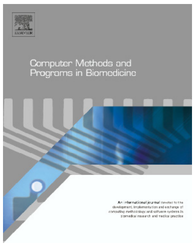
COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 130 (2016) 22–30

ELSEVIER

journal homepage: www.intl.elsevierhealth.com/journals/cmpb



Copper oxide nanoparticles analysis with water as base fluid for peristaltic flow in permeable tube with heat transfer

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ARTICLE INFO

Article history:
Received 3 November 2015
Received in revised form
22 January 2016
Accepted 2 March 2016

Keywords:
MHD
Peristaltic flow
Copper oxide nanoparticle
Permeable tube

ABSTRACT

The peristaltic flow of a copper oxide water fluid investigates the effects of heat generation and magnetic field in permeable tube is studied. The mathematical formulation is presented, the resulting equations are solved exactly. The obtained expressions for pressure gradient, pressure rise, temperature, velocity profile are described through graphs for various pertinent parameters. It is found that pressure gradient is reduce with enhancement of particle concentration and velocity profile is upturn, beside it is observed that temperature increases as more volume fraction of copper oxide. The streamlines are drawn for some physical quantities to discuss the trapping phenomenon.

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1. Introduction

In some psychological and physical process filtration and mass transfer occur as a fluid flows through a permeable tube. This term is seen in reverse osmosis desalination; in extra-corporeal circuitry for body fluid processing, like the hemodialyzer; in lymphatic flow, and inflow in the nephron tubules.

The pressure and velocity areas in these situations are different from simple Poiseuille flow in an impermeable tube because fluid in contact with the wall has a normal velocity component. Laminar flow in a pipe with consistent leakage or injection has been observed by Friedlander and MacKenzie [1] who obtained perturbation solutions for "small" and "large" transmural. In research of specific vital human physiological phenomena, the mechanism of peristaltic pumping is interest worthy in relation to transportation of fluids through flexible tubes. This mechanism is there in urine transfer from kidney to bladder, movement of the ovum in the Fallopian tubes and in the vasomotion of small blood vessels. Pumps having industrial and physiological applications adopting the principle of peristalsis have been developed by the engineers.

Non-steady peristaltic transport in a finite length tube has been searched by Li and Brasseur [2], who investigated the fluctuations in pressure and shear stress arise due to a non-integral number waves in the finite length tube. Retrograde motion of fluid particles during peristaltic transport reflux has an inherently different behavior with a single peristaltic wave as compared with multiple train waves. Research on the peristaltic transport of a fluid in the existence of an external magnetic field and rotation is of great importance with

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http://dx.doi.org/10.1016/j.cmpb.2016.03.003
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regard to certain problems involving the movement of conductive physiological fluids, saline water and blood are the examples. An analytical study of the MHD flow of a micro polar fluid through a porous medium induced by sinusoidal peristaltic waves traveling down the channel wall was conducted by Pandey and Chaube [3].

Li et al. [4] analyzed that an impulsive magnetic field in the combined therapy of patients with stone fragments in the upper urinary tract. It was understood that the Impulsive Magnetic Field activates the impulsive activity of the arterial smooth muscles in 100% of cases. Mekheimer and Al-Arabi [5] investigated the non-linear peristaltic transport of MHD flow through a porous medium was studied in non-uniform channels recently Nadeem and Ijaz [6] present a precise model for studying the influence of metallic nanoparticles on blood flow through catheterized tapered elastic arteries with radially varying magnetic field.

CuO, categorized into transition metal oxide group, is a p type, narrow band gap semiconductor. It has monoclinic structure and many interesting characteristics: super thermal conductivity, photovoltaic properties, high stability, and antimicrobial activity. Due to such exclusive properties, CuO can be used in many technological fields, for example, active catalyst [7], gas sensor [8–10], high efficiency thermal conducting material [11], magnetic recording media [12], with very good selectivity, or solar cell applications [13].

