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Bioconvection Peristaltic Transport of Nanofluid in a Channel containing Gyrotactic microorganism

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Abstract: This research paper is deals with the behavior of gyrotactic in peristaltic transport of nano Eyring-Powell fluid in non-uniform channel. The advantages of adding motile micro-organism to the nanofluid suspension enhanced the heat transfer, mass transfer and improve the nanofluids stability. The governing equations have been fabricated for long wavelength and low Reynolds number assumptions. The solutions have been described for pressure gradient, temperature, nanoparticle concentration and density of motile microorganism equations and solved by using powerful technique known as Homotopy Analysis Method (HAM). Results are reported for different values of the some significant parameters on peristaltic transport through a non-uniform channel and obtained results are displayed in graphs.

Keywords: Biconvection, gyrotactic microorganism, Peristaltic flow, Eyring-Powell fluid model.

1. Introduction

In rheology, the fluids can easily be transport from one region to another region with help of pumping. This type of pumping is known as peristalsis. The peristalsis is a form of fluid flow produced by a continuous wave of area clasping and also compressing propagates of tube or channel. Peristalsis helps in transporting physiological fluids in the human body such as swallowing of food through oesophagus, movement of chime in the gastrointestinal tracts and the vasomotion of small blood vessels. Latham [1] was first initiated the concept of peristaltic mechanism in 1966. After the work of Latham, Jaffrin et al. [2] explore the peristaltic pumping system. They studied the peristaltic flow for the long wavelength and low Reynolds number assumptions. Many researchers and scientist diverted their research interest towards study the peristaltic transport by considering viscous and non-viscous fluids with different models and with different geometries, few references are given in [3-7]. As we know many physiological flows are not uniform. Hence, many of the researchers studied peristaltic flow problems through uniform and non-uniform channels for different fluid models. Some of these investigations have been reported in the references [8-12].

The word “nanofluid” was first formulated by Choi in 1995 [13]. Nanofluid is a liquid that containing nanoparticles with representative length of 1-100nm [14]. The study of nanotechnology based on nanofluids has received general attention due to its applications in engineering and biomedical. Nanofluids are new kind of fluids conceived by destruction of nanometer-sized materials in base fluids such as ethylene-glycol or lubricants, water and silk fibroin etc. Dissimilar nanoparticles have many importances in different fields, like Copper nanoparticles have diverse range of applications in heat transfer systems, sensors and catalysts. In biomedical, magnetite nanoparticles are targeted for magnetic resonance imaging (MRI) and during in drug delivery.In present days, the flow of non-Newtonian fluids has received much awareness due to its applications in medical, industries and technology. To study the non-Newtionian fluids several models have been developed. Among them Eyring-Powell model has certain advantage over other fluid model. Firstly, kinetic theory of liquid is used to obtained the concentrate of fluid model, secondly, at low and high shear rates the concentrate of the model helps to recover the error-free results of viscous nanofluid. Eyring-Powell fluid model was first initiated by Eyring and Powell in 1994 [15]. Many researchers are study the peristaltic flow in different geometrics by considering Eyring-Powell model as cited in references [16-22].

Bioconvection has large amount of applications in biomedical and biotechnology. The bioconvection is defined as flow induced by collective swimming of motile microorganisms which are little denser than water is studied by John [23]. The self- propelled motile microorganisms intensify the base fluid density in a particular direction. Collection of microorganisms at the top of the layer makes suspension more impenetrable than the lower layer due to unstable density distributions. Under such circumference, convection instability and generation of convection patterns take place. Such a quick and random movement pattern of microorganisms causes bioconvection procedure within the system. Bioconvection instability is developed from an initially uniform suspension without an unstable density disturbance was given by Pedley et al. [24]. Many researchers worked on the bioconvection flow with different geometries are given in the ref. [25-27]. In biological fluid mechanics, recent significant growing are nano bioconvection flows. Application of microorganisms is one of the most detectable methods of various bio-methods of nanoparticle production. It is found that the inclusion of particles makes suspension more stable. Kuznetsov et al. [28] studied the suspension of gyrotactic microorganisms in layer of finite depth by adding small solid particles. The nanoparticles are not self-inflicted like motile micro-organisms, nanoparticles motion are due to thermophoresis and Brownian motion. If concentration of nanoparticle is small, bioconvection is occurs in nanofluid. Recent research papers on bioconvection flow containing microorganisms are mentioned in references [29-37].

