Advances in Applied Mathematics and Mechanics
Adv. Appl. Math. Mech., Vol. **3**, No. 4, pp. 389-400

DOI: 10.4208/aamm.10-m1038
August 2011

Mixed Convection Heat and Mass Transfer in a Micropolar Fluid with Soret and Dufour Effects

D. Srinivasacharya* and Ch. RamReddy

Department of Mathematics, National Institute of Technology, Warangal-506004, Andhra Pradesh, India

Received 19 March 2010; Accepted (in revised version) 6 January 2011

Available online 10 July 2011

Abstract. A mathematical model for the steady, mixed convection heat and mass transfer along a semi-infinite vertical plate embedded in a micropolar fluid in the presence of Soret and Dufour effects is presented. The non-linear governing equations and their associated boundary conditions are initially cast into dimensionless forms using local similarity transformations. The resulting system of equations is then solved numerically using the Keller-box method. The numerical results are compared and found to be in good agreement with previously published results as special cases of the present investigation. The non-dimensional velocity, microrotation, temperature and concentration profiles are displayed graphically for different values of coupling number, Soret and Dufour numbers. In addition, the skin-friction coefficient, the Nusselt number and Sherwood number are shown in a tabular form.

AMS subject classifications: 80M20, 80A20, 76A05, 76E06

Key words: Mixed convection, heat and mass transfer, micropolar fluid, Soret and Dufour effects.

1 Introduction

Flows in which the acceleration forces are large in comparison with the viscous forces, or the diffusion times are large in comparison with the convection times, or the convection velocities are large in comparison with the diffusion velocities, it can be shown that, e.g., the influences of wall boundaries on flows are restricted to small region (thin layer) near the walls. This thin layer where friction effects cannot be ignored is called the boundary layer. Such flows can therefore be subdivided into body-near regions, where viscous influences on flows have to be considered, and regions that are distant from the wall, which can be regarded as being free from viscous influences. This

*Corresponding author.
URL: `http://www.nitw.ac.in/nitwnew/facultypage.aspx?didno=9&fidno=557`
Email: dsc@nitw.ac.in (D. Srinivasacharya), chittetiram@gmail.com (Ch. RamReddy)

boundary layer theory was proposed by Ludwig Prandtl in 1904. Prandtl concluded that it might be sufficient in an analysis of a flow field to consider action of viscosity within these boundary layers, whereas the flow outside the boundary layers may be considered inviscid. He then proceeded to simplify the conservation equation by estimating the order of magnitude of the various terms in the conservation equations, and thus he derived the so-called boundary layer equations (Eckert and Drake, see [1]). Analytical treatment of the Navier-Stokes equations present great difficulties even in the case of steady two-dimensional incompressible flows. Only a limited number of exact solutions are known to exist for some special cases of these equations. An important contribution by Prandtl was to show that the Navier-Stokes equations can be simplified to yield an approximate set of boundary layer equations (Bejan, see [2]).

The analysis of mixed convection boundary layer flow along a vertical plate embedded in viscous fluid has received considerable theoretical and practical interest. The phenomenon of mixed convection occurs in many technical and industrial problems such as electronic devices cooled by fans, nuclear reactors cooled during an emergency shutdown, a heat exchanger placed in a low-velocity environment, solar collectors and so on. Several authors have studied the problem of mixed convection about different surface geometries. When heat and mass transfer occur simultaneously in a moving fluid, the relations between the fluxes and the driving potentials are of a more intricate nature. It has been observed that an energy flux can be generated not only by temperature gradients but also by concentration gradients. The energy flux caused by a concentration gradient is termed the diffusion-thermo (Dufour) effect. On the other hand, mass fluxes can also be created by temperature gradients and this embodies the thermal-diffusion (Soret) effect. In most of the studies related to heat and mass transfer process, Soret and Dufour effects are neglected on the basis that they are of a smaller order of magnitude than the effects described by Fouriers and Ficks laws. But these effects are considered as second order phenomena and may become significant in areas such as hydrology, petrology, geosciences, etc. The Soret effect, for instance, has been utilized for isotope separation and in mixture between gases with very light molecular weight and of medium molecular weight. The Dufour effect was recently found to be of order of considerable magnitude so that it cannot be neglected (see Eckert and Drake [1]). Dursunkaya and Worek [3] studied diffusion-thermo and thermal-diffusion effects in transient and steady natural convection from a vertical surface, whereas Kafoussias and Williams [4] presented the same effects on mixed convective and mass transfer transfer steady laminar boundary layer flow over a vertical flat plate with temperature dependent viscosity. Postelnicu [5] studied numerically the influence of a magnetic field on heat and mass transfer by natural convection from vertical surfaces in porous media considering Soret and Dufour effects. Both free and forced convection boundary layer flows with Soret and Dufour effects have been addressed by Abreu et al. [6]. Alam and Rahman [7] have investigated the Dufour and Soret effects on mixed convection flow past a vertical porous flat plate with variable suction. Recently, the effect of Soret and Dufour parameters on free convection heat and mass transfers from a vertical surface in a doubly stratified Darcian