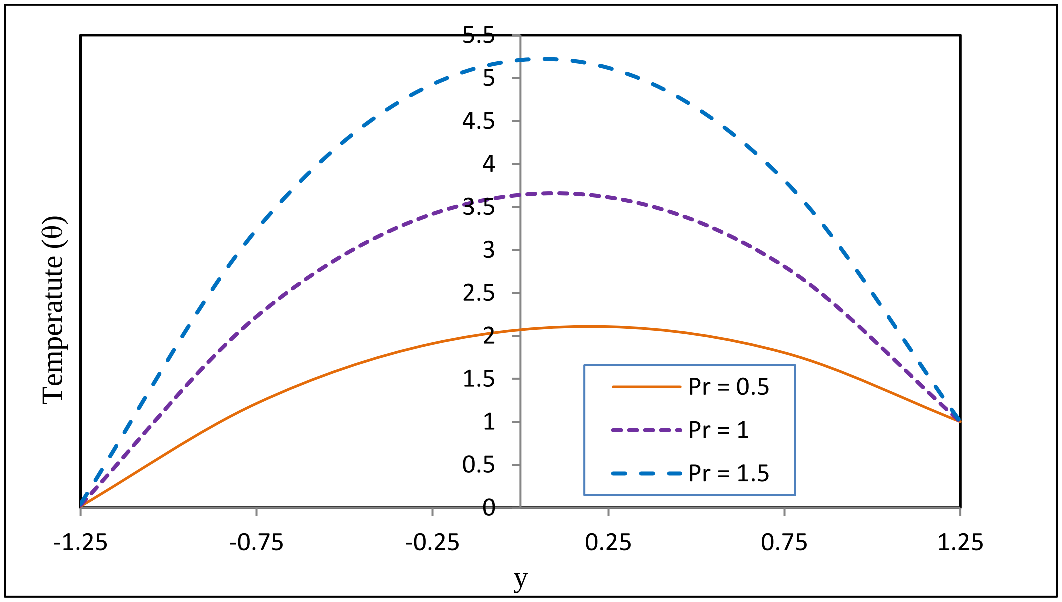

Figure (12): Temperature profile (θ) for different values of Pr with fixed β = 2, k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.

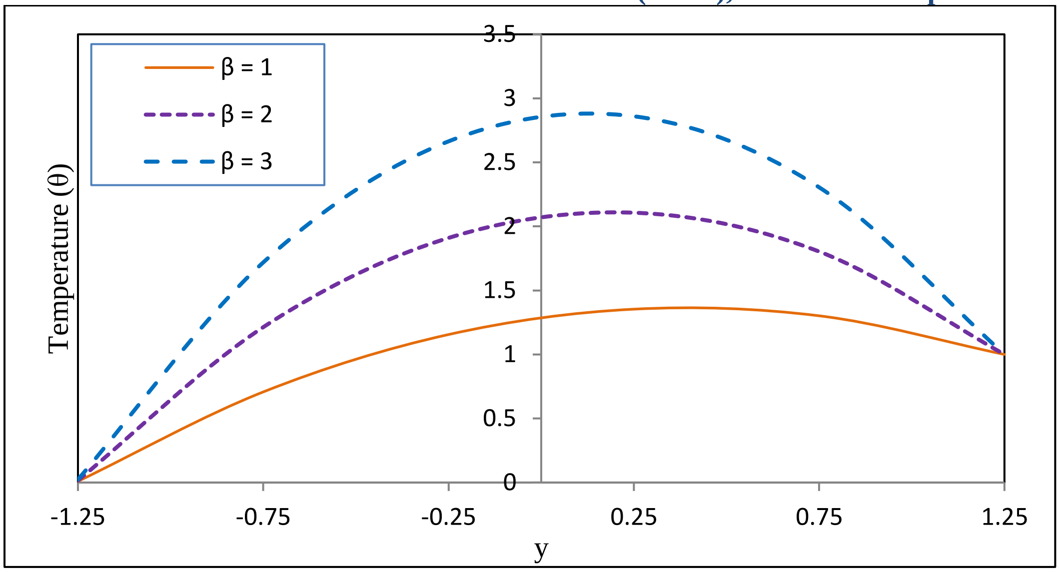

Figure (13): Temperature profile (θ) for different values of β with fixed Pr = 0.5, k_1= 0.1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.

