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PULSATILE FLOW OF BLOOD THROUGH AN INCLINED BELL SHAPE STENOSED TUBE UNDER PERIODIC BODY ACCELERATION WITH MAGNETIC EFFECT

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ABSTRACT

This is about the mathematical model for blood flow through an inclined bell shape stenosed tube under periodic body acceleration and magnetic field. Using appropriate boundary conditions, analytical expressions for the velocity, the volumetric flow rate, the fluid acceleration have been derived. These expressions are computed numerically and the computational results are presented graphically.

Key Words: *Pulsatile flow, Stenosis, Bell shaped Stenosis, Periodic body acceleration, magnetic field, Inclined tubes.*

INTRODUCTION

Velocity measurements in steady flow through axisymmetric stenosis at moderate Reynolds number is studied by Ahmad and Gidden[1]. Joshi, *et.al.* [2] studied two layered model of blood flow through composite stenosed artery. Jung and Park [3] studied asymmetric flow of non-Newtonian fluids in symmetric stenosed artery. Liu, *et.al*., [4]studied the numerical study of pulsating flow through a tapered artery with stenosis. Mandal, *et.al*., [5] studied numerical study on the unsteady flow of non-Newtonian fluid through diffrerently shaped arterial stenosis. Medhavi, *et.al*. [6]studied two-phase arterial blood flow through a composite stenosis. Mekheimer and El-Kot. [7] studied the magnetic field and hall currents influences on blood flow through a stenotic arteries. Mishra and Verma [8] studied the effects of porous parameter and stenosis on the wall shear stress for the flow of blood in human body. Pralhad and Schultz[9]studied the modeling of arterial stenosis and its applications to blood diseases. Ponalagusamy [10] studied the blood flow through an artery with mild stenosis: two layered model, different shapes of stenosis and slip velocity at the wall.Sankar, *et.al*., [11] studied two-layered suspension blood flow through a composite stenosis. Siddiqui, *et.al*, [12]studied the mathematical modelling of pulsatile flow of blood through a time dependent stenotic blood vessel. Morgan and Young [13] studied an integral method for the analysis of flow in arterial stenosis. Azuma and Fukushima [14] studied the flow patterns in stenotic blood vessel models. Young, *et.al*, [15] studied the hemodynamics of arterial stenoses at elevated flow rates. On steady flow through modeled vascular stenosis is studied by MacDonald [16]. Momentum integral method for studying flow characteristics of blood through a stenosed vessel is studied by Misra and Kar[17]. Srivastava [18] studied the flow of couple stress fluid through stenotic blood vessels. On the effect of the concentration profile of red cells on blood flow in the artery with stenosis is studied by Perkkio and Keskinen [19]. Chaturani and Palanisamy [20] studied the micro continuum model for pulsatile blood flow through a stenosed tube. Arterial blood flow through a non-symmetrical stenosis with applications is studied by Srivastava [21].

MATHEMATICAL FORMULATION

Let us consider a one-dimensional pulsatile flow of blood through a uniform straight and stenosed inclined cylindrical tube using magnetic field by considering blood as a couple stress fluid. The flow is considered as axially symmetric, pulsatile and fully developed. The pressure gradient and body acceleration G are given by the expressions

$$-\frac{\partial P}{\partial z} = A_0 + A_1 \cos(\omega_P t) \tag{1}$$

$$G = a_0 \cos(\omega_b t + \phi) \tag{2}$$

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where A_0 and A_1 are pressure gradient of steady flow and amplitude of oscillatory part respectively, a_0 is the amplitude of body acceleration, $\omega_p = 2\pi f_p$, $\omega_b = 2\pi f_b$ with f_p is the pulse frequency and f_b is body acceleration frequency, ϕ is the phase angle of body acceleration G with respect to pressure gradient and time, t.