In addition to some shared properties of metal oxide nanostructures, such as TiO_2, ZnO, WO_3, and SnO_2, CuO nanostructures have other unique magnetic and super-hydrophobic [14] properties. Furthermore, these nanostructures show very promising applications in heterogeneous catalysis in the complete conversion of hydrocarbons into carbon dioxide, enhancement of thermal conductivity of nanofluid, nanoenergetic materials, and super-hydrophobic surfaces or anode materials for lithium ion batteries (LIBs). However, this material has not got attention of scientists at right level until recent years. Compared with other oxides of transition metal such as Fe_2O_3, TiO_2, and ZnO only few reports have described the synthesis strategies adopted for CuO nanostructures along with the introduction of their related applications.

Nadeem and Akbar [15] studied the influence of radially varying MHD on the peristaltic flow in an annulus with heat and mass transfer. Mekheimer and Elmaboud [16] discussed the influence of heat transfer and magnetic field on the peristaltic flow of Newtonian fluid in a vertical annulus under a zero Reynolds number and long wavelength approximation. Ebaid [17] studied a new numerical solution for the MHD peristaltic flow of a biofluid with variable viscosity in a circular cylindrical tube by an Adomian decomposition method. Mekheimer [18] investigated the impacts of the induced magnetic field on the peristaltic flow of a couple stress fluid in a slit channel Akbar and Butt [19] recently discussed magnetic field effects for copper suspended nanofluid with permeable wall, Akbar and Butt [20] entropy generation analysis for the peristaltic flow of Cu–water nanofluid in a tube with viscous dissipation, they found that the entropy generation number attains high values in the region close to the walls of the tube, while it gains low values near the center of the tube.

This has also been concluded that heat transfer can be augmented through the improvement in the thermal properties of energy transmission fluids. If small solid particles in the fluid are restricted, this might be a creative path of reforming the thermal conductivities of fluids. Nanofluids are evaluated to display the conventional heat transfer fluids as comparing with superior heat transfer properties [21]. Choi [22] gave this concept of suspensions of colloidal particles dubbed as nanofluid, his view was that small amounts of metallic or metallic oxide nanoparticles are dispersed into water and other fluids. Further, some important and recent contribution to enhancement the heat transfer and cooling system have been presented [23–30].

With the above discussion in mind, the purpose of this study is to analyze the effect of peristaltic flow with heat generation of nanofluid with the presence of magnetic field in a permeable tube. It is note that copper oxide–water nanofluid is used as the model in this article. The analysis is performed under the well-established long wavelength and low Reynolds number approximations. The exact solution for the stream function, temperature and pressure gradient is given. All the physical features of the problems have been described with the help of graphs.

2. Mathematical formulation

We have considered the peristaltic course of an incompressible copper oxide nanoparticles for the peristaltic flow with water as base fluid under influence of permeable walls. The flow is generated by sinusoidal wave trains propagating with constant speed c_1 along the walls of the tube. Heat transfer along with nanoparticle phenomena has been taken into account. The wall of the tube is maintaining at temperature $\bar{T}_0$ and solid nanoparticle volume fraction $\bar{C}_0$ while at the center we have used symmetry condition on both temperature and solid nanoparticle volume fraction. The geometry of the wall surface is defined as

$$\overline{h} = a(\overline{Z}) + \omega \sin \frac{2\pi}{\lambda}(\overline{Z} + c_1\overline{t}), \tag{1}$$

where $a(\overline{Z}) = a_0 + K_1\overline{Z}$ the radius of the tube at any axial distance from inlet is also a_0 is the radius of the inlet, K is a constant whose magnitude depends on the length of the tube, exit and inlet dimensions, ω is the wave amplitude, λ is the wavelength, c_1 is the propagation velocity and $\bar{t}$ is the time. We are considering the cylindrical coordinate system $(\bar{R}, \bar{Z})$ in which $\bar{Z}$-axis lies along the center line of the tube and $\bar{R}$ is transverse to it. The transformations between the two frames are

$$\begin{aligned} &\overline{r} = \overline{R}, \quad \overline{z} = \overline{Z} - c_1\overline{t}, \\ &\overline{u} = \overline{U}, \quad \overline{w} = \overline{W} - c_1, \end{aligned} \tag{2}$$

where $\overline{u}$ and $\bar{w}$ are the velocities in the wave frame.

$$\frac{1}{\overline{r}}\frac{\partial(\overline{r}\overline{u})}{\partial \overline{r}} + \frac{\partial \overline{w}}{\partial \overline{z}} = 0, \tag{3}$$

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