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Variable Fluid Properties and Thermal Radiation Effects on Mixed Convection Flow over a Horizontal Surface

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Variable Fluid Properties and Thermal Radiation Effects on Mixed Convection Flow over a Horizontal Surface

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The effects of variable viscosity and thermal conductivity on mixed convection flow of a viscous incompressible fluid past a semi-infinite horizontal permeable surface aligned parallel to a uniform free stream in the presence of thermal radiation have been investigated. The transformed equations have been solved numerically. The effects of various parameters on the velocity and temperature profiles as well as on the local skin-friction coefficient and the local Nusselt number are presented and discussed.

Keywords Boundary layers, horizontal surface, thermal radiation, laminar mixed convection

1. INTRODUCTION

In classical boundary-layer theory, there is no pressure variation across the boundary-layer. However, if the surface temperature differs from that of the free stream, the tangential component of the buoyancy gives rise to a hydrostatic pressure across the boundary-layer. Consequently, an appropriate modification of laminar boundary layer equations is needed. Theoretical studies of free convection on a horizontal surface under the action of the buoyancy force were first investigated by Stewartson [1] and Gill et al. [2]. In contrast to the problem of mixed convective flow along a vertical flat plate, less attention has been given to studies of buoyancy force effects on laminar forced convection over a horizontal flate plate. Mori [3] and Sparrow and Minkowycz [4] were the first investigators to treat this problem. Since then, extensive studies have been conducted by Schneider [5], Dey [6], Ramarchandran et al. [7], Raju et al. [8], De Hoog et al. [9], Afzal and Hussain [10], Merkin and Ingham [11], Risbeck et al. [12], Schneider et al. [13], Risbeck et al. [14], Steinrück[15], Rudischer and Steinrück [16], Magyari et al. [17], Mahmoud [18], Chen and Armaly [19].

On the other hand, at high temperature the effect of radiation in space technology, space vehicle re-entry, nuclear engineering applications and other industrial areas are very significant. Bestman and Adjepong [20] studied the unsteady hydromagnetic free convection flow with radiative heat transfer in a rotating fluid. Takhar et al. [21] examined the radiation effect on MHD free convection flow of a gas past a semi-infinite vertical plate. Raptis and Perdikis [22] investigated the steady flow of a viscoelastic fluid past an unmoving infinite plate in the presence of radiation using Rosseland approximation for radiation. Raptis [23] analyzed the steady flow of an elastico-viscous fluid past a semi-infinite plate by the presence of radiation when the free stream velocity and the temperature of the plate are not constant. Hossain and Takhar [24] discussed the natural convection boundary layer flow with conduction-radiation interaction of a viscous incompressible fluid along an isothermal horizontal surface. Pop et al. [25] investigated the radiation effects on the flow of an incompressible viscous fluid over a flat sheet near the stagnation point. Raptis et al. [26] studied the effect of thermal radiation on the MHD flow of a viscous fluid past a semi-infinite stationary plate. Muthucumaraswamy and Chandrakala [27] studied the effects of thermal radiation on flow past an impulsively started infinite vertical isothermal plate with variable mass diffusion. Mahmoud et al. [28] studied the effect of thermal radiation on the hydromagnetic boundary layer micropolar fluid flow over a stretching surface embedded in a non-Darcian porous medium. Sajid and Hayat [29] analytically examined the effect of radiation on the boundary layer flow and heat transfer of a viscous fluid over an exponentially stretching sheet.

In all the above-mentioned studies, the fluid properties was assumed uniform in the flow region. It is known that these physical properties change significantly with temperature. Thermal radiation effects on MHD flow of a micropolar fluid over a stretching surface with variable thermal conductivity have been studied by Mahmoud [30]. Jang and Lin [31] investigated the free convection flow over a uniform heat flux surface with temperature–dependent viscosity. Pop et al. [32] examined the effect of variable viscosity on flow and heat transfer to a continuous moving flat plate. Kafoussius and Williams [33] discussed the effect of temperature-dependent viscosity on free-forced convection laminar boundary layer flow past a

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