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MHD non-Darcian mixed convection heat and mass transfer over a non-linear stretching sheet with Soret–Dufour effects and chemical reaction ☆

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ABSTRACT

A study has been carried out to analyze the effects of variable thermal conductivity, Soret (thermal-diffusion) and Dufour (diffusion-thermo) on MHD non-Darcy mixed convection heat and mass transfer over a non-linear stretching sheet embedded in a saturated porous medium in the presence of thermal radiation, viscous dissipation, non-uniform heat source/sink and first-order chemical reaction. The governing differential equations transform into a set of non-linear coupled ordinary differential equations using similarity analysis. Similarity equations are then solved numerically using shooting algorithm with Runge–Kutta Fehlberg integration scheme over the entire range of physical parameters. A comparison with previously published work has been carried out and the results are found to be in good agreement. Graphical presentation of the local skin-friction coefficient, the local Nusselt number and the local Sherwood number as well as the temperature profiles show interesting features of the physical parameters.

1. Introduction

The problem of flow, heat and mass transfer of an incompressible viscous fluid on mixed convection over a stretching surface in a saturated porous medium has an important bearing on several applications in the field of metallurgy and chemical engineering. For instance, it occurs in many metallurgical processes which involve the extrusion of a polymer in a melt-spinning process, the extrudate from the die is generally drawn and simultaneously stretched into a sheet which is then solidified through quenching or gradual cooling by direct contact with water. The properties of the final product depend greatly on the rate of cooling so that final products of desired characteristics might be achieved. The rate of cooling can be controlled by drawing such strips through an electrically conducting fluid in the presence of transverse magnetic field. Tsou et al. [1] studied flow and heat transfer in the boundary layer on a continuous moving surface while Gupta and Gupta [2] solved the boundary layer flow with suction and injection. Andresson and Bech [3] have studied the MHD flow of the power law fluid over a stretching sheet. Pavlov [4] gave an exact similarity solution to the MHD boundary layer equations for the steady two-dimensional flow caused solely by the stretching of an elastic surface in the presence of a uniform magnetic field.

A considerable interest has been shown in radiation interaction with convection for heat transfer in fluids. This is due to the significant role of thermal radiation in the surface heat transfer when convection heat transfer is small. Further thermal radiation on flow and heat transfer processes is of major importance in the design of many advanced energy conversion systems operating at high temperature. Thermal radiation effects become important when the difference between the surface and the ambient temperature is large. Thus, thermal radiation is one of the vital factors for controlling the heat transfer in a non-isothermal system. The effect of radiation in various situations was addressed by [5–8]. It is well known that there exists non-Darcian flow phenomenon besides inertia force effect and solid boundary viscous resistance. These non-Darcian effects include non-uniform porosity distribution and thermal dispersion. To model this, an improved formulation with the Forchheimer's extension [9] and the Brinkman's extension [10] is used to account for the influence of inertia effect and boundary viscous effect, respectively.

In all the above-mentioned studies the thermal-diffusion and diffusion-thermo effects are negligible. However, the thermal-diffusion and diffusion-thermo effects are interesting macroscopically physical phenomenon in fluid mechanics. The effect of diffusion-thermo and thermal-diffusion of heat and mass has been developed by Chapman and Cowling [11] and Hirshfelder et al. [12] from the kinetic theory of gases. The heat transfer caused by concentration gradient is called the diffusion-thermo or Dufour effect. On the other hand, mass transfer caused by temperature gradients is called Soret or thermal diffusion effect. Usually, in heat and mass transfer problems the variation of density with temperature and concentration give rise

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