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Transport phenomena of carbon nanotubes and bioconvection nanoparticles on stagnation point flow in presence of induced magnetic field

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ABSTRACT

This article is a numerical study of stagnation point flow of carbon nanotubes over an elongating sheet in presence of induced magnetic field submerged in bioconvection nanoparticles. Two types of carbon nanotubes are considered i.e. single wall carbon nanotube and multi wall carbon nanotube mixed in based fluid taken to be water as well as kerosene-oil. The emphasis of present study is to examine effect of induced magnetic field on boundary layer flows along with influence of SWCNT and MWCNT. Physical problem is mathematically modeled and simplified by using appropriate similarity transformations. Shooting method with Runge-Kutta of order 5 is employed to compute numerical results for non-dimensional velocity, induced magnetic field and temperature. The effects of pertinent parameters are portrayed through graphs. Numerical values of skinfriction coefficient and Nusselt number are tabulated to study the behaviors at the stretching surface. It is depicted that induced magnetic field is an increasing function of solid nanoparticles volumetric fraction. Moreover, MWCNT contributes in rising induced magnetic field more as compared to SWCNT for both water and kerosene-oil based fluids.

1. Introduction

At present, rapid progress in thermal engineering and industries directly influence the need of improving and growing more effective and reduced heat exchange frameworks. This can be achieved by primarily two approaches the passive techniques in which usually thermal conductivity is raised depending on the special surface geometries and thermal packaging or fluid additives and active techniques where thermal conductivity is controlled by external forces such as magnetic and electric field.

The pioneer work of Choi [1] made it evident that heat transfer rate can be raised by using nanofluids instead of simple fluids. Industrial applications of nanofluids include microelectronics, biotechnology and micro electromechanical systems. The suspensions of nano scaled size metal or non-metal particles, their oxides, carbides and nitrates usually contribute in rising thermal conductivity from 15% to 45%. The nanoparticles used in base fluids like water, ethylene glycol, toluene and kerosene or engine oil are typically metals such as Al, Cu, Ag or Au, metal oxides likes Al_2O_3, CuO, TiO_2, SiO_2, carbides SiC, nitrides AlN, SiN or non-metals as graphite, carbon nanotubes. Generally, nanofluids consist of 5% volume fraction of nanoparticles. The use of nanoparticles was first comprehensively studied by a research group at Argonne National Laboratory. They concluded different results depending on size, shape and contact surface of nanoparticles. It is observed that heat transfer rate of nanotubes is more than spherical or brick shaped nanoparticles. Nanotubes are cylindrical like structure whose length to diameter ratio is up to 132,000,000 to 1. They have remarkable properties which are indispensable for nano technology, electronics and optics. Carbon nanotubes (CNTs) have vital role in batteries, super conductors, data storage, electromagnetic shielding, semiconductors, biosensor, transistors and solar storage as thermal conductors. These tubes are classified as single wall carbon nanotubes (SWCNT) and multiple wall carbon nanotubes (MWCNT) based on chained structure of carbon. Masuda et al. [2] analyzed variation of thermal conductivity and viscosity of liquid by diffusing ultra-fine particles. Role of nanofluids for heat transfer enhancement of separated flow encountered in a backward facing step was investigated by Abu Nada [3]. Lee et al. [4] measured thermal conductivity of fluid containing oxide nanoparticles. Fan et al. [5] reviewed nanofluid heat conduction which reveals nanoparticles and nanotubes suspensions endowed more conductivity enhancement than the oxide particle suspensions. Boundary layer flow over a moving surface in a nanofluid with suction or injection was examined by Bachok et al. [6]. Khorasanizadeh et al. [7] studied entropy generation of $Cu -$ water nanofluid mixed convection in a cavity. Mixed convective heat transfer of water/alumina nanofluid inside a vertical micro-channel was

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explored by Malvandi and Ganji [8]. Volder et al. [9] highlighted commercial and industrial usage of carbon nanotubes. Akbar et al. [10] examined effects of slip and convective boundary conditions on stagnation-point flow of CNT suspended nanofluid over a stretching sheet. Comprehensive references on nanofluid can be found in review papers [11–15].

Another factor that plays a vital role in controlling heat and mass transfer is existence of magnetic field. Moreover, the effect of magnetic field in nanofluids is of great practical interest because it occurs in a number of engineering processes. Kumari et al. [16] investigated the effect of induced magnetic field with heat transfer over a stretching sheet. Influence of induced magnetic field on large scale pulsed MHD generator was examined by Koshiba et al. [17]. Ghosh et al. [18] investigated consequences of induced magnetic field on hydro-magnetic free convection flow. Heat transfer in stagnation point flow towards a stretching sheet was studied by Mahapatra and Gupta [19]. Pop et al. [20] extended this idea under the effects of radiation energy. Effects of variable thermal conductivity and heat source/sink on MHD flow near a stagnation point on a linearly stretching sheet were explored by Sharma and Singh [21]. A Homogenous-Heterogeneous reaction in stagnation point flow of carbon nanotubes with Newtonian heating was considered by Hayat et al. [22]. Recently, Hayat et al [23] investigated melting heat transfer in stagnation point flow of carbon nanotubes towards variable thickness surface. Ali et al. [24] examined MHD stagnation-point flow and heat transfer towards stretching sheet with induced magnetic field.

