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Hydromagnetic flow of generalized Newtonian fluid through a uniform tube with peristalsis

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Abstract

We have analyzed the mechanics of peristaltic pumping of a non-Newtonian fluid through an axisymmetric conduit subjected to a constant transverse magnetic field. The material represented by the constitutive equation for a power-law fluid. A perturbation series in dimensionless Hartmann number ($M < 1$) was used to obtain explicit forms for the velocity field and relation between the flow rate and pressure gradient, in terms of the dimensionless power-law index and the occlusion. The expressions for the pressure rise and friction force on the wall of tube (small intestine) were computed numerically and were plotted with variation of the flow rate for different values of power-law index, Hartmann number and amplitude ratio. The results were compared with other studies, in both Newtonian and non-Newtonian cases.

Keywords: Peristalsis; Non-Newtonian fluid; Magnetic field; Uniform geometry

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1. Introduction

It has been accepted that most of the physiological fluids behave like a non-Newtonian fluid so the purpose of this paper is to study effect of magnetic field, that is used in magnetotherapy, on peristaltic motion for generalized Newtonian fluid. Based on experimental controls, it was shown that the controlled application of low intensity and frequency pulsing magnetic fields could modify cell and tissue behavior. Biochemistry has taught us that cells are formed of positive or negative charged molecules. This is why these magnetic fields applied to living organisms may induce deep modifications in molecule orientation and in their interaction. Experimental studies are used an impulse magnetic field in the combined therapy of patients with stone fragments in the upper urinary tract by Li et al. [22]. It was found that impulse magnetic field (IMF) activates impulse activity of ureteral smooth muscles in 100% of cases. Furthermore, the non-invasive radiological test that uses a magnetic field (not radiation) to evaluate organs in abdomen prior to surgery in the small intestine (but not always). Hence, magnetically susceptible of chyme can be satisfied from the heat generated by magnetic field or the ions contained in chyme. We hope to study the effect of magnetic field on peristaltic motion for power-law fluid through conduit with application on the small intestine. Due to the complexity of the non-linear equations of motion, we only consider the case: axisymmetric flow, infinite wave trains on the tube, an incompressible power-law fluid.

The mechanics of peristalsis has been examined by a number of investigators. Latham [7] may be first in print with his thesis; however, Fung and Yih [23] and Shapiro et al. [11] worked on very similar time lines. Lew et al. [8] suggested chyme as a non-Newtonian material having plastic-like properties and observed that Reynolds number in the small intestine was very small. Shukla et al. [12] investigated the effects of peripheral-layer viscosity on peristaltic transport of a bio-fluid in uniform tube and used the long wavelength approximation as in Shapiro et al. [11]. Böhme and Friedrich [21] discussed peristaltic flow of viscoelastic liquids assuming the relevant Reynolds number is small enough to neglect inertia forces, ratio of the wavelength and channel height is large, that implies the pressure is constant over the cross-section. Pozrikidis [9] considered peristaltic flow under the assumption of creeping motion and used boundary integral method for Stokes flow. Agrawal and Anwaruddin [20] studied the effect of moving magnetic field on blood flow. They studied a simple mathematical model for blood through an equally branched channel with flexible outer walls executing peristaltic waves. The results shown that velocity of the fluid increases with increasing the magnetic field. Srivastava and Srivastava [14,15] showed the effects of power-law fluid in uniform and non-uniform tube and channel under zero Reynolds number and long wavelength approximations. Siddiqui and Schwarz [13] illustrated peristaltic flow of a second order fluid in tubes and used a perturbation method to second