The pulsatile couple stress equation (Stokes), in cylindrical polar coordinates under the periodic body acceleration with inclined angle and magnetic field can be written in the form:

$$\rho\frac{\partial u}{\partial t} = -\frac{\partial p}{\partial z} + \rho G + \mu\nabla^2 u - \eta\nabla^2(\nabla^2 u) + \rho g\sin\theta - \sigma B_0^2 u$$

$$\text{Where } \nabla^2 = \frac{1}{\xi}\left(\frac{\partial}{\partial\xi}\left(\xi\frac{\partial}{\partial\xi}\right)\right) \tag{3}$$

where $u(\xi, t)$ is axial velocity, ρ and μ are the density and viscosity of blood, η is the couple stress parameter and ξ is the radial coordinate.

Let us introduce the following dimensionless quantities:

$$u^* = \frac{u}{\omega R},\ t^* = t\omega,\ A_0^* = \frac{R}{\mu\omega}A_0,\ A_1^* = \frac{R}{\mu\omega}A_1,\ a_0^* = \frac{\rho R}{\mu\omega}a_0,\ z^* = \frac{z}{R},\ g^* = \frac{\rho R}{\mu w}g \tag{4}$$

Consider the axisymmetric flow of blood through a bell shaped stenosis, specified at the location as shown in Figure 1, in an artery. The geometry of the stenosis, assumed to be manifested in the arterial wall segment, is described (Srivastava et al. 2012) as

$$\frac{R(z)}{R_0} = \begin{cases} 1 - \dfrac{\delta}{R_0}\exp\left(\dfrac{-\omega^2\varepsilon^2 z^2}{R_0^{\ 2}}\right); |z| \le L_0 \\ 1; otherwise \end{cases} \tag{5}$$

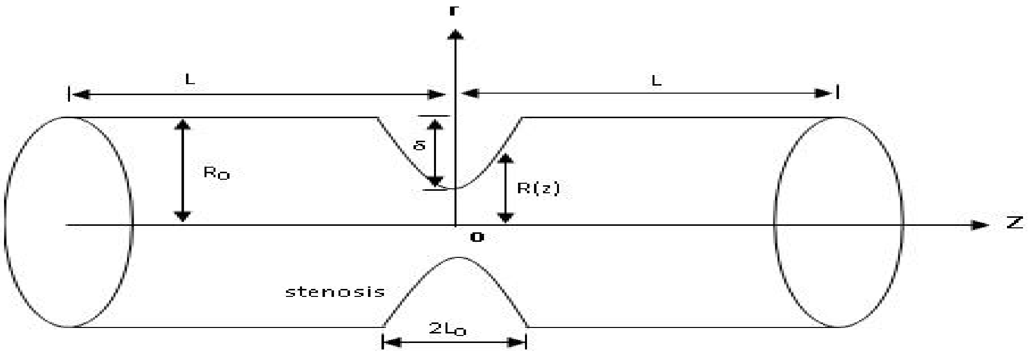

Figure-1: The geometry of a bell shaped stenosis in an artery

where R_0 is the radius of the arterial segment in the non-stenotic region, R(z) is the radius of the stenosed portion located at the axial distance z from the left end of the segment, δ is the depth of stenos is at the throat and, ω is a parametric constant, ε is the relative length of the constriction, defined as the ratio of the radius to half length of the stenosis, i.e., $\varepsilon = R_0 / L_0$ and let us introduce a radial coordinate transformation given by:

$$\xi = \frac{r}{R(z)}$$

In terms of these variables, equation (3) [after dropping stars] becomes:

$$\bar{\alpha}^2\alpha^2\frac{\partial u}{\partial t} = \bar{\alpha}^2 A_0 + \bar{\alpha}^2 A_1\cos\ (bt) + \bar{\alpha}^2 a_0\cos\ (ct+\varphi)$$
$$+\bar{\alpha}^2\left(\frac{1}{\xi}\frac{\partial}{\partial\xi}\left(\xi\frac{\partial u}{\partial\xi}\right)\right) - \left(\frac{1}{\xi}\frac{\partial}{\partial\xi}\left(\xi\frac{\partial}{\partial\xi}\right)\right)\cdot\left(\frac{1}{\xi}\frac{\partial}{\partial\xi}\left(\xi\frac{\partial u}{\partial\xi}\right)\right) + \bar{\alpha}^2 g\ \sin\theta - \bar{\alpha}^2 H^2 u \tag{6}$$

where $\bar{\alpha}^2 = R^2\left(\dfrac{\mu}{\eta}\right)$ -- Couple stress parameter, $\alpha^2 = R^2\left(\dfrac{\omega\rho}{\mu}\right)$-- Womersley parameter,