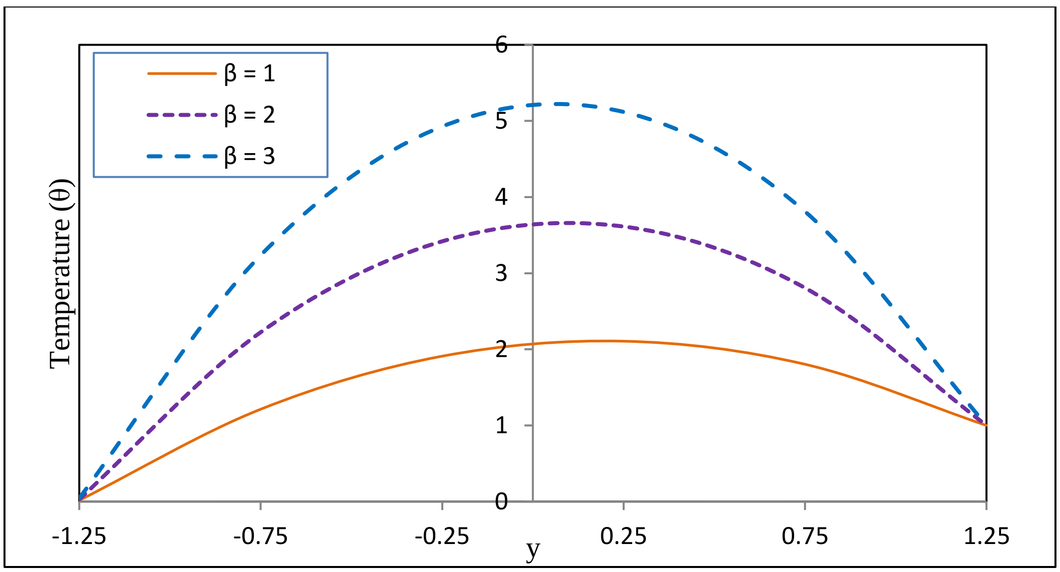

Figure (14): Temperature profile (θ) for different values of β with fixed Pr = 1, k_1= 0.1, x =0.6, t =0. 4, ε = 0.2, ϕ = π/6.

