Numerical Solution of the Free Convection Boundary Layer Flow over a Horizontal Circular Cylinder with Convective Boundary Conditions

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Abstract. Numerical solution for the steady free convection boundary layer flow near the lower stagnation point of a horizontal circular cylinder subjected to a convective boundary condition, where the heat is supplied to the fluid through a bounding surface with a finite heat capacity are presented in this paper. The governing boundary layer equations are transformed using non-similar variables into non-similar equations and were solved numerically using an implicit finite difference scheme known as the Keller-box method. The solutions are obtained for the skin friction coefficient, the local wall temperature, as well as the velocity and temperature profiles with two the variations of two parameters, namely the conjugate parameter γ and the Prandtl number Pr.

Keywords: Boundary layer flow, convective boundary conditions, free convection, horizontal circular cylinder.
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INTRODUCTION

The study on free convection boundary layer has progressed over the past decade due to the demand in the industrial manufacturing processes and engineering applications such as to handle hot wire, steam pipe, understanding of weather and climate, the dispersion of pollutants, exchange of heat and many more. Researches on this area are either been studied by theoretical analysis, experimental work or by numerical simulation. For this particular paper, the latter approach is used.

The pioneering work of free convection boundary layer flow has been investigated by Elliott [1] on a two-dimensional, or axisymmetric body. He obtained a solution in terms of power of square of the time, and his theory was later been applied to a horizontal circular cylinder. Burggraf *et al.* [2] examined the same problem in which the body shape is a horizontal plate. For the case when the body shape is a horizontal circular cylinder, it seems that Merkin [3] was the first to complete the solution of this problem by using the Gortler and Blasius series expansion method along with an integral method and a finite difference scheme.

Following Merkin's work, Ingham [4] analyzed the free convection boundary layer flow on an isothermal horizontal circular numerically. Ingham and Pop [5] then continued their studies on free convection about a heated horizontal cylinder embedded in a fluid saturated porous medium. Natural convection flow from an isothermal horizontal circular cylinder in the presence of heat generation has been reported by Molla *et al.* [6]. Next, Molla *et al.* [7] revisited the same problem and considered constant heat flux as the boundary conditions.

In micropolar fluid, there have been a few works published in the literature. Nazar *et al.* [8] examined the problem of free convection boundary layer on an isothermal horizontal circular cylinder in micropolar fluid with two heating processes; which is constant wall temperature and constant heat flux. Salleh and Nazar [9] studied the similar problem, but with Newtonian heating boundary conditions. Besides Salleh and Nazar [9], Ahmad *et al.* [10], Yamamoto *et al.* [11], Aldos and Ali [12], also studied almost similar problems in viscous and micropolar fluids.

Despite the fact that numerous studies were carried out in the past on this problem, most of the studies above considered either constant heat flux (CHF), constant wall temperature (CWT) or Newtonian heating (NH). Here a somewhat different mechanism for heating process is considered; namely convective boundary condition (CBC) where the heat is supplied to the convecting fluid through a bounding surface with a finite heat capacity. This results in the heat transfer rate through the surface being proportional to the local temperature difference (Merkin [13]).