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Short Communication

Impact of chemical reaction on Cu, Al_2O_3 and SWCNTs–nanofluid flow under slip conditions

R. Kandasamy [a,*], Radiah Mohamad [a], Muhaimin Ismoen [b]

[a] Faculty of Science, Technology and Human Development, Research Centre for Computational Mathematics, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[b] Engineering Mathematics Unit, Faculty of Engineering, Brunei Institute of Technology, Negara, Brunei Darussalam

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ABSTRACT

Single walled carbon nanotube, alumina and copper nanoparticles on convective mass transfer in the presence of base fluid (water) over a horizontal plate are investigated numerically. The governing partial differential equations with auxiliary conditions are reduced into the system of coupled ordinary differential equations via similarity transformation and it has been solved numerically using fourth or fifth order Runge–Kutta–Fehlberg method with shooting technique. The results display that the diffusion boundary layer thickness of the water based Cu and SWCNTs is stronger than Al_2O_3–water with increase of chemical reaction.

1. Introduction

Due to the low diffusion conductivity of mass transfer fluids used in power generation, microelectronics cooling, chemical production, refrigeration and air-conditioning, transportation, and many other applications, it is necessary to enhance effective diffusion conductivity of these fluids to improve mass transfer rate. One of the techniques, to enhance effective diffusion conductivity of these mass transfer fluids, is to add nanoparticles or nanotubes in the base fluids. Particularly with respect to mass transfer, and compared with more conventional mass transfer fluids (i.e. coolants) currently available, nanofluidic coolants exhibit enhanced diffusion conductivity.

Carbon nanotubes (CNTs) are allotropes of carbon with a cylindrical nanostructure. Nanotubes have been designed significantly larger than for any other material and these cylindrical carbon molecules have extraordinary properties, which are important for Nanoscience and Nanotechnology. In particular, owing to their extraordinary diffusion conductivity and mechanical and electrical properties, carbon nanotubes find applications as additives to enhance mass transfer in various industrial applications.

Carbon nanotubes are classified as single-walled nanotubes (SWNCTs) and multi-walled nanotubes (MWNCTs) and the carbon nanotubes naturally align themselves into “ropes” retained together by van der Waals forces, more specifically, pi-stacking. Nanofluids act enhanced diffusion properties by diffusing nanoparticles into base fluids [1–3]. Nanofluids with stronger diffusion conductivity and mass transfer coefficients associated to the base fluid can be significantly useful in many applications [4–7].

Single walled carbon nanotubes (SWCNTs) with high diffusion conductivity have attracted significantly important attention from researchers [8–10]. In particular, research on different divisional features of SWCNTs–nanofluids are certainly necessary to advance their potential applications in science and technology. Recently, it is investigated that the nanoparticles upgraded the mass transfer inside binary nanofluids (Xuan [11], Bhattacharyya [12], Sridhara and Satapathy [13], Uddin et al. [14], Pang et al. [15], Kumar et al. [16], Rout et al. [17], Ibrahim and Reddy [18] and Gangadhar et al. [19]). Recently several authors investigated about nanofluid flow and mass transfer [20–47].

We consider the two-dimensional boundary slip flow over a flat plate with water as base fluid encompassing single walled carbon nanotubes. Carbon nanotubes are shown to have special diffusion properties with very high diffusion conductivity. The objective of the present study is to find the approximate numerical solutions for the problem and to compare the diffusion behavior

* Corresponding author. Tel.: 006 01779 77259, fax: 006 07453 6051.
E-mail address: future990@gmail.com (R. Kandasamy).
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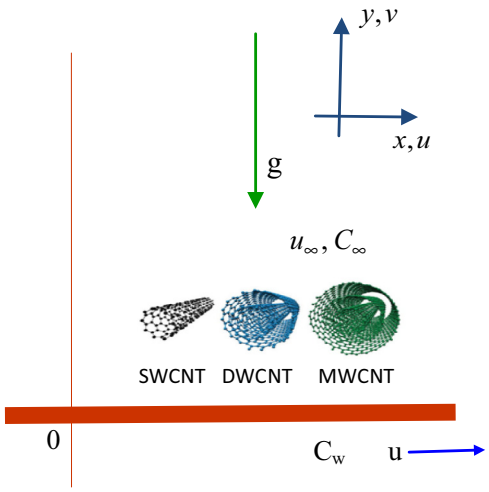
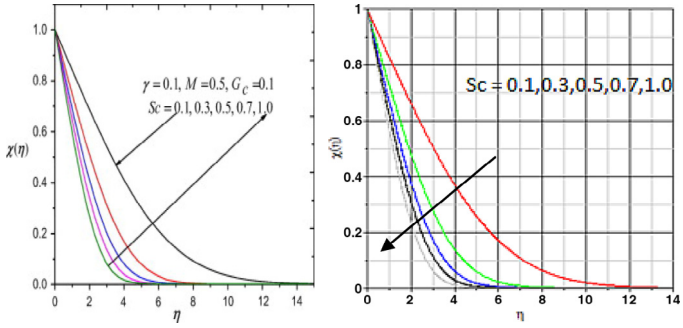


Fig. 1. Physical model of the flow and coordinate system. (a) Singh and Kumar [44]. (b) Present result.



