

Impact of electrokinetic variable viscosity on peristaltic transfer of Jeffrey fluid

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Abstract. This article presents a mathematical model to study the impact of electro kinetic variable viscosity on peristaltic transfer of Jeffrey fluid. We have considered the non-Newtonian Jeffrey fluid model with the use of linear momentum. Poisson-Boltzmann equations are simplified by using Debye-Hückel linearization approximation. The closed form analytical solutions are presented by using long wavelength and low Reynolds number assumptions. The expressions for pressure rise and pressure gradient are determined by using perturbation method. The influence of various parameters like Jeffrey fluid parameter, Electro-osmotic parameter, Electroosmotic velocity and Viscosity parameter on the flow characteristics are discussed through graphs. It is revealed that with an increase in the Viscosity parameter there is decrease in the pumping, free pumping, enhances in the augmented pumping region and the axial pressure gradient decreases with increasing Viscosity.

Keywords: Jeffrey fluid, Electro-osmotic, Electroosmotic velocity and Viscosity parameter

1. Introduction

The phenomena of peristaltic are of great importance in many engineering and biological systems. Latham [1] has coined the idea of fluid transport by means of peristaltic waves in mechanical and physiological studies. Peristaltic flow of non-Newtonian fluids in a tube was first studied by Raju and Devanathan [2]. Information on the topic is quite reasonable and researchers mention a few recent representative attempts and several useful references in their investigations [3-8].

Divya et al. [9] described the hemodynamics of variable liquid properties on the MHD peristaltic mechanism of Jeffrey fluid with heat and mass transfer. Here it is observed that increase in the variable viscosity parameter is found to accelerate the fluid flow. Abbasi et al. [10] described the hydro magnetic peristaltic transport of copper-water nanofluid with temperature-dependent effective viscosity. Their analysis shows that, pressure gradient in the wider part of the channel is found to increase as a function of the variable viscosity. Akbar and Nadeem [11] have analyzed the simulation of variable viscosity and Jeffrey fluid model for blood flow through a tapered artery with a stenosis. Farooq et al. [12] studied the magneto hydrodynamic peristalsis of variable viscosity Jeffrey fluid with heat and mass transfer. It is noticed that velocity has small resistance in the case of variable viscosity. Nadeem and Akbar [13] discussed the peristaltic flow of a Jeffrey fluid with Variable Viscosity in an asymmetric channel.

Flow of fluids in channels under the effect of an electrical field is a key area in both medical engineering and energy sciences. R. E Abo-Elkhalr et al. [14] studied combine impacts of electro kinetic variable viscosity and partial slip on peristaltic MHD flow through a Micro-Channel, observing that they are especially used to relieve pain and also to accelerate fracture healing in bones. These remedial procedures have also been employed to accelerate the flow of blood. Laxmi et al. [15] studied the peristaltically induced Electroosmotic flow of Jeffrey fluid with Zeta potential and Navier- Slip at the wall. Electrokinetic flow of peristaltic transport of Jeffrey fluid in a porous channel analyzed by Laxmi et al. [16]. Microchannels are used in fluid control. Sharma et al. [17] demonstrated the analysis of double diffusive convection in electroosmosis regulated peristaltic transport of nanofluids. Their analysis can be utilized in clinical significances like drug delivery systems, cell therapeutics and particles filtrations. Some researchers studied on microchannel [18-20].

In this paper the impact of electro kinetic variable viscosity on peristaltic transfer of Jeffrey fluid were investigated. Consider the approximation of long wavelength and low Reynolds number, the governing flow problem is simplified by using perturbation method. The resulting equations are solved analytically and

exact solutions are presented. The impact of all the physical parameters of interest is taken into consideration with the help of graphs.