Present work is a numerical investigation of SWCNT and MWCNT embedded nanofluid stagnation point flow under the influence of induced magnetic field. To the best of authors knowledge, no attempt are made to study the effect of induced magnetic field on CNTs transport and heat transfer. Present article focuses on examining the influence of induced magnetic field on single and multi wall CNTs considering two different base fluids namely, water and Kerosene oil for a comparative analysis. The physical problem is first mathematically modeled accompany with the simplification by means of appropriate similarity transformation. Graphs and tables are sketched to examine the effect of significant physical parameters on fluid velocity, induced magnetic field and temperature profiles. This study may be useful in academic research and discussion on CNTs usage in electrically conducting base fluids like water or kerosene oil. Moreover, presented results explains the theoretical aspects which may be examined experimentally.

2. Problem structure and governing model

We consider steady two-dimensional stagnation point flow of carbon nanotubes (CNTs) and bioconvection nanofluid towards a linear stretching surface. This surface is situated along $x-$ axis and nanofluid occupies the region $y > 0$. For the comparative analysis two types of carbon nanotubes are considered i.e., single and multiple walls CNTs. Moreover, water and kerosene oil are taken as the base fluid. Spherical bioconvection nanoparticles are suspended in base fluid. The free stream velocity is taken as $U_e(x) = ax$ and velocity of stretching sheet is $U_w(x) = cx$, where a and c are the positive constants. Furthermore, we assumed that H is induced magnetic field vector with magnetic field at free stream $H_e(x) = H_0 x$ in which H_0 is upstream uniform magnetic field at infinity. In addition, we take H_1 and H_2 parallel and normal components of induced magnetic field H. At the surface, normal component H_2 vanishes whereas parallel component H_1 becomes H_0 (see Ref. [24]). We take T_w be the surface temperature and T_∞ denotes the ambient temperature. We chose Cartesian coordinates in such a way that $x-$ axis is along the direction of flow while $y-$ axis is normal to the flow. The physical flow structure is presented in Fig. 1.

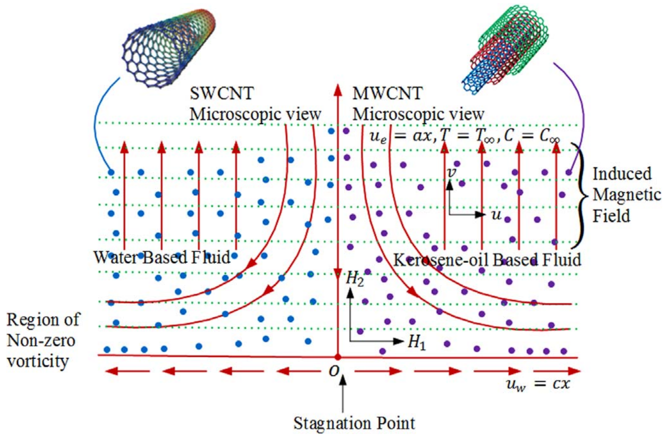

Fig. 1. Physical flow structure.

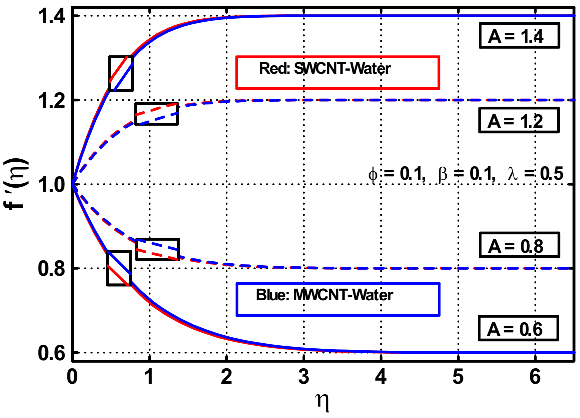

Fig. 2. Variation of A on $f'(\eta)$ for water based CNTs.

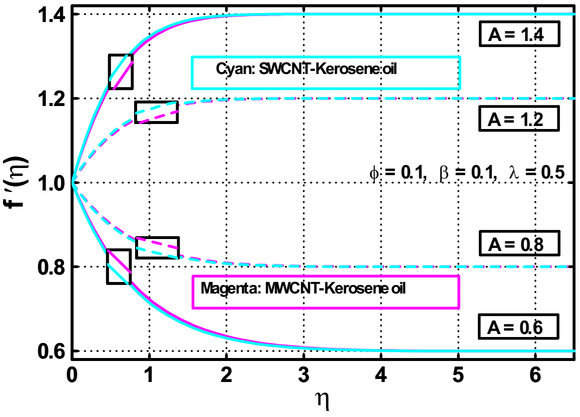

Fig. 3. Variation of A on $f'(\eta)$ for Kerosense oil based CNTs. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Now the boundary layer equations governing the stagnation-point flow and heat transfer in electrically conducting viscous fluid containing carbon nanotubes (CNTs) and bioconvection nanofluid are (see Ref. [24]):

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0, \tag{1}$$

$$\frac{\partial H_1}{\partial x} + \frac{\partial H_2}{\partial y} = 0, \tag{2}$$