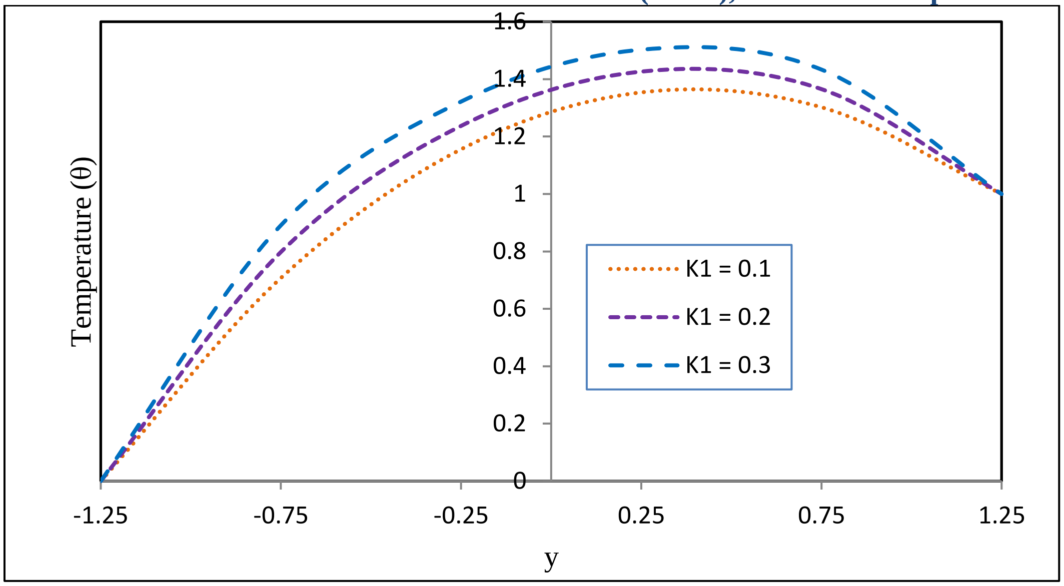

Figure (15): Temperature profile (θ) for different values of K_1 with fixed Pr = 0.5, β = 1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.

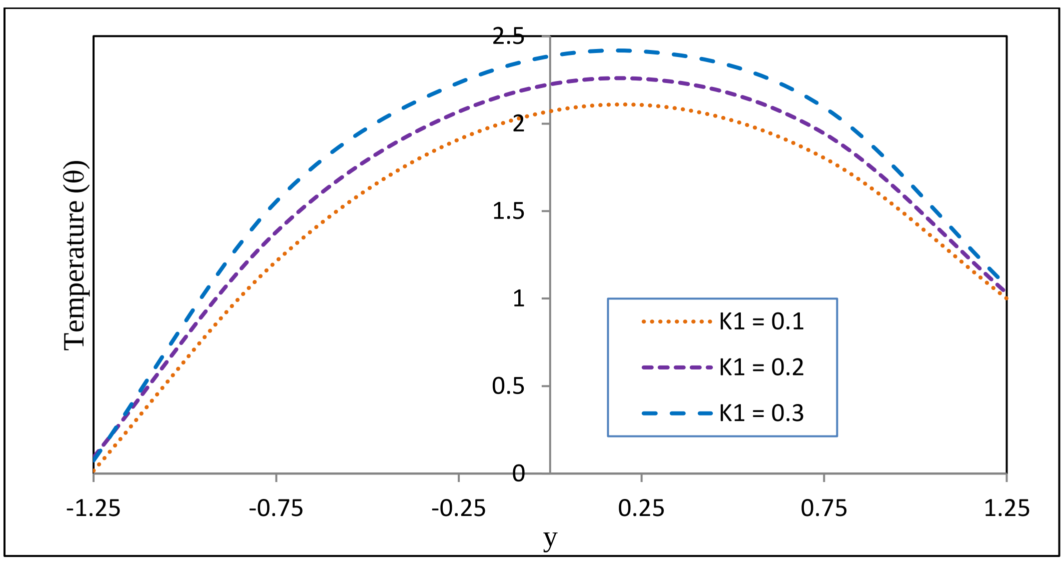

Figure (16): Temperature profile (θ) for different values of k_1 with fixed Pr = 1, β = 1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/6.

Figures 17 and 18 represent the effects of Prandtl number on the heat transfer coefficient at the wall $y = h_1$ against x. Figure (17) reveals the heat transfer coefficient decreases in the region xε [0, 0.55] and then it is increases in the region xε [0.55, 1] when Prandtl number increased with β = 1 being other parameters fixed. From figure (18), we notice that the heat transfer coefficient decreases in the region xε [0.0.55] and then it is increases in the rest of the region xε [0.55, 1] when Prandtl number increased with β = 2 being other parameters fixed. From the figures 19 and

20, it is clear that the heat transfer coefficient decreases in the region xε [0.0.55] and then it is increases in the region xε [0.55, 1] when heat generator operator β increased with Pr = 1(fig 19) and Pr = 1.5 (fig 20) with fixed t =0. 4, ε = 0.2, ϕ = π/4.

