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Convective heat transfer in the flow of viscous Ag–water and Cu–water nanofluids over a stretching surface

K. Vajravelu [a,*], K.V. Prasad [b,1], Jinho Lee [c], Changhoon Lee [c,d], I. Pop [e], Robert A. Van Gorder [a]

[a] Department of Mathematics, University of Central Florida, Orlando, FL 32816, USA
[b] Department of Mathematics, Bangalore University, Bangalore 560001, India
[c] School of Mechanical Engineering, Yonsei University, Seoul 120-749, South Korea
[d] Department of Computational Science and Engineering, Yonsei University, Seoul 120-749, South Korea
[e] University of Cluj, R-3400 Cluj, CP 253, Romania

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ABSTRACT

An analysis is carried out to study the convective heat transfer in a nanofluid flow over a stretching surface. In particular, we focus on Ag–water and Cu–water nanofluids, and investigate the effects of the nanoparticle volume fraction on the flow and heat transfer characteristics under the influence of thermal buoyancy and temperature dependent internal heat generation or absorption. The numerical results indicate that an increase in the nanoparticle volume fraction will decrease the velocity boundary layer thickness while increasing the thermal boundary layer thickness, even in the presence of free convection currents and internal heat generation. Meanwhile, the presence of nanoparticles results in an increase in the magnitude of the skin friction along the surface and a decrease in the magnitude of the local Nusselt number. Such effects are found to be more pronounced in the Ag–water solution than in the Cu–water solution; indeed, the Ag–water solution decreases the boundary layer thickness more than that of the Cu–water solution.

1. Introduction

The fluid dynamics due to a stretching sheet has gained interest in the recent past due to its number of applications in several engineering processes. Such applications include the aerodynamic extrusion of plastic sheets, the boundary layer along a liquid film in condensation process, the cooling of metallic plate in a cooling bath, glass and fiber industries. Provoked by the process of polymer extrusion in which extradite emerges from a narrow slit: Crane [1] first analyzed the two-dimensional fluid flow over a linearly stretching surface. Later, this problem has been extensively studied in various directions: For example, for non-Newtonian fluids, porous space and magneto-hydrodynamics. Some interesting recent investigations are presented in references [2–12].

The physical situation discussed by Chen and Char [3] is one of the possible cases. Another physical phenomenon is the case in which the difference between the surface temperature and the free stream temperature namely, $(T_w - T_\infty)$ is appreciably large. The findings for such a physical phenomenon will have a definite bearing on the plastic, fabric and polymer industries. Hence, it is interesting to study the effects of thermal buoyancy and the Prandtl number. In many practical situations the material moves in a quiescent fluid with the fluid flow induced by the motion of the solid material and by the thermal buoyancy: Therefore the resulting flow and the thermal fields are determined by these two mechanisms. It is well known that the buoyancy force stemming from the heating or cooling of a continuous stretching sheet alters the flow and the thermal fields and thereby heat transfer characteristics of the manufacturing processes. However, the buoyancy force effects were not considered in the afore-mentioned studies. Effects of the thermal buoyancy force on the Newtonian/non-Newtonian fluid flow and heat transfer over a stretching sheet were reported by several investigators [13–20]. Furthermore, combined free and forced convection heat transfer at a stretching sheet maintained at a variable temperature was investigated by Vajravelu [13]. Similar analyses were performed numerically by Chen and Strobel [14], and Moutsoglou and Chen [15] for Newtonian fluids under different physical situations. Very recently, Makinde and Aziz [20] studied the influence of convective boundary condition on hydro-magnetic

* Corresponding author.
E-mail address: vajravel@mail.ucf.edu (K. Vajravelu).
[1] Presently, visiting the Department of Mathematics, University of Central Florida, Orlando, Florida 32816, USA.

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