$b = \dfrac{\omega_1}{\omega}$, $c = \dfrac{\omega_2}{\omega}$, $H = B_0 R\left(\dfrac{\sigma}{\mu}\right)^{1/2}$ -- Hartman number and R -- radius of the tube

The initial and boundary conditions for this problem are:

$$u(\xi,0) = 2\sum_{n=1}^{\infty}\frac{J_0(\xi\lambda_n)\bar{\alpha}^2}{\lambda_n J_1(\lambda_n)}.\frac{[A_0 + A_1 + a_0\cos\Phi + g\sin\theta]}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]} \tag{7a}$$

$$u \text{ and } \nabla^2 u \text{ are all finite at } \xi = 0 \tag{7b}$$

$$u = 0,\ \nabla^2 u = 0 \qquad \text{at } \xi = 1$$

(7c)

INTEGRAL TRANSFORMS:

If $f(\xi)$ satisfies Dirichlet conditions in closed interval (0, 1) then it's finite Hankel transform, Sneddon, is defined as

$$f^*(\lambda_n) = \int_0^1 \xi\ f(\xi)\ J_0(\xi\lambda_n) \tag{8}$$

Where λ_n are the roots of $J_0(\lambda_n) = 0$. Then at each point of the interval at which $f(\xi)$ is continuous:

$$f(\xi) = 2\sum_{n=1}^{\infty} f^*(\lambda_n)\frac{J_0(\xi\lambda_n)}{J_1^2(\lambda_n)}, \tag{9}$$

Where the sum is taken over all positive roots of $J_0(\xi) = 0$, J_0 and J_1 are Bessel functions of first kind.

The Laplace transform of any function is defined as:

$$\bar{f}(s) = \int_0^{\infty} e^{-st}\ f(t)dt, \qquad s > 0 \tag{10}$$

SOLUTIONS:

Employing the Laplace transforms (10) to equation (6) in the light (7b), we get:

$$\bar{\alpha}^2\alpha^2\left(s\bar{u} - u(\xi,\,0)\right) = \bar{\alpha}^2\frac{A_0}{s} + \bar{\alpha}^2\frac{A_1 s}{s^2+b^2} + \bar{\alpha}^2\left(\frac{a_0(s\cos\varphi - c\sin\varphi)}{s^2+c^2}\right) + \bar{\alpha}^2\left(\frac{1}{\xi}\frac{\partial}{\partial\xi}\left(\xi\frac{\partial u}{\partial\xi}\right)\right)$$
$$-\left(\frac{1}{\xi}\frac{\partial}{\partial\xi}\left(\xi\frac{\partial}{\partial\xi}\right)\right).\left(\frac{1}{\xi}\frac{\partial}{\partial\xi}\left(\xi\frac{\partial\bar{u}}{\partial\xi}\right)\right) + \bar{\alpha}^2 g\sin\theta - \bar{\alpha}^2H^2u \tag{11}$$

Where

$$\bar{u}(\xi,\,s) = \int_0^{\infty} e^{-st}u(\xi,\,t)dt \tag{12}$$

Now applying the finite Hankel transform (8) to (11) and using (7c) .we obtain:

$$\bar{u}(\lambda_n,s) = \frac{J_1(\xi\lambda_n)\bar{\alpha}^2}{\lambda_n}\left[\begin{array}{l}\dfrac{A_0}{s} + \dfrac{A_1 s}{s^2+b^2} + \dfrac{a_0\ (s\cos\ \varphi - c\sin\varphi)}{s^2+c^2} + \dfrac{g\sin\theta}{s} \\ +m\displaystyle\sum_{n=1}^{\infty}\dfrac{[A_0 + A_1 + a_0\cos\ \varphi + g\sin\theta]}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\end{array}\right].\times\frac{1}{[sm + \lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}$$