Figures (21-24) is illustrated to show that the heat transfer coefficient at the wall y =h_2. It can be seen that the heat transfer coefficient increases in the region xε [0, 0.1] ∪[0.7, 1] and decreases in the region xε [0.1, 0.7] when increased Prandtl number and heat generation operator in entire tapered channel.

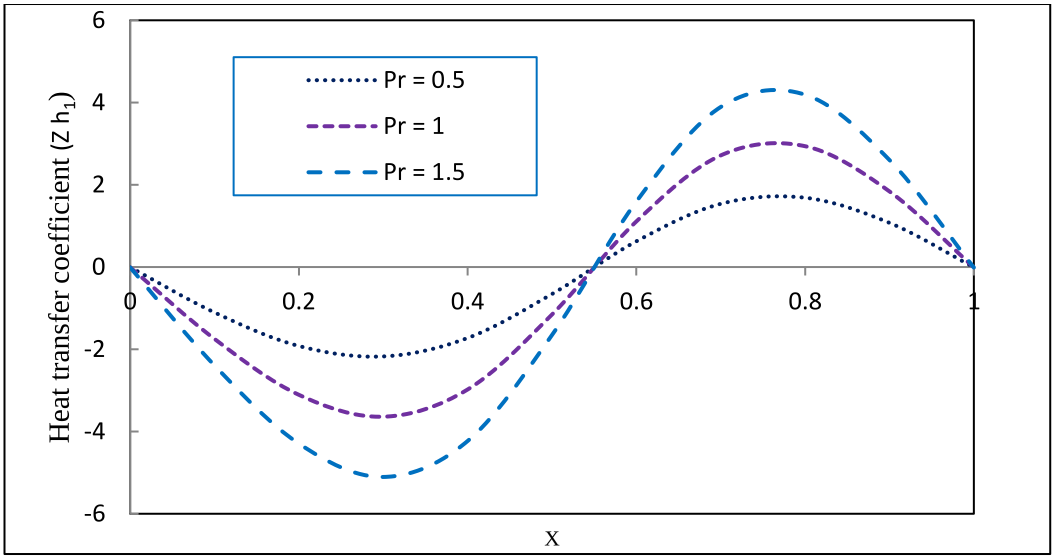

Figure (17): Heat transfer coefficient at the wall y = h_1 for different values of Pr with fixed β = 1, x = 0.6, t =0. 4, ε = 0.2, ϕ = π/4.