Literature review revealed that no work has been done on bioconvection peristaltic flow. However, recently Nooren [38] have studied the bioconvection peristaltic flow containing gyrotactic microorganisms in nanofluid in a symmetric channel. Bhatti et al. [39] investigated the peristaltic flow of non- Newtonian Jeffrey nanofluid containing gyrotactic microorganism in annulus. Since, Peristalsis is well known mechanism to transport physiological fluid in most biological organs. Many biological systems are observed to be non-uniform. The purpose of the present study is therefore to understand how the free convection affects the peristaltic transport of blood in a small blood vessel. Here we consider blood as Erying-Powell nanofluid model. The present study has wide range of applications in biomedical science and engineering. Since microorganisms are favorable in decomposition of organic material, producing oxygen and maintaining human health. The dilution of microorganisms in the nanofluids modifies its thermal conductivity. In the present paper, the solution for Pressure gradient, temperature, concentration and motile microorganism's density along with boundary conditions are obtained by using the Homotopy Analysis Method [40, 41]. The effect of various physical parameters on velocity, pressure gradient, temperature and motile-microorganisms density are analysed through graphs.

Mathematical Analysis

Let us consider a peristaltic transport of nano Eyring-Powell fluid in a two dimensional channel. The physical model of the wall surface can be written as

$$\tilde{h}(\tilde{X},\tilde{t}) = a(\tilde{X}) + d\,sin\left(\frac{2\pi}{\lambda}(\tilde{X} - c\tilde{t})\right), \tag{1}$$

here $a(\tilde{X}) = a_{20} + k\tilde{X}$ is the half width of the channel, wavelength of the wall surface is λ, $\tilde{t}$ is the time and d represents the wave amplitude. Let $\tilde{U}$ and $\tilde{V}$ are velocity components along $\tilde{X}$and $\tilde{Y}$directions respectively, the velocity field Vcan be written as

$$V = \left(\tilde{U}(\tilde{X},\tilde{Y},\tilde{t}), \tilde{V}(\tilde{X},\tilde{Y},\tilde{t}), 0\right). \tag{2}$$

The Eyring-Powell fluid model of the shear stress tensor is given by

$$\tilde{S} = \mu\nabla\tilde{V} + \frac{1}{\beta}sinh^{-1}\left(\frac{1}{c^*}\nabla\tilde{V}\right),$$

(3)

where the coefficient of shear viscosity is μ, $\beta$and c^* are the fluid parameters.

$$sinh^{-1}\left(\frac{1}{c^*}\nabla\tilde{V}\right) \approx \frac{1}{c^*} - \frac{1}{6}\left(\frac{1}{c^*}\nabla\tilde{V}\right)^3, \left|\frac{1}{c^*}\nabla\tilde{V}\right| <= 1. \tag{4}$$

The governing equations for the nano Eyring-Powell fluid can be formulated as follows
The continuity equation:

$$\frac{\partial\tilde{U}}{\partial\tilde{X}} + \frac{\partial\tilde{U}}{\partial\tilde{Y}} = 0. \tag{5}$$

The momentum equation:

$$\rho_f\left(\frac{\partial\tilde{U}}{\partial\tilde{t}} + \tilde{U}\frac{\partial\tilde{U}}{\partial\tilde{X}} + \tilde{V}\frac{\partial\tilde{U}}{\partial\tilde{Y}}\right) = -\frac{\partial\tilde{p}}{\partial\tilde{X}} + \left(\mu + \frac{1}{\beta c^*}\right)\left(\frac{\partial^2\tilde{U}}{\partial\tilde{X}^2} + \frac{\partial^2\tilde{U}}{\partial\tilde{Y}^2}\right) - \frac{1}{2\beta c^{*3}}\left(\frac{\partial\tilde{U}}{\partial\tilde{X}} + \frac{\partial\tilde{U}}{\partial\tilde{Y}}\right)^2\left(\frac{\partial^2\tilde{U}}{\partial\tilde{X}^2} + \frac{\partial^2\tilde{U}}{\partial\tilde{Y}^2}\right) + (1 - \phi_1)\rho_f g\beta_1(\tilde{T} - \tilde{T}_0) - (\rho_p - \rho_f)g(\tilde{C} - \tilde{C}_0) - (\rho_m - \rho_f)\gamma g(\tilde{n} - \tilde{n}_0) \tag{6}$$

$$\rho_f\left(\frac{\partial\tilde{V}}{\partial\tilde{t}} + \tilde{U}\frac{\partial\tilde{V}}{\partial\tilde{X}} + \tilde{V}\frac{\partial\tilde{V}}{\partial\tilde{Y}}\right) = -\frac{\partial\tilde{p}}{\partial\tilde{Y}} + \left(\mu + \frac{1}{\beta c^*}\right)\left(\frac{\partial^2\tilde{V}}{\partial\tilde{X}^2} + \frac{\partial^2\tilde{V}}{\partial\tilde{Y}^2}\right) - \frac{1}{2\beta c^{*3}}\left(\frac{\partial\tilde{V}}{\partial\tilde{X}} + \frac{\partial\tilde{V}}{\partial\tilde{Y}}\right)^2\left(\frac{\partial^2\tilde{V}}{\partial\tilde{X}^2} + \frac{\partial^2\tilde{V}}{\partial\tilde{Y}^2}\right). \tag{7}$$