where $m = \bar{\alpha}^2.\alpha^2$

Now rearranging the terms for taking the inverse Laplace transform,

$$\bar{u}^*(\lambda_n, s) = \frac{J_1(\xi\lambda_n)\bar{\alpha}^2}{\lambda_n}\Big[\frac{A_0}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\left(\frac{1}{s}-\frac{1}{s+h}\right)$$
$$+\frac{A_1[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}{[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+b^2m^2]}\left\{-\frac{1}{s+h}+\frac{s}{s^2+b^2}+\frac{b^2m}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2](s^2+b^2)}\right\}$$
$$+\frac{a_0[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]\cos\varphi}{[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+c^2m^2]}\left\{-\frac{1}{s+h}+\frac{s}{s^2+c^2}+\frac{c^2m}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2](s^2+b^2)}\right\}$$
$$-\frac{a_0\,c\,m\sin\varphi}{[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+c^2m^2]}\left\{\frac{1}{s+h}-\frac{s}{s^2+c^2}+\frac{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}{m(s^2+c^2)}\right\}$$
$$+\frac{g\sin\theta}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\left\{\frac{1}{s}-\frac{1}{s+h}\right\}+\sum_{n=1}^{\infty}\frac{[A_0+A_1+a_0\cos\varphi+g\sin\theta]}{(s+h)[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\Big] \tag{13}$$

where $$h=\frac{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}{m} \tag{14}$$

Now taking the inverse Laplace transform of (13) gives

$$u^*(\lambda_n) = \frac{J_1(\xi\lambda_n)\bar{\alpha}^2}{\lambda_n}[\{\frac{A_0}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}$$
$$+\frac{A_1[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}\cos(bt)+m\sin(bt)]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+b^2m^2}$$
$$+\frac{a_0[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}\cos(ct+\varphi)+c\,m\sin(ct+\varphi)]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+c^2m^2}+\frac{g\sin\theta}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\}$$
$$-e^{-ht}\{\frac{A_0}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}+\frac{A_1[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+b^2m^2}$$
$$+\frac{a_0[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}\cos\varphi+c\,m\sin\varphi]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+c^2m^2}+\frac{g\sin\theta}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}$$
$$-\sum_{n=1}^{\infty}\frac{(A_0+A_1+a_0\cos\varphi+g\sin\theta)}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\}] \tag{15}$$

The finite Hankel inversion of (15) gives the final solution as:

$$u(\xi,t)=2\sum u^*(\lambda_n)\frac{J_0(\xi\lambda_n)}{J_1^2(\lambda_n)}$$

$$u(\xi,t)=2\sum_{n=1}^{\infty}\frac{A_0J_0(\xi\lambda_n)\bar{\alpha}^2}{\lambda_nJ_1(\lambda_n)}\Big[\Big\{\frac{1}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}+\frac{A_1/A_0[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}\cos(bt)+m\sin(bt)]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+b^2m^2}$$
$$+\frac{a_0/A_0[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}\cos(ct+\varphi)+c\,m\sin(ct+\varphi)]}{[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+c^2m^2]}+\frac{(1/A_0)g\sin\theta}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\Big\}$$

$$-e^{-ht}\{\{\frac{1}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}+\frac{A_1/A_0[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+b^2m^2}$$
$$+\frac{a_0/A_0[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}\cos\varphi+cm\sin\varphi]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+c^2m^2}+\frac{(1/A_0)g\sin\theta}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\}$$
$$-\frac{[1+(A_1/A_0)+(a_0/A_0)\cos\varphi+(1/A_0)g\sin\theta]}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\}] \tag{16}$$

The expression for the flow rate Q can be written as:

$$Q=2\pi\int_0^{\xi}\xi u\,d\xi \tag{17}$$

Then

$$Q(\xi,t)=4\pi\sum_{n=1}^{\infty}\frac{A_0\bar{\alpha}^2}{\lambda_n^2}[\{\frac{1}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}+\frac{A_1/A_0[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}\cos(bt)+m\sin(bt)]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+b^2m^2}$$
$$+\frac{a_0/A_0[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}\cos(ct+\phi)+cm\sin(ct+\phi)]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+c^2m^2}+\frac{(1/A_0)g\sin\theta}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\}$$
$$-e^{-ht}\{\frac{1}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}+\frac{A_1/A_0[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+c^2m^2}$$
$$+\frac{a_0/A_0[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}\cos\phi+cm\sin\phi]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+c^2m^2}+\frac{(1/A_0)g\sin\theta}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}$$
$$-\frac{[1+(A_1/A_0)+(a_0/A_0)\cos\phi+(1/A_0)g\sin\theta]}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\}] \tag{18}$$