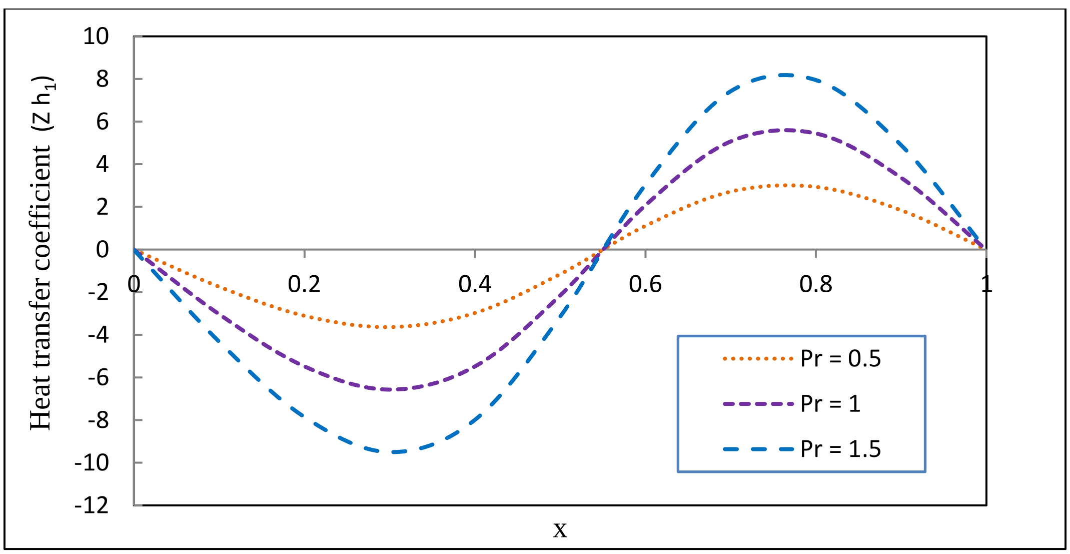

Figure (18): Heat transfer coefficient at the wall y = h_1 for different values of Pr with fixed β = 2, t =0. 4, ε = 0.2, ϕ = π/4.

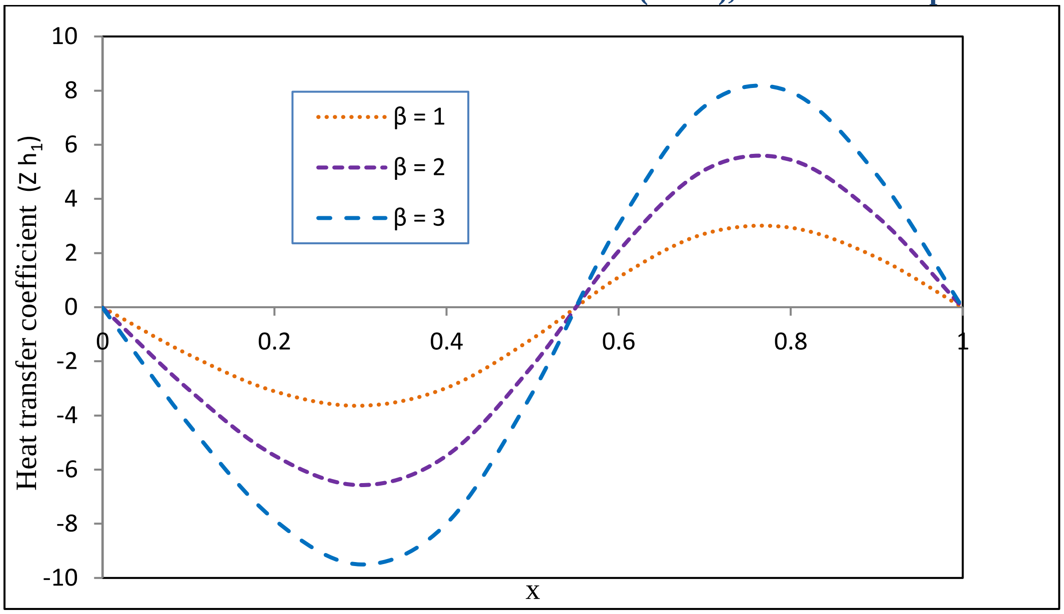

Figure (19): Heat transfer coefficient at the wall $y = h_1$ for different values of β with fixed $Pr = 1$, $t = 0.4$, $\varepsilon = 0.2$, $\phi = \pi/4$.

