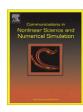
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Study of hydromagnetic heat and mass transfer flow over an inclined heated surface with variable viscosity and electric conductivity

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ABSTRACT

The effects of variable electric conductivity and temperature dependent viscosity on hydromagnetic heat and mass transfer flow along a radiate isothermal inclined permeable surface in a stationary fluid in the presence of internal heat generation (or absorption) are analyzed numerically presenting local similarity solutions for various values of the physical parameters. The research shows that the difference in the results between variable Prandtl number and constant Prandtl number are significant when fluid viscosity strongly dependents on the temperature. The results also show that skin friction coefficient, Nusselt number and Sherwood number are lower for the fluids of constant electric conductivity than those of the variable electric conductivity.

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1. Introduction

The study of thermal boundary layer flows of variable viscosity on isothermal heated surfaces not only possesses theoretical interest but also models many fluid transport mechanisms encountered in industries and engineering systems. Amongst others, we can name hot rolling, wire drawing, glass fiber production, paper production, gluing of labels on hot bodies, drawing of plastic films, etc. When a cooler fluid flows around a hot body, the temperature of the fluid will rise in a thin layer around the body and in a wake behind it. This thin layer is known as the thermal boundary layer. In this layer, flow and thermal phenomena interact nonlinearly and governed by the so-called thermal boundary layer equations. In classical treatment of thermal boundary layers, the kinematic viscosity is assumed to be constant; however, experiments indicate that this assumption only makes sense if temperature does not change rapidly for the application of interest. Indeed, for liquids, experimental data shows that viscosity decreases with temperature.

Viscosity changes with temperature, for example the absolute viscosity of water decreases by 240% when the temperature increases from 10 °C to 50 °C which has been shown by Herwig and Wickern [1]. Film of fluids with constant viscosity along an inclined heated plate was investigated by Saouli and Saouli [2]. Meanwhile, several authors have investigated the effects of temperature dependent viscosity on the flow of non-Newtonian fluids in a channel under various conditions (e.g. Makinde [3], Szeri and Rajagopal [4], Yurusoy and Pakdemirli [5]). Ali [6] has studied the effect of

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Nomenclature
            applied magnetic field (Wbm<sup>-2</sup>)
           species concentration (kg m<sup>-2</sup>)
C
Cf
           skin friction coefficient
           specific heat at constant pressure (Jkg<sup>-1</sup>K<sup>-1</sup>)
C_p
           concentration at the porous plate (kg m<sup>-2</sup>)
C_w
           species concentration at infinity (kg m<sup>-2</sup>)
C_{\infty}
            molecular diffusivity (m^{-2}s^{-1})
D_m
           dimensionless stream function
fw
           dimensionless suction parameter
            acceleration due to gravity (ms<sup>-2</sup>)
           Grashof number
Gr
            modified Grashof number
Gc
Nux
           local Nusselt number
Pn
            radiative Prandtl number
Pr
           variable Prandtl number
Pr_{\infty}
            ambient Prandtl number
            surface heat flux (W m<sup>-2</sup>)
Q
            local heat generation parameter
            heat generation parameter (W)
Q_0
            radiation parameter
Re_x
            local Reynolds number
            Schmidt number
Sc
Sh_x
            local Sherwood number
            temperature within boundary laver (K)
T
T_{w}
            temperature at the plate (K)
T_{\infty}
            temperature of the ambient fluid (K)
            velocity along x-axis (m s<sup>-1</sup>)
11
U_0
            characteristic velocity (m s<sup>-1</sup>)
U_{\infty}
            velocity outside the boundary layer (m s^{-1})
            velocity along y-axis (m s^{-1})
ν
            suction velocity (m s<sup>-1</sup>)
v_0
           coordinate along the surface (m)
х
           coordinate normal to the surface (m)
y
Greek symbols
α
           angle of inclination (rad)
           coefficient of volume expansion (K<sup>-1</sup>)
β
\beta^*
            coefficient of volume expansion with concentration (K<sup>-1</sup>)

ho_{\infty}
            mass density of the ambient fluid (kg m^{-3})
           coefficient of dynamic viscosity (Pa s)
и
            apparent kinematic viscosity (m<sup>-2</sup>s<sup>-1</sup>)
υ
            electric conductivity (m\Omegam<sup>-1</sup>)
\sigma
            magnetic permeability (NA<sup>-2</sup>)
\sigma_0
            thermal conductivity (W m<sup>-1</sup>K<sup>-1</sup>)
ĸ
η
            similarity parameter
            stream function (m<sup>-2</sup>s<sup>-1</sup>)
ψ
\theta
            dimensionless temperature
Θ
            viscosity parameter
            dimensionless concentration
```

temperature dependent viscosity on laminar mixed convection boundary layer flow and heat transfer on a continuously moving vertical surface. Laminar falling liquid film with variable viscosity along an inclined heated plate has been studied by Makinde [7]. A steady two-dimensional flow of an electrically conducting incompressible fluid over a heated stretching sheet with variable viscosity has been investigated by Mukhopadhyay et al. [8]. Pop et al. [9], and Elbashbeshy and Bazid [10] have studied the effect of variable viscosity using the similarity solution with no buoyancy force. Although viscosity varies with temperature, all of the afore-mentioned works considered constant Prandtl number (a parameter directly proportional to fluid viscosity, see Section 3) within the boundary layer. So one of the objectives of this study is to investigate the roll of variable Prandtl number on the heat and mass transfer flows.

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