Similarly the expression for fluid acceleration F can be obtained from:

$$F(\xi,t)=\frac{\partial u}{\partial t} \tag{19}$$

Then we have

$$F(\xi,t)=2\sum_{n=1}^{\infty}\frac{A_0J_0(\xi\lambda_n)\bar{\alpha}^2}{\lambda_nJ_1(\lambda_n)}[\{\frac{A_1/A_0[bm\cos(bt)-\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}b\sin(bt)]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+b^2m^2}$$
$$+\frac{a_0/A_0\,c[cm\cos(ct+\phi)-\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}\sin(ct+\phi)]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+c^2m^2}+\frac{(1/A_0)g\sin\theta}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\}$$
$$+he^{-ht}\{\frac{1}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}+\frac{A_1/A_0[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+b^2m^2}$$
$$+\frac{a_0/A_0[\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}\cos\phi+cm\sin\phi]}{\{\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2\}^2+c^2m^2}+\frac{(1/A_0)g\sin\theta}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}$$
$$-\frac{[1+(A_1/A_0)+(a_0/A_0)\cos\phi+(1/A_0)g\sin\theta]}{[\lambda_n^2(\lambda_n^2+\bar{\alpha}^2)+\bar{\alpha}^2H^2]}\}] \tag{20}$$

RESULTS

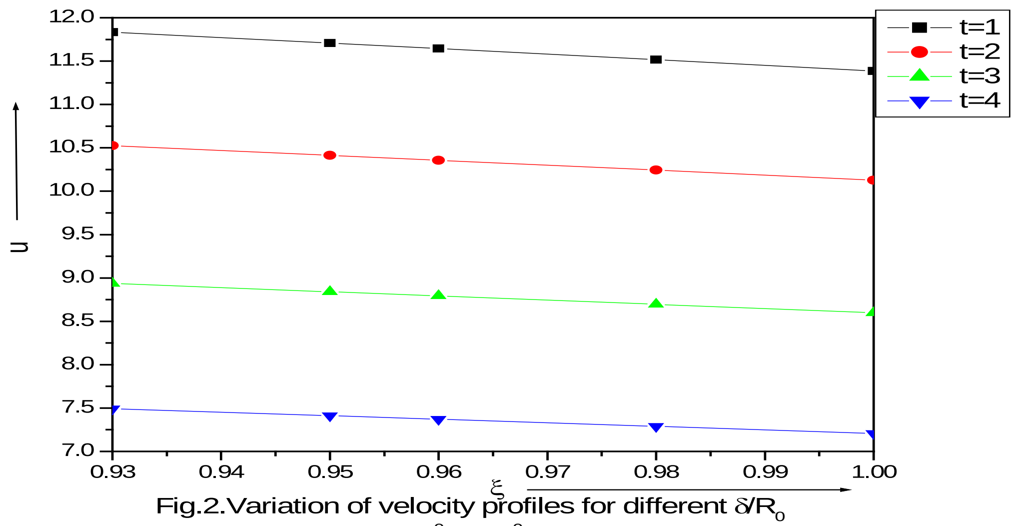

Fig.2.Variation of velocity profiles for different δ/R_o against ξ with $\phi=30^0,\theta=30^0,H=1,g=9.8$