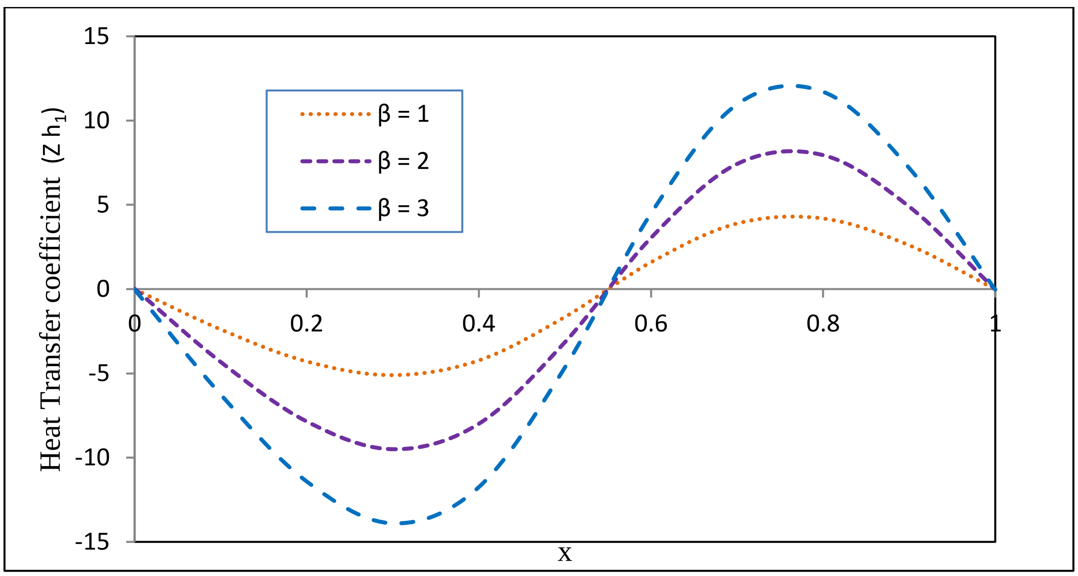

Figure (20): Heat transfer coefficient at the wall $y = h_1$ for different values of β with fixed $Pr = 1.5$, $t = 0.4$, $\varepsilon = 0.2$, $\phi = \pi/4$.

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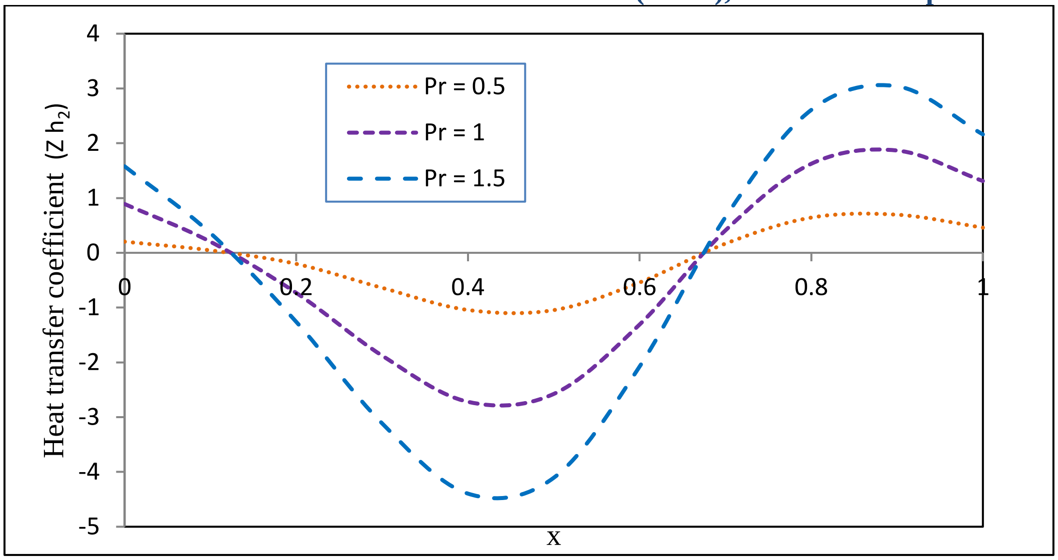

Figure (21): Heat transfer coefficient at the wall y = h_2 for different values of Pr with fixed $\beta = 1$, $x = 0.6$, $t = 0.4$, $\varepsilon = 0.2$, $\phi = \pi/4$.

