International Communications in Heat and Mass Transfer 38 (2011) 377–382

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ichmt

Convection heat and mass transfer in a hydromagnetic flow of a second grade fluid in the presence of thermal radiation and thermal diffusion ☆

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ARTICLE INFO

Available online 2 December 2010

Keywords:
Heat and mass transfer
Hydromagnetic
Thermal radiation
Thermal diffusion
Second grade fluid

ABSTRACT

The convection heat and mass transfer in a hydromagnetic flow of a second grade fluid past a semi-infinite stretching sheet in the presence of thermal radiation and thermal diffusion are considered. The governing coupled non-linear partial differential equations describing the flow problem are transformed into non-linear ordinary differential equations by method of similarity transformation. The resulting similarity equations are solved numerically using Runge–Kutta shooting method. The results are presented as velocity, temperature and concentration fields for different values of parameters entering into the problem. The skin friction, rate of heat transfer and mass transfer are presented numerically in tabular form. In addition, the results obtained showed that these parameters have significant influence on the flow, heat and mass transfer.

1. Introduction

The study of flow of non Newtonian fluids has attracted the attention of engineers and scientist in recent times due to its important application in many engineering processes. The analysis of such flows is very important in both theory and practice. From a theoretical point of view, flows of this type are fundamental in fluid mechanics and convective heat transfer. From a practical point of view, these flows have applications in convection cooling processes where a coolant is impinged on a continuously moving plate. Heat and mass transfer of non-Newtonian fluids is also very important in many engineering applications, such as oil recovery, food processing, paper making and slurry transporting.

Abel et al. [1] examined the effects of viscous dissipation and non-uniform heat source/sink on the boundary layer flow and heat transfer characteristics of a second grade, non-Newtonian fluid through a porous medium. Ahmad [2] carried out the mathematical analysis of heat transfer effects on the axisymmetric flow of a second grade fluid over a radially stretching sheet using the homotopy analysis method. Ahmed [3] presented Lie group analysis and the basic similarity reductions for the MHD aligned slowly flowing and heat transfer in second grade fluid with neglecting the inertial terms.

Bikash [4] studied the numerical solution of the laminar flow and heat transfer of an incompressible, third grade, electrically conducting fluid impinging normal to a plane in the presence of a uniform magnetic field. Cheng-Hsing and Kai-Long [5]studied the conjugate heat transfer of a plate fin cooled or heated by high or low Prandtl number, second grade viscoelastic fluid with conduction–convection parameter.

Chung Liu [6] and [7] presented analytical solutions for the flow and heat transfer in a steady laminar boundary flow of an electrically conducting fluid of second grade subject to a transverse uniform magnetic field past a semi-infinite stretching sheet with power-law surface temperature or power-law surface heat flux. Hayat and Sajid [8] examined the steady laminar flow and heat transfer in an axisymmetric flow of a second grade fluid is induced due to linear stretching of a sheet.

Hayat et al. [9] considered the laminar flow problem of convective heat transfer for a second grade fluid over a semi-infinite plate in the presence of species concentration and chemical reaction, they gave the boundary layer analysis of the solution obtained by homotopy analysis method. Hayat et al. [10] obtained the series solutions for the flow and heat transfer problem of an incompressible and electrically conducting second grade fluid film over an unsteady stretching sheet using the homotopy analysis method. Hayat et al. [11] obtained the series solution and analyzed the convergences for heat transfer on the flow of a fourth grade fluid past a porous plate using the homotopy analysis method. Hayat et al. [12] examined the influences of the Hall parameter and porosity of the medium on the velocity and temperature profiles for the heat transfer on a rotating flow of a second grade fluid past a porous plate with variable suction. Hayat et al. [13] presented analytical solutions of the equations of motion and energy of a electrically conducting fluid second grade fluid for the developed flow over a semi-infinite porous stretching sheet with slip condition.

Hayat et al. [14] examined a two-dimensional mixed convection boundary layer magnetohydrodynamic (MHD) stagnation-point flow through a porous medium bounded by a stretching vertical plate with

☆ Communicated by W.J. Minkowycz.

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doi:10.1016/j.icheatmasstransfer.2010.11.006