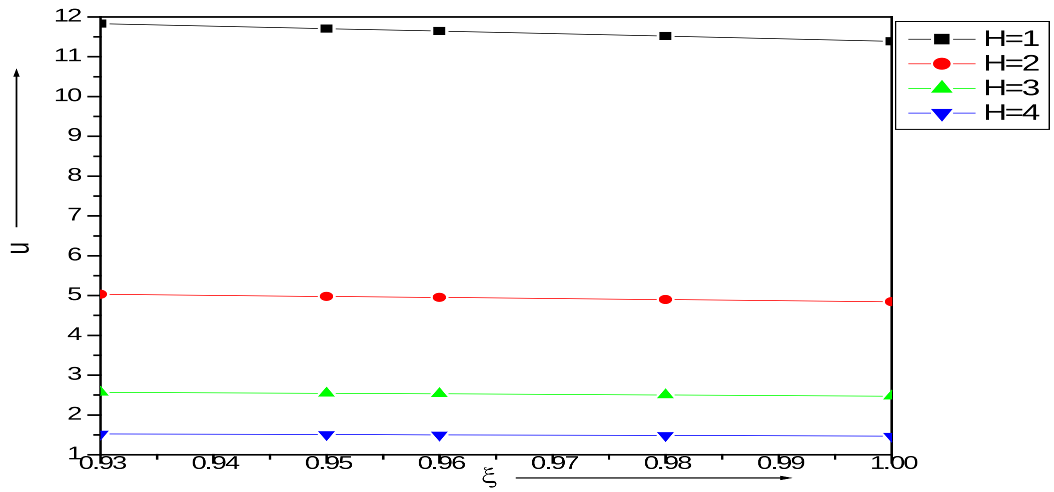

Fig.3.Variation of velocity profiles for different δ/R_o against ξ with $\phi=30,\theta=30^0,t=1,g=9.8$

