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Modelling study on heated couple stress fluid peristaltically conveying gold nanoparticles through coaxial tubes: A remedy for gland tumors and arthritis

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ABSTRACT

This paper represents an innovative technique to cure some of the fatal diseases such as rheumatoid arthritis and tumors by injected nano-size gold particles (gold salt in the veins through a hotted slim tube. In the proposed model large atomic number enables gold particles in attaining further heat and conveys medicine to the effected organs and erodes malign tissues or cells. The couple stress fluid is treated as blood inside the two coaxial tubes containing nanoparticles. The inner tube is considered to be rigid in configuration while the outer is elastic or flexible to eventuate a sinusoidal wave once the fluid passes within the gap of tubes. A set of nonlinear and coupled mathematical equations governing the flow model has been converted into a system of ordinary differential equations using suitable transformations prior to seeking an analytical solutions. A comprehensive parametric study has also been made to make the presented analysis more realistic to ensure that the presented study adheres with the physical phenomenon. Effects of velocity, temperature and concentration of the particles are examined corresponding to variate physical parameters contributing in the flow. Besides, highlighting graphically, the impact of each sundry parameters has been explained in detail at the end. It is worth mentioning that the results for Newtonian fluid can be obtained from the reported results by taking couple stress parameter is zero.

1. Introduction

A microscopic solid particle of size ranging in between 1 nanometer to 100 nm, is known as nanoparticle whereas a liquid drifting some quantity of nanoparticles, is termed as nanofluid. This concept is not very new to engineers and scientists. It was in last century world, for the very first time came to know utility of nanoparticles and their applications incorporated with base fluids of various types. Choi [1] is regarded as the pioneer for introducing nanoparticles as supporting agent to optimize thermal conductivity of the base fluid. Application of nanoparticles has revolutionized human life for their variety of potential application [2–14]. Moreover, convective transfer of heat examined by Buongiorno [15,16] in nanofluids. The emphasis was on how dispersion and rotation of such submicronic particles can enhance convective heat transfer at large level, besides, resulting turbulence at the same time. But, discarded all these three claims of previous scientists in their articles and maintained that such arguments don't cause any prominent change in heat enhancement. However, he did succeed in proposing a novel nanofluid model known as Buongiorno Model. This model mutually relates the velocity of both base-fluid and nanoparticle which was used by various mathematicians and engineers in their quest for nanofluid. H. Xu et al. [17] used the same model to examine mixed convection and enhancement of heat transfer characteristics. They performed their investigation by taking a vertical channel.

Furthermore, among all metals the significance of gold can't be replaced from designing various forms of jewelry, elevating one's life style, to as a useful agent in curing patients. For long, diseases like cancer, gland tumors and arthritis were considered as incurable. But, thanks to selfless and untiring efforts of scientists, chemists and surgeons remedy is not a dream any more. Now, there are potent medicines and drugs available to get rid of them. In addition to this, invention of new and sophisticated apparatuses in field of medical sciences, made surgeons feel confident and bold enough to perform some critical operations and surgeries. Same applies when it comes to eradicate malign tissues and caner present in human body without opting the choice of dissecting parts or organs. Penetration of nano-size gold particles through catheter carrying the required drugs, to the damaged organs has shown remarkable results.

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Nomenclature

V	dimensional nanofluid velocity
$\tilde{U}$	dimensional radial velocity component
$\tilde{R}$	radial direction of the flow in fixed frame
u	dimensionless radial velocity component
r	radial direction of the flow in fixed frame
b	amplitude of peristaltic wave
$\tilde{P}$	dimensional pressure
N_t	thermophoresis parameter
N_b	Brownian motion parameter
D_t	thermophoretic diffusion coefficient
P	constant pressure
a_2	dimensional radius of outer tube
p	dimensionless pressure
r_2	dimensionless radius of outer tube
g	gravitational acceleration
$\tilde{W}$	dimensional lateral velocity component
$\tilde{Z}$	axial direction of the flow in fixed frame
w	dimensionless lateral velocity component
z	axial direction of the flow in fixed frame
$\tilde{t}$	time
c	propagating velocity of wave
k	thermal conductivity
G_r	Grashof number
D_b	Brownian motion coefficient
a_1	dimensional radius of inner tube
B_r	Brownian diffusion constant
r_1	dimensionless radius of inner tube

