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REVIEW ARTICLE

Analytical study of the non orthogonal stagnation point flow of a micro polar fluid

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Abstract In this paper we consider the steady two dimensional flow of micro polar fluids on a flat plate. The flow under discussion is the modified Hiemenz flow for a micro polar fluid which occurs in the *hjkns* + *skms* boundary layer near an orthogonal stagnation point. The full governing equation reduced to a modified Hiemenz flow. The solution to the boundary value problem is governed by two non dimensional parameters, the material parameter K and the ratio of the micro rotation to skin friction parameter n. The obtained nonlinear coupled ordinary differential equations are solved by using the Homotopy perturbation method. Comparison between numerical and analytical solutions of the problem is shown in tables form for different values of the governing parameters K and n. Effects of the material parameter K on the velocity profile and microrotation profiles for different cases of n are discussed graphically as well as numerically. Velocity profile decreases as the material parameter K increases and the microrotation profile increases as the material parameter K increases for different cases of n.

Contents

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1. Introduction

The behavior of the flow near a stagnation-point is a fundamental topic in fluid dynamics, and it has attracted the attention of many researchers during the past several decades because of its wide industrial and technical applications, such as heat exchangers placed in a low-velocity environment, cooling of nuclear reactors during emergency shutdown, solar central receivers exposed to wind currents, cooling of electronic devices by fans, and many hydrodynamic processes. Hiemenz (1911) and Homann (1936) initiated the study of two dimensional and axisymmetric three dimensional stagnation point flows, respectively. Eckert (1942) extended Hiemenz's work by including the energy equation and obtained an exact similarity solution for the thermal field. Later, the problem of stagnation point flow was extended numerically by Schlichting and Bussmann (1943) and analytically by Ariel (1994) to include the effect of suction. Further, Mabood et al. (2015) worked on heat and mass transfer by Magnetohydrodynamics (MHD) stagnation point flow toward a permeable stretching surface. Rosali et al. (2014) analyzed the unsteady boundary layer flow toward a mixed convection stagnation point flow on a heated vertical surface. Borrelli et al. (2015) has discussed the influence of a non uniform external magnetic field on the steady three dimensional stagnation point flow of a micropolar fluid.

In fluid mechanics we study the behavior of particles at every point within the domain under various physical conditions. To describe the physical phenomena in fluid mechanics we use mathematical models for different types of fluids such as Newtonian fluids (Picchi et al., 2014; Fzal and Kim, 2014; Villone et al., 2014; Hatami and Domairry, 2014) and non Newtonian fluids (Hatami and Ganji, 2014a,b; Liu et al., 2013). There are many special cases of non-Newtonian fluids such as nano fluids (Domairry and Hatami, 2014; Hatami et al., 2014; Ahmadi et al., 2014; Shaikhoeslam et al., 2014), micropolar fluid (Srinivasacharya and Upendar, 2014; Hatami and Ganji, 2014c; Pažanin, 2013).

Models of micropolar fluids were first pioneered by Eringen (1966) and explained the characters of certain real fluid flows. The attractiveness and power of the model of micropolar fluids come from the fact that it is both a significant and a simple generalization of the classical Navier Stokes model. Recently many researchers worked on different models of micropolar fluids. Faltas and Saad (2014) obtained a solution of Stokes axisymmetrical flow problems of viscous fluid moving perpendicular to an impermeable bounding surface for cylindrical and spherical cases. Borrelli et al. (2015) examined the effects of the magnetic field and the temperature on the steady mixed convection of a micropolar fluid. Similarly, Mohanty et al. (2015) investigated heat and mass transfer effects of micropolar fluid over stretching sheet numerically. Shaikhoeslam et al. (2014) has studied the flow of micropolar fluid and heat transfer in a permeable channel.

Micropolar fluid problems can be studied in different applications like Liquid crystals, animal blood, colloidal fluids, flow of low concentration suspensions etc. Some researchers worked on the two main applications. Oahimire and Olajuwa (2014) solved heat and mass transfer effects on an unsteady flow of a chemically reacting micropolar fluid through porous medium. Abd Alla et al. (2013) studied effects of rotation and magnetic field of a micropolar fluid through a porous medium. Abdalla et al. obtained closed form solution under the consideration of long wavelength and low renold number. Another important application is Lubrication theory. Prakash and Sinha (1975) considered a steady laminar flow of a incompressible micropolar fluid of Lubrication theory. Bayada and kaszewic (1996) derived an analog of the classical renold equation of the theory of lubrication and discussed its particular forms depending on the assumption imposed on the viscosities and the data.

Lok and Pop (2007) analyzes the steady two dimensional stagnation-point flow of a micropolar fluid impinging on a flat rigid wall obliquely. This flow appears when a jet of viscous fluids impinge on a rigid wall obliquely. In many cases, the jet may be oblique to the impinged surface due to surface contouring or physical constraints on the nozzle (Wang, 1985). In particular, we investigate the behavior of the micropolar fluid and velocity profile of the fluid particle near the wall for various values of the micropolar parameter and rate of particle rotation to the skin friction at the plate.

To deal with such kind of problems, we needed a strong analytical tool. Interest in analytical techniques for studying nonlinear problems increased dramatically over the past two decades. Analytical methods have significant advantages over numerical methods in providing analytic, verifiable, rapidly convergent approximations. Therefore, many methods have been used to deal with highly nonlinear problems such as the homotopy perturbation transform method (Khan and Muhammad, 2014; Khan and Wu, 2011), differential transform method (Masayebidorchen et al., 2014; Hatami et al., 2014; Shaikholeslam et al., 2015; Domairy and Shaikholeslam, 2012), optimal homotopy analysis method (Shaikholeslam and Ganji, 2014; Shaikholeslam et al., 2012), least square method (Sheikholeslami et al., 2013; Hatami et al., 2014), Hamiltonian approach (Nianga and Recho, 2014; Reinhardt and Heffner, 2012; Lan, 2011), homotopy analysis method (Sheikholeslami et al., 2012, 2014), variational iteration method (Biazar et al., 2010; Faraz, 2011; Faraz et al., 2011), and decomposition method (Sheikhoeslami et al., 2013; Sheikholeslami et al., 2012; Shakeri Aski et al., 2014; Guo-cheng, 2011). One of the semi-exact methods is the homotopy perturbation method (HPM) (Sheikholeslami and Ganji, 2013; Shaikholeslami et al., 2011; Sheikholeslami et al., 2012, 2013; Jun Yang et al., 2014). He (2007, 2003, 2004a,b) developed and formulated HPM by merging the standard homotopy and perturbation. He's HPM is proved to be compatible with the versatile nature of physical problems and has been applied to a wide class of functional equations (Brzdęk et al., 2014; Galleas and Lamers, 2014). In general the solutions produced by the HPM are as accurate as the solutions given by the other