(a)- Padam Singh and Manoj Kumar [44] (b)-present result

Fig. 2. Comparison of concentration profiles for Sc with Fig. 8 of Singh and Kumar [44].

Table 1
Thermophysical properties of nanofluids, Singh and Kumar [44] and Talley et al. [45].

	$\rho(kg/m^3)$	$c_p(J/kgK)$	$k(W/mK)$	$\beta_c \times 10^{-5}(K^{-1})$
Pure water	997.1	4179	0.613	63
Copper (Cu)	8933	385	401	4.89
Alumina (Al_2O_3)	3970	765	40	2.55
SWCNTs	2600	425	6600	0.99

of SWCNTs–water with Cu and Al_2O_3–water in the presence of chemical reaction.

2. Mathematical analysis

Consider the steady two-dimensional laminar boundary layer slip flow of water based SWCNTs, Al_2O_3 and Cu with coordinate system that is given in Fig. 1 and the thermophysical properties of the fluid and nanoparticles are presented in Table 1. Under the boundary layer approximation, the basic steady conservation of mass, momentum and diffusion equations can be written (Singh and Kumar [44], Magyari [46] and Mamut [47]) as

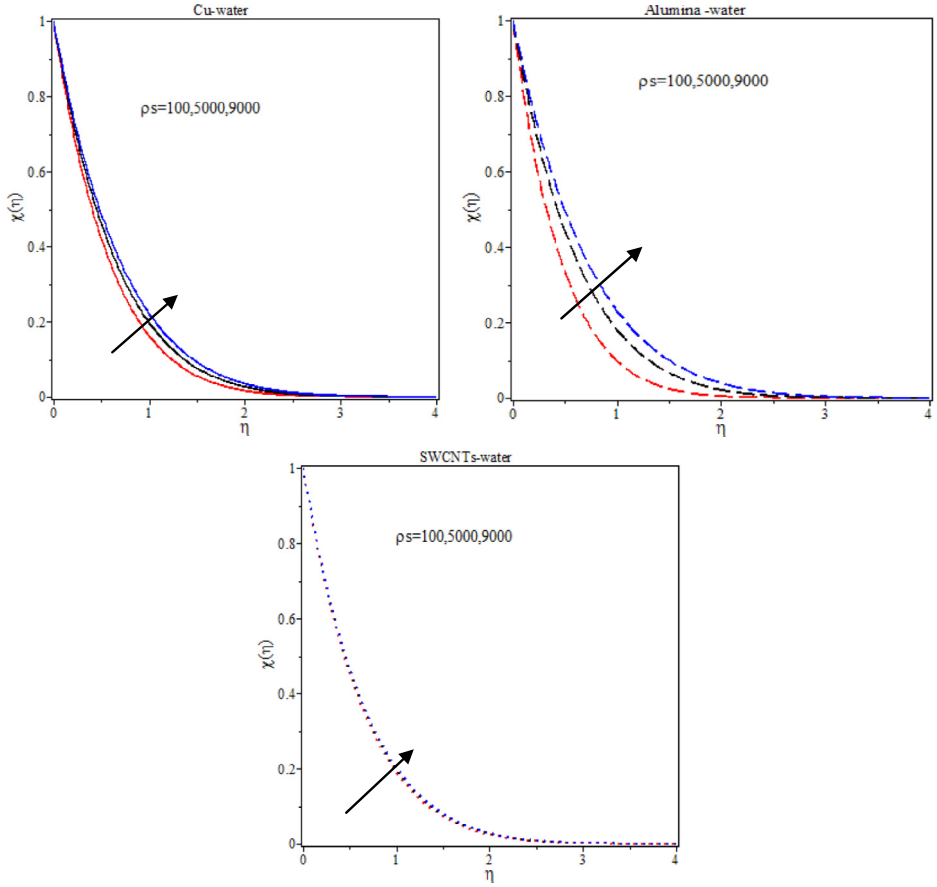


Fig. 3. Density of the nanofluids on concentration profiles with $\lambda = 0.5, \gamma = 0.1, Sc = 6.2, \gamma_2 = 0.1, \gamma_1 = 0.5$.