Greek symbols

τ	a constant ratio defined as $\frac{(\tilde{\rho}c)_f}{(\tilde{\rho}c)_p}$
η	constant associated with couple stress
$(\tilde{\rho}c)_f$	heat capacity of base fluid
$(\tilde{\rho}c)_p$	heat capacity of particle
μ	dynamic viscosity
$\tilde{\phi}$	dimensional mass concentration
ϕ_m	mass concentration
$\tilde{\theta}$	dimensional temperature
θ_m	fluid temperature
β_T	volumetric coefficient of expansion
$\overline{\epsilon}$	ratio of wave amplitude to radius of outer tube
δ	temperature difference parameter
$\tilde{\rho}_f$	density of nanofluid at reference temperature
$\tilde{\rho}_p$	density of nanoparticle at reference temperature
γ	couple stress parameter
ν	kinematic viscosity
ϕ_w	reference or pipe concentration
ϕ	nanoparticle concentration
θ_w	reference or pipe temperature
θ	dimensionless temperature
λ	wavelength of peristaltic waves
α	ratio of thermal conductivity to heat capacity of base fluid

Subscripts

f	base fluid
p	particle

Besides, the peristaltic movement of non-Newtonian fluids through tubes (i.e. veins and arteries) is one of the examples related to real life application [18,19]. Similarly, transport through two coaxial tubes affirms the application of endoscope or catheterized artery in medical sciences. In addition, along with the various numerical and analytical methods the preference of Homotopy Analysis Method [20–22] has not been diminished, yet. Quiet recently, many authors highly value this method to seek a reliable solution, even for nonlinear and coupled differential equations. It is an undeniable fact that there are certain benefits and advantages that make this method, still as a favorite of many.

In this article peristaltic transport of nanofluid through the hollow gap of annulus is examined. Inner tube is assumed to be rigid while peristaltic wave moves down the wall of outer tube. Couple stress non-Newtonian fluid (base fluid) is taken as blood. Effects of applied heat (thermally charged catheter) and transfer of gold nanoparticle (GNPs) have also been taken in to account. Long wave approximation and similarity transformation converted the governing partial differential equation in to a set three nonlinear and coupled ordinary differential equations. An analytical solution is sought with the help of Homotopy Analysis Method (HAM). A parametric study, finally is made to apprehend the role of pertinent variables and constant on main field variables through graphs which affirm the credibility of this mathematical model and found to be in great agreement.

2. Problem formulation

Let $\overrightarrow{V} = [\tilde{U}(\tilde{R},\tilde{Z},\tilde{t})\ \ 0\ \ \tilde{W}(\tilde{R},\tilde{Z},\tilde{t})]$ be the velocity of couple stress fluid containing the Nano-sized particles of gold, peristaltically moving through the gap between two coaxial tubes, ignoring the circumferential coordinate. Configuration of inner tube is assumed to be rigid in nature, whereas, the walls of outer tube are flexible which is attributed to be the main reason of the flow, for a sinusoidal wave that travels down the outer walls, in fact, pushes the nanofluid forward, as shown in the diagram (Fig. 1).

The governing equations involving the field variable such as velocity, temperature and the nanoparticle volume fraction, after employing

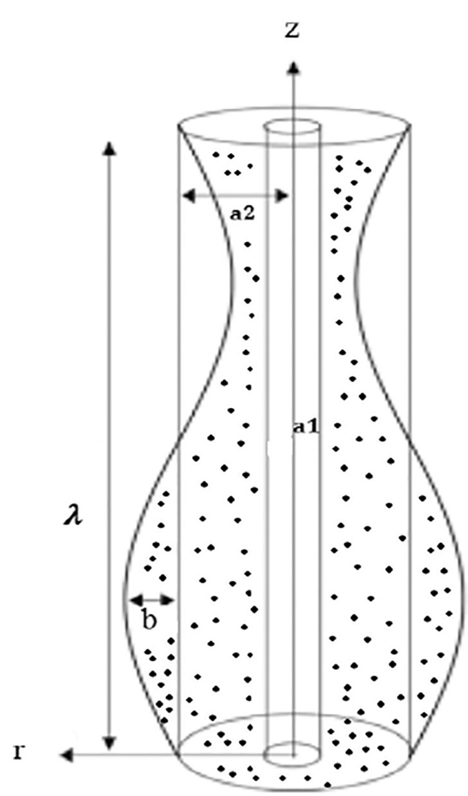

Fig. 1. Configuration of coaxial tubes.