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Effects of Heat and Mass Transfer on the Perfect Conducting Polar Fluid Over a Stretching Sheet Due to Thermal Radiation

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Abstract. The objectives of the present study are to investigate the effects of heat and mass transfer on the unsteady flow of a perfect conducting polar fluid over a flat sheet with a linear velocity in the presence of thermal radiation. Successive approximation method developed in Zakaria [Appl. Math. Comput. 10 (2002), Appl. Math. Comput. 155 (2005)] is adopted to solve the problem. The effects of Alfven velocity, mass transfer, various material parameters, Prandtl number, Schmidt number and relaxation time on the velocity, angular velocity, temperature and concentration are discussed and illustrated graphically.

AMS subject classifications: 80A20

Key words: Heat and mass transfer, relaxation time, perfectly conducting, polar fluid.

1 Introduction

Due to the increase of importance in the processing industries and elsewhere of materials whose flow behavior in shear cannot be characterized by classical fluid, a new stage in the evolution of fluid dynamic theory achieves development. Hoyt and Fabula [1], Vogel and Patterson [2] have shown experimentally that fluids containing minute polymeric additives indicate considerable reduction of the skin friction near a rigid body (about 25-30%), a concept which can be well explained by the theory of polar fluids. The classical fluid mechanics could not explain this phenomenon. Therefore, Aero et al. [3] and D'ep [4] have proposed the theory of the polar fluids taking in consideration that the inertial characteristics of the substructure particles which are allowed to undergo rotation. This theory can be used to explain the flow of the colloidal fluids liquid crystals animal blood etc.

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Polar fluid dynamics is concerned with the fluids motion whose material points possess orientations. It is distinguished from classical fluid dynamics (which is also known as Newtonian fluid dynamics or Navier-Stokes (N-S) theory) in the classical fluid dynamics, which is not assumed to possess oriented material points. Thus, against the three translational degrees of freedom of the classical theory, polar fluids possess six degrees of freedom: three of them are translational degrees and the other rotational degrees. The rotational degrees of freedom play a role in the nonsymmetrical stress tensors and couple tresses, which are missing from the classical theory.

Boundary layer flow on continuous moving surfaces is an important type of flow occurring in a number of engineering processes. Aerodynamic extrusion of plastic and rubber sheets, cooling of an infinite metallic plate in a cooling path, which may be an electrolyte, crystal growing, the boundary layer along a liquid film in condensation processes and a polymer sheet or filament extruded continuously from a die, or along thread traveling between a feed roll and a wind-up roll are examples of practical applications of continuous moving surfaces. Glass blowing, continuous casting, and spinning of fibers also involve the flow due to the stretching surface. Various aspects of this problem have been studied by Sakiadis [5–7]. Eldabe and Ouaf [8] studied the heat and mass transfer in a hydromagnetics flow of a micro polar fluid past a stretching surface. Kleson and Desseaux analyzed the effect of surface conditions on flow of a micro polar fluid driven by a porous stretching sheet [9]. Massive amount of works have been done on heat and mass transfer for a hydromagnetics flow over a stretching sheet [10–13].

In the above mentioned works, the effect of the induced magnetic field was neglected. Recently Zakaria [14, 15], also Ezzat and Zakaria [16, 17] studied the effects of induced magnetic field and heat transfer of polar and viscoelastic fluid flow over a stretching sheet. The modification of the heat-conduction equation from diffusive to a wave type may be affected either by a microscopic consideration of the phenomenon of heat transport or in a phenomenological way by modifying the classical Fourier law of heat conduction.

In this work, we use a more general model of MHD perfect conducting polar fluid over a stretching sheet due to thermal radiation under the effects of heat and mass transfer, which also includes the relaxation time of concentration, heat conduction and the electric displacement current [18, 19]. The inclusion of the relaxation time and the electric displacement current modifies the governing thermal, concentration and electromagnetic field equations, changing them from the parabolic to a hyperbolic type, and thereby eliminating the unrealistic result that thermal, concentration and electromagnetic disturbances are realized instantaneously everywhere within a perfectly conducting polar fluid.

2 Mathematical formulation

In our consideration of two-dimensional problem of hydromagnetics heat and mass