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ScienceDirect
Journal of the Nigerian Mathematical Society 35 (2016) 227–244
Journal of the Nigerian Mathematical Society
www.elsevier.com/locate/jnnms

Impact of velocity slip and joule heating on MHD peristaltic flow through a porous medium with chemical reaction

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Received 17 August 2015; received in revised form 11 February 2016; accepted 16 February 2016
Available online 21 March 2016

Abstract

The present study investigates the effect of joule heating and velocity slip on MHD peristaltic flow in a porous medium with chemical reaction. The relevant equations on the fluid flow have been developed. Analytic solution is carried out under long-wavelength and low-Reynolds number approximations. Exact solution is evaluated for the stream function, which is used to find the velocity of the fluid flow, temperature, concentration. Numerical computations have been performed for the influence of various emerging parameters on the flow characteristics velocity, temperature, concentration are shown and discussed with the help of graphs. Also, the expressions for skin friction coefficient, Nusselt number and Sherwood number at the channel wall are obtained and analyzed. It is found that a generative chemical reaction is greater than the destructive chemical reaction on the concentration. The size of the trapping bolus increases with increasing velocity slip parameterβ.

Keywords: Peristalsis; MHD; Porous medium; Chemical reaction; Slip flow; Compliant walls

1. Introduction

It is well established fact that peristaltic process is a mechanism for mixing and transporting fluids, which is caused by a progressive wave of contraction and expansion travelling on the walls of the channel/tube. Such process is encountered in the transport of urine from kidney to bladder, swallowing of food through esophagus, lymph transport in the lymphatic vessels and in vasomotion of small blood vessels such as arterioles, venules and capillaries etc. Roller and finger pumps also work under the peristaltic mechanism. The seminal research on the peristaltic motion has been presented by Latham [1] and Jaffrin and Shapiro [2]. Since then the various experimental and theoretical studies have been presented in the viscous and non-Newtonian fluids [3–10]. Makinde [11] investigated the laminar flow in a channel of varying width with permeable boundaries. Asymptotic approximations for oscillatory flow in a tube of varying cross-section with permeable isothermal wall was analyzed by Makinde [12]. In view of the importance of oxygenation and dialysis, the peristaltic flows with heat transfer have been also investigated [13–15]. Very recently, Effects of stenosis on non-Newtonian flow of blood in blood vessels has been reported by Prakash et al. [16].

Peer review under responsibility of Nigerian Mathematical Society.
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http://dx.doi.org/10.1016/j.jnnms.2016.02.005

In several applications the flow pattern corresponds to a slip flow, the fluid presents a loss of adhesion at the wetted wall making the fluid slide along the wall. When the molecular mean free path length of the fluid is comparable to the distance between the plates as in nanochannels or microchannels, the fluid exhibits non-continuum effects such as slip-flow as demonstrated experimentally by Derek et al. [17]. Investigations of the effects of slip on the peristaltic motion have been recently reported in [18–21].

The study of magnetohydrodynamic (MHD) peristaltic flow of a fluid is of special interest in certain problems of conductive physiological fluids as the influence of magnetic field may be utilized as a blood pump in carrying out cardiac operations for the flow of blood in arteries with arterial disease like arterial stenosis or arteriosclerosis. The usage of the Giant Magneto Resistive (GMR) technology which is a device that applies a magnetic field with a very sensitive sensor, accurately detect the small movements of an object within a magnetic field. This technology has the potential to facilitate the study of peristaltic activity in some tubular structures such as a bowel, fallopian tube and perhaps even in the vas deferens. Hydromagnetic effects on internal flow separation in a diverging channel have been reported by Makinde and Mhone [22]. The influence of magnetic field on Peristaltic transport of Jeffrey fluid in a porous medium with compliant walls was studied by Hayat et al. [23]. Prakash and Makinde [24] have presented the radiative heat transfer to blood flow through a stenotic artery in the presence of erythrocytes and magnetic field. Hayat et al. [25] have analyzed the peristaltic transport of a Jeffrey fluid under effects of an endoscope and applied magnetic field. Mekheimer [26] has examined the peristaltic transport of a couple stress fluid under influence of an induced magnetic field. Kothandapani and Srinivas [27] presented the effect of wall properties on MHD peristaltic transport through a porous medium. Gad [28] describes the peristaltic transport under the effect of Hall currents in a channel having compliant boundaries. MHD Peristaltic Flow of a Nanofluid with Newtonian Heating was studied by Noreen Sher Akbar [29]. Sarkar et al. [30] have presented the impact of Magnetohydrodynamic peristaltic flow on nanofluids in a convectively heated vertical asymmetric channel in the presence of thermal radiation. Very recently, the influence of Joule heating on MHD peristaltic flow of a nanofluid with compliant walls was investigated by Gnaneswara Reddy and Venugopal Reddy [31].

Consideration of wall properties such as wall stiffness, wall rigidity, mass per unit area of the channel walls, wall tension etc. is very important in peristalsis. In particular the increased intensity of such effects can significantly influence the blood pressure in human body. Peristaltic motion in a channel with complaint walls has been discussed previously. The peristaltic flow of Johnson–Segalman fluid in a channel with complaint walls was investigated by Hayat et al. [32]. The influence of heat and mass transfer on MHD peristaltic flow through a porous space with compliant walls investigated by Srinivas and Kothandapani [33].

Moreover, it is well known that heat and mass transfer problem in the presence of chemical reaction is very significant in the processes of geothermal reservoirs, drying, enhanced oil recovery, flow in a desert cooler, cooling of nuclear reactors thermal insulation and evaporation at the surface of a water body. These types of flows involve many practical operations such as molecular diffusion of species in presence of chemical reaction within or at boundary. Heat and mass transfer effects are also encountered in chemical industry like in the study of hot salty springs in sea, in thermal recovery processes and in reservoirs. The results obtained for title problem reveal many interesting behaviors that warrant further study on heat and mass transfer problems with chemical reaction.

However, no attempt has been made to investigate joule heating and velocity slip effects on the MHD peristaltic transport of non-Newtonian fluid in a porous space with chemical reaction. Such an analysis is of great interest in medical research. The momentum, temperature equations and concentration equations have been linearized under long-wavelength and low-Reynolds number assumptions and analytical solutions for the flow variables have been derived. The contribution of several interesting parameters embedded in the flow system is examined by graphical representations. The present work may be beneficial in understanding the dynamics of blood flow in blood vessels by taking into account the chemical reaction and important wall elastic properties. The current model can be described through the impacts of magnetic field, velocity slip and chemical reaction in the walls of the blood vessels.

2. Mathematical formulation

The flow of a Newtonian viscous fluid through a two-dimensional channel of uniform thickness is considered. The motion in a channel are induced by imposing moderate amplitude sinusoidal waves on the compliant walls of the