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A note on magnetohydrodynamic flow of a power-law fluid over a stretching sheet

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Abstract

This paper presents a numerical study of the flow of an electrically conducting power-law fluid in the presence of a uniform transverse magnetic field. This flow is governed by the non-linear differential equation

$$n(-f'')^{(n-1)}f''' - (f')^2 + \left(\frac{2n}{n+1}\right)ff'' - Mf' = 0$$

where a prime denotes differentiation with respect to the similarity variable η and n, M are respectively the power-law index and the magnetic parameter. In this work, the numerical solutions are obtained using a Runge–Kutta algorithm for high-order initial value problems.

1. Introduction

The study of boundary layer flow over a continuous solid surface moving with a constant speed was first investigated by Sakiadis [1]. Since this pioneering work, various aspects of the problem have been investigated by many authors. Crane [2] studied the boundary layer flow of a Newtonian fluid caused by the stretching of an elastic flat surface and presented exact solutions. The

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uniqueness of the exact analytical solution presented in [2] was proved by McLeod and Rajagopal [3].

Rajagopal et al. [4] examined the boundary layer flow over a stretching sheet for a special class of non-Newtonian fluids known as second-order fluids. They obtained similarity solutions of the boundary layer equations numerically. Dandapat and Gupta [5] studied the same problem with heat transfer. They presented an exact analytical solution of the non-linear equation governing this self-similar flow. They also confirmed that both the analytical and the numerical results in [4] shows a good agreement. Recently, Cortell [6] extended the work of Dandapat and Gupta [5] and investigated the heat transfer in an incompressible second-order fluid caused by a stretching sheet with a view to examining the influence of the elastic parameter on heat-transfer characteristics. He observed that the temperature distribution depends on elastic parameter, in accordance with the results in [5].

Andersson and Dandapat [7] extended the work of Crane [3] to an important class of non-Newtonian fluid obeying the power-law model.

On the other hand, Chakrabarti and Gupta [8] extended the work of Pavlov [9] and studied, the hydromagnetic flow and heat transfer in a fluid initially at rest and at uniform temperature over a stretching sheet at a different uniform temperature. Recently, Vajravelu and Nayfeh [10] studied hydromagnetic flow of a dusty fluid over a stretching sheet including, the effects of suction. Ray and Dandapat [11] and Andersson et al. [12] have analyzed the magnetohydrodynamic flow on a rotating disk. Andersson et al. [13] have further investigated the magnetohydrodynamic flow over a stretching sheet of an electrically conducting incompressible fluid obeying the power-law model. Their study was performed for both shear-thinning and shear-thickening fluids. They observed that the magnetic field tends to make the boundary layer thinner, thereby increasing the wall friction. We further independently investigate the same flow as in [13] and obtain numerical solutions by means of a Runge–Kutta algorithm for nth-order initial value problems (see [14,15]).

2. Analysis

Let us suppose that an electrically conducting fluid (with electric conductivity σ) obeying the power-law model in the presence of a transverse magnetic field B_0 is flowing past a flat sheet which coincides with plane $y = 0$ and flow confined to $y > 0$. Two equal and opposite forces are introduced along the x-axis (see Fig. 1 of Ref. [8]), so that the wall is stretched keeping the origin fixed. The basic boundary-layer equations in usual notation are

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