2. Mathematical model

Consider an incompressible Jeffrey fluid in a two dimensional micro-channel of width $2a$. The sinusoidal wave trains propagate along the channel wall with constant speed C and propped the fluid along the walls. In a regular co-ordinate system (X, Y) , the geometry of the wall surface is described by

$$H(x, t) = a + b \cos \frac{2\pi}{\lambda} (X - ct). \quad (1)$$

where b is amplitude of the waves and λ is the wave length, c is the velocity of wave propagation and X is the direction of wave propagation.

The constitutive equations for Jeffrey fluid are given by

$$\bar{T} = -P\bar{I} + \bar{S}. \quad (2)$$

$$\bar{S} = \frac{\mu(\bar{Y})}{1+\lambda_1} (\dot{\gamma} + \lambda_2 \ddot{\gamma}). \quad (3)$$

where $\bar{T}$ and $\bar{S}$ are the Cauchy stress tensor and extra stress tensor, $\bar{P}$ is the pressure, $\bar{I}$ is the identity tensor, μ is the dynamic viscosity, λ_1 is the ratio of relaxation to retardation times, λ_2 is the retardation time, $\dot{\gamma}$ is the shear rate and dots over the quantities denote differentiation.

Under the assumptions that the channel length is an integral multiple of the wave length λ and the pressure difference across the ends of the channel is a constant, the flow is inherently unsteady in the laboratory frame $(\bar{X}, \bar{Y})$ and become steady in the wave frame $(\bar{x}, \bar{y})$ which is moving with velocity c along the wave. The transformation between these two frames is given by $x = \bar{X} - ct, y = \bar{Y}, u = \bar{U}, v = \bar{V}$. (4)

Where U and V are velocity components within in the laboratory frame and u and v are the velocity components within the wave frame.

The equations governing the electro osmotic flow are taken as

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0. \quad (5)$$

$$\rho \left[u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} \right] = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} - \frac{\mu}{k} (u + c) + \rho_e E_x. \quad (6)$$

$$\rho \left[u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} \right] = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y}. \quad (7)$$

where E_x denote electro kinetic body force. The Poisson's equation is defined as

$$\Delta^2 \Phi = -\frac{\rho_e}{\epsilon}. \quad (8)$$

in which k is the permeability of the porous medium, ρ_e is the density of the total ionic charge and ϵ is the permittivity. The Boltzmann equation is expressed as

$$n^\pm = n_0 \exp \left[\pm \frac{e z \Phi}{K_B T} \right]. \quad (9)$$

Where n_0 represents concentration of ions at the bulk, which is independent of surface electrochemistry, e is the electronic charge, is the charge balance, K_B is the Boltzmann constant, and T is the average temperature of the electrolytic solution.

Introducing the non-dimensional quantities

$$\begin{aligned} \bar{x} &= \frac{x}{\lambda}, \bar{y} = \frac{y}{a}, \bar{u} = \frac{u}{c}, \bar{v} = \frac{v}{c\delta}, \delta = \frac{a}{\lambda}, p = \frac{a^2 \bar{p}}{\mu_0 c \lambda}, \\ \bar{t} &= \frac{ct}{\lambda}, \bar{\tau} = \frac{a\tau}{\mu_0 c}, \varphi = \frac{b}{a}, \bar{\Phi} = \frac{\Phi}{a^2}, \\ R_e &= \frac{\rho c a}{\mu} \text{ and } \bar{\mu}(\bar{y}) = \frac{\mu(y)}{\mu_0} \end{aligned} \quad (10)$$

The equations governing the flow become

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0. \quad (11)$$

$$R_e \delta \left[u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} \right] = -\frac{\partial p}{\partial x} + \delta \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} - \frac{1}{D_a} (u + 1) + m^2 U_{hs} \Phi. \quad (12)$$

$$\delta^3 R_e \left[u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} \right] = -\frac{\partial p}{\partial y} + \delta^2 \frac{\partial \tau_{xy}}{\partial x} + \delta \frac{\partial \tau_{yy}}{\partial y}. \quad (13)$$

where