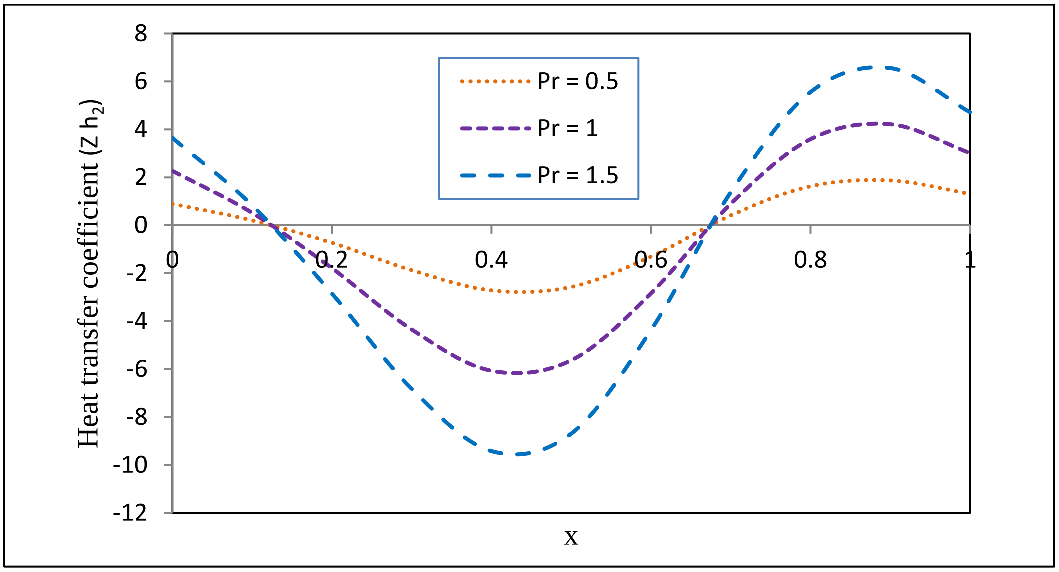

Figure (22): Heat transfer coefficient at the wall y = h_2 for different values of Pr with fixed $\beta = 2$, $x = 0.6$, $t = 0.4$, $\varepsilon = 0.2$, $\phi = \pi/4$.

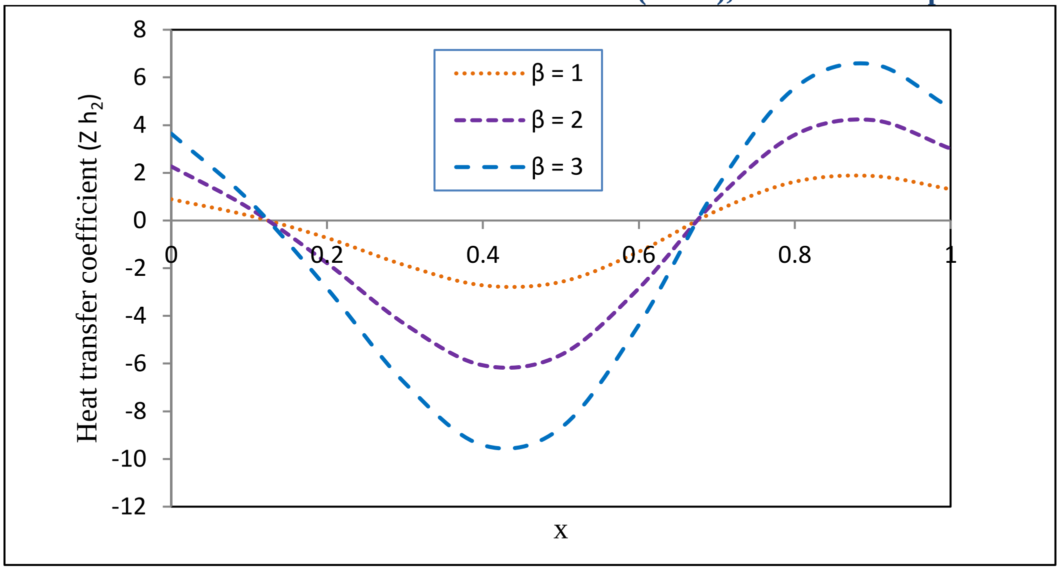

Figure (23): Heat transfer coefficient at the wall $y = h_2$ for different values of β with fixed Pr = 1, t =0. 4, ε = 0.2, ϕ = π/4.

