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Axisymmetric Stagnation-Point Flow of Nanofluid Over a Stretching Surface

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Abstract. This paper investigates the laminar boundary layer flow of nanofluid induced by a radially stretching sheet. Nanofluid model exhibiting Brownian motion and thermophoresis is used. Series solutions for a reduced system of nonlinear ordinary differential equations are obtained by homotopy analysis method (HAM). Comparative study between the HAM solutions and previously published numerical results shows an excellent agreement. Velocity, temperature and mass fraction are displayed for various values of parameters. The local skin friction coefficient, the local Nusselt number and the local Sherwood number are computed. It is observed that the presence of nanoparticles enhances the thermal conductivity of base fluid. It is found that the convective heat transfer coefficient (Nusselt number) is decreased with an increase in concentration of nanoparticles whereas Sherwood number increases when concentration of nanoparticles in the base fluid is increased.

AMS subject classifications: 76D10, 80A20

Key words: Nanofluid, axisymmetric flow, stagnation point, Nusselt number, Sherwood number.

1 Introduction

There has been an increasing interest of the recent researchers in the flows induced by a stretching surface. This is because of extensive applications of such flows in polymer processing, metallurgy, drawing of plastic sheets, cable coating, continuous casting, glass blowing, spinning synthetic fibers etc. Since the pioneering work of Crane [1] on the

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titled problem, the two-dimensional flows caused by a stretching sheet have been examined under various aspects (see [1–5]) and several References therein). However it is noted that flows generated by radially stretching surface is scarce. For instance, Ariel [2] analyzed slip effects on axisymmetric flow of viscous fluid induced by a stretching surface. Hayat et al. [3] considered axisymmetric unsteady flow of micropolar fluid between radially stretching surfaces. Hayat et al. [4] discussed thermal-diffusion and diffusion-thermo effects on axisymmetric flow of second grade fluid between radially stretching surfaces. Hayat and Nawaz [5] investigated axisymmetric flow between radially stretching surfaces. The studies [2–5] and several References therein are restricted to axisymmetric flows of Newtonian and non-Newtonian fluids and no study regarding axisymmetric flow of nanofluids over a radially surface is investigated so far. Therefore present investigation is an attempt in this direction. Literature survey also reveals that no study regarding stagnation point flow of nanfluid over a radially stretching sheet is discussed so far. However several studies on stagnation point flow of other than nanofluids are conducted. For example, stagnation point flows towards a stretching sheet are also studied by the researchers. The stagnation point flow of viscous fluid over a stretching surface has been addressed by Chiam [6]. Mahapatra et al. [7] considered stagnation point flow of power-law fluid towards a stretching surface. Labropulu and Li [8] studied slip effects on stagnation point flow of second grade fluid. Numerical solution for stagnation point flow of viscous fluid over a radially stretching surface has been computed by Attia [9]. Mixed convection in the stagnation point flow towards a stretching vertical permeable sheet is considered by Ishak et al. [10]. The unsteady stagnation-point flow driven by rotating disk has been examined by Hayat and Nawaz [11].

Recently, the flow analysis of nanofluids has been the topic of great interest due to their occurrence in nuclear reactors, transportation, biomedicine etc. Actually many ordinary fluids including water, toluene, ethylene glycol and mineral oils etc. are commonly used in cooling processes in industry. These fluids have poor thermal characteristics. Experimental and theoretical investigations show that the inclusion of micro-scaled particles in the base fluids enhances their thermal conductivity. Such mixture of the fluids and nanoparticles are called nanofluids. Perhaps, Choi [12] was the first to use the word nanofluid. It is known fact now that presence of nanoparticles in base fluid improves its thermal conductivity. Furthermore, nanofluids show better stability and rheological properties in comparison with base fluid. At present, the reasonable literature on nanofluids is available. For example, Masuda et al. [13] studied the effects of ultra fine particles on thermal conductivity of the base fluid. Das [14] concluded that thermal conductivity of the base fluid can be enhanced by injecting nanoparticles into it. The transfer of heat in fluid containing metallic oxide particles (nanoparticles) has been studied by Pak and Cho [15]. Eastman et al. [16] noted an increase in thermal conductivity of ethylene-glycol containing nanoparticles. Effects of nanoparticles on thermal conductivity of water have been investigated by Minsta [17]. Razi et al. [18] studied the pressure drop and heat transfer of nanofluid flow inside horizontal flattened tubes. Mixed convection of a nanofluid in an inclined enclosure cavity is discussed by Alinia et al. [19]. Rana