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Radiative heat transfer of variable viscosity and thermal conductivity effects on inclined magnetic field with dissipation in a non-Darcy medium

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Abstract

The study of thermal radiative heat transfer of an electrically conducting fluid over a continuously stretching sheet in the presence of a uniform inclined magnetic field with dissipation in a porous medium is investigated for power-law variation in the sheet temperature. The fluid viscosity and thermal conductivity are assumed to vary as a function of temperature. The governing partial differential equations of the model are reduced to a system of coupled non-linear ordinary differential equations by applying similarity variables and then solved numerically using shooting technique with fourth-order Runge–Kutta method. The results for Skin friction and Nusselt numbers are presented and discussed.

Keywords: Radiation; Variable viscosity; Dissipation; Thermal conductivity; Non-Darcy medium

1. Introduction

Studies on heat transfer in boundary layers over continuously moving or stretching sheet on free convection flow induced by the simultaneous actions of uniform inclined magnetic field and buoyancy forces resulting from variable viscosity and thermal conductivity is gaining attention due to its interesting applications in glass fibre, metal extrusion, materials handling conveyors, plastic and rubber manufacturing.

In few of these applications, Saleh et al. [1] considered heat and mass transfer in MHD visco-elastic fluid flow through a porous medium over a stretching sheet with chemical reaction. Krishnendu [2] studied heat transfer in boundary layer stagnation-point flow towards a shrinking sheet with non-uniform heat flux. It was reported that, the direct variation and inverse variation of heat flux along the sheet have completely different effects on the temperature distribution. Makinde [3] carried out analysis on heat and mass transfer by MHD mixed convection stagnation point flow toward a vertical plate embedded in a highly porous medium with radiation and internal heat generation and Siti et al. [4] investigated hydromagnetic boundary layer flow over stretching surface with thermal radiation. It was

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Nomenclature

x:	Distance along the sheet, m
y:	Distance perpendicular to the sheet, m
u:	Non Darcian Velocity component in x-direction, m s^{-1}
v:	Non Darcian Velocity component in y-direction, m s^{-1}
g:	Acceleration due to gravity, m s^{-2}
B_0:	Magnetic induction, Wb m^{-2}
q^r:	Radiative heat flux, W m^{-2}
Q:	Heat source/sink, W
T:	Fluid temperature, K
C_p:	Specific heat at constant pressure, J kg^{-1} K^{-1}
k:	Thermal conductivity, W m^{-1} K^{-1}
u_w:	Fluid velocity at the wall, m s^{-1}
K^*:	Permeability of the porous medium
A, b, m:	Prescribed constants
H_a:	Hartmann number
D_a:	Darcy number
G_r:	Thermal Grashof number
E_c:	Eckert number
R:	Radiation parameter
P_r:	Prandtl number
f:	Dimensionless stream function

Greek symbols

ν:	Kinematic viscosity, m^2 s^{-1}
α:	Angle of inclination of the magnet, deg
μ:	Viscosity, kg m^{-1} s^{-1}
ρ_∞:	Free stream density, kg m^{-3}
β_T:	Thermal expansion coefficient, K^{-1}
σ:	Electric Conductivity, mΩ m^{-1}
ψ:	Stream function, m^{-2} s^{-1}
η:	Similarity variable
ϕ:	Viscosity parameter
λ:	Heat source/sink parameter
φ:	Porous media inertia coefficient

noticed that the magnetic parameter decreases the skin friction coefficient thus reduces the momentum boundary layer thickness. Mohebujjaman et al. [5] considered MHD heat transfer mixed convection flow along a vertical stretching sheet in the presence of magnetic field with heat generation while Dulal [6] investigated heat and mass transfer in stagnation-point flow in viscous fluid over a stretching vertical sheet by considering buoyancy force and thermal radiation. Singh & Makinde [7] analyzed computational dynamics of MHD free convection flow along an inclined plate with Newtonian heating in the presence of volumetric heat generation. All the above investigations were carried out on fluid flow without considering viscosity and thermal conductivity as a function of temperature.

The pioneering work of sakiadis [8] considered momentum transfer for a flow over a continuously moving plate in quiescent fluid; Mureithi et al. [9] studied boundary layer flow over a moving surface in a fluid with temperature-dependent viscosity. Makinde et al. [10] reported on the MHD variable viscosity reacting flow over a convectively heated plate in a porous medium with thermophoresis and radiative heat transfer. It was found that skin friction is lower and Nusselt number is higher when the viscosity is temperature dependent. Abel & Mahesha [11] investigated heat transfer in MHD viscoelastic fluid flow over a stretching sheet with variable thermal conductivity, non-uniform