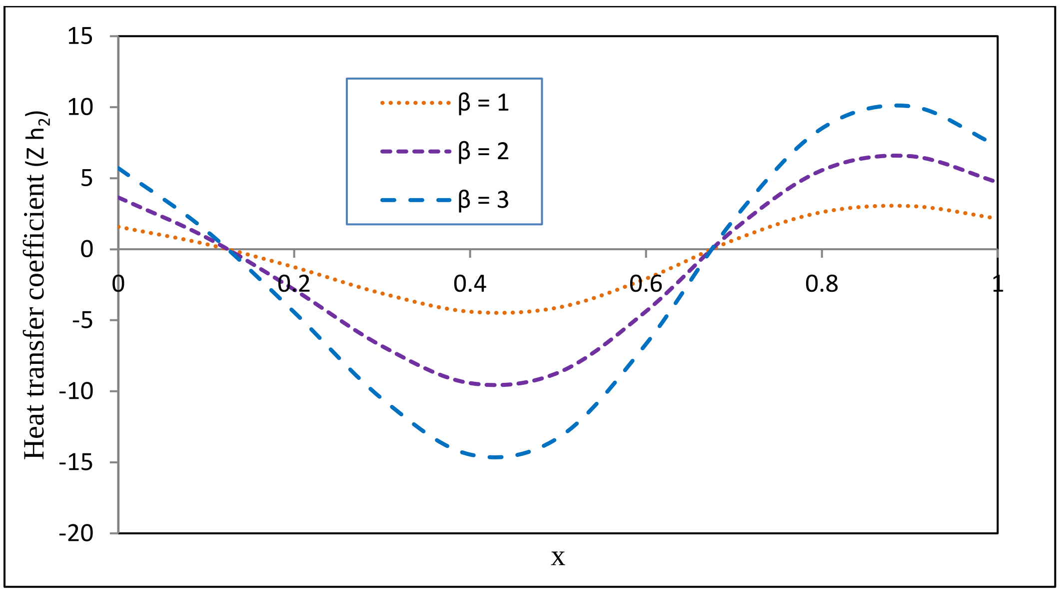

Figure (24): Heat transfer coefficient at the wall $y = h_2$ for different values of β with fixed Pr = 1.5, t =0. 4, ε = 0.2, ϕ = π/4.

CONCLUSIONS

In this research article we have proposed a theoretical study of an influence of heat transfer on magnetohydrodynamic peristaltic flow of blood with porous medium through coaxial vertical asymmetric tapered channel- an analysis of blood flow study. The study has paid a special attention to examine the effects of Hartmann number, porous parameter, Prandtl number, heat generator operator, non uniform parameter, volume flow rate on the flow characteristics. The results are discussed through graphs and concluded to the following observations:

(a) The velocity decreases when Hartman number increased (M).

(b) The velocity increases when porous parameter increases (Da).
(c) Pressure gradient (dp/dx) increases as increase in Hartman number (M).
(d) Pressure gradient (dp/dx) decreases when volume flow rate $\overline{Q}$ increases.
(e) Temperature distribution (θ) increases by increase in Prandtl number, heat generator operator and non porous parameter.
(f) Heat transfer coefficient (at the wall y = h1) decreases in the region xε[0, 0.55] and then increases in the rest of the region xε[0.55,1] by increase in prandtl number and heat generator operator.
(g) Heat transfer coefficient(at the wall $y = h_2$) increases in the region xε [0, 0.1] $\cup$ [0.7, 1] and then decreases in the rest of channel xε [0.1, 0.7] by increasing the values of prandtl number and heat generation operator in entire tapered channel

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