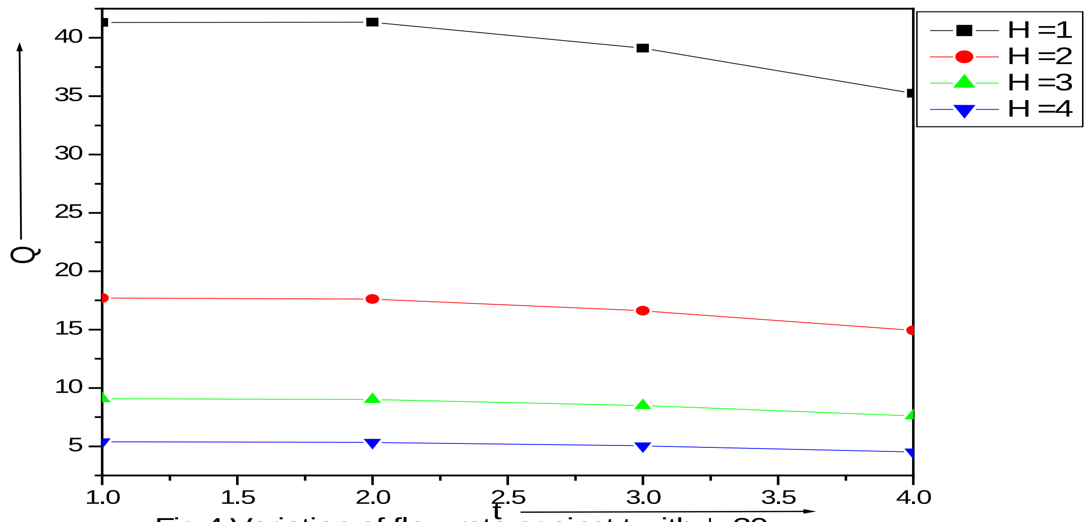

Fig.4.Variation of flow rate against t with $\phi=30,\theta=30^0,t=1,g=9.8$

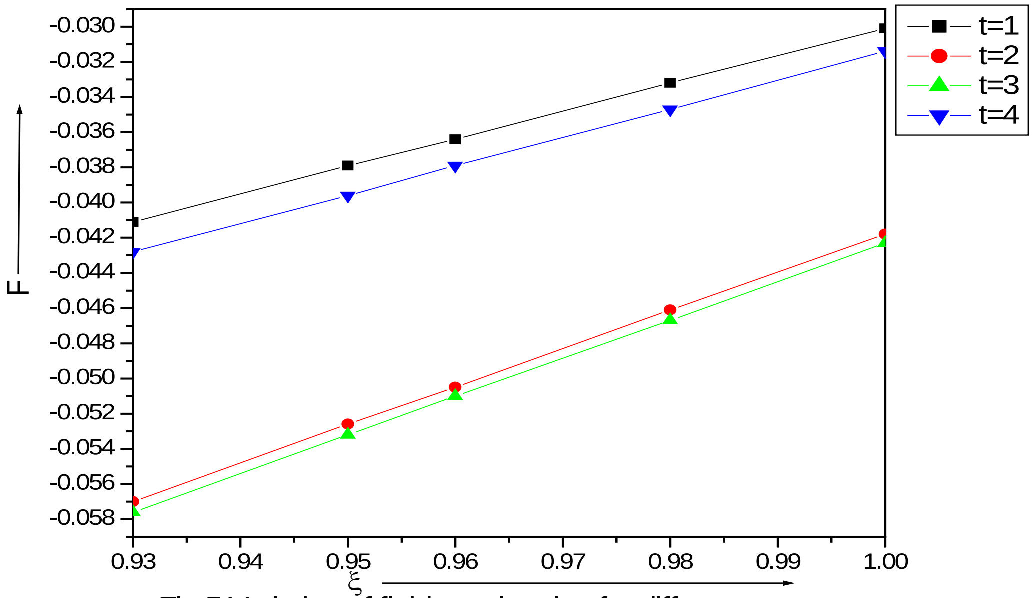

Fig.5.Variation of fluid accelaration for different δ/R_0 against ξ with $\phi=30^0,\theta=30^0$,H=1,g=9.8

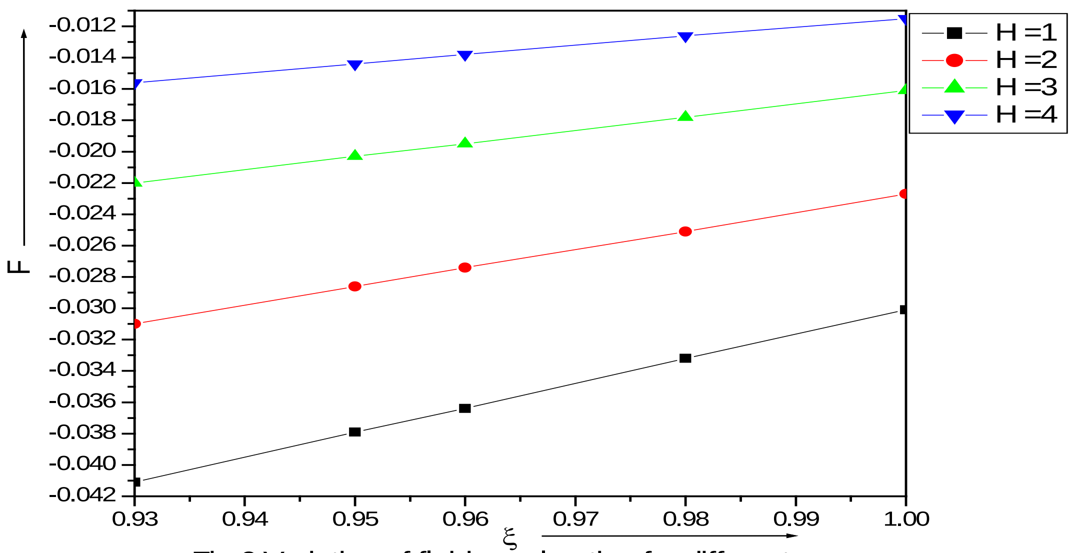

Fig.6.Variation of fluid accelaration for different δ/R_0 against ξ with $\phi=30^0,\theta=30^0$,t=1,g=9.8

In Fig 2, velocity u versus ξ for different time t is plotted. It is observed that velocity u decreases with increase in ξ .As t increases, velocity u decreases.

In Fig 3, velocity u versus ξ for different H is plotted. Velocity u decreases with increase in ξ and as H increases u decreases.

In Fig 4, flow rate Q versus ξ for different H is plotted. As H increases, flow rate Q decreases and as t increases, Q decreases.

In Fig 5, fluid acceleration F versus ξ for different time t is plotted. As ξ increases, F increases. Also, as t increases, F decreases.

In Fig 6, fluid acceleration F versus ξ for different time H is plotted. As ξ increases, F increases and as H increases, F increases.

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