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The effects of Ohmic heating and viscous dissipation on unsteady MHD and slip flow over a porous rotating disk with variable properties in the presence of Hall and ion-slip currents ☆

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Abstract

The effects of Ohmic heating and viscous dissipation on unsteady laminar magneto-hydrodynamics (MHD) flow of a viscous Newtonian and electrically conducting fluid over a rotating disk taken into account the variable fluid properties (density, (ρ), viscosity, (μ) and thermal conductivity, (κ)) in the presence of Hall and ion-slip currents effects have been examined. These fluid properties are taken to be dependent on temperature. The unsteady Navier–Stokes equations along with the energy equation are reduced to a system of ordinary differential equations by using similarity transformations and the resulting equation system is solved numerically by using a shooting method. Results for the details of the velocity as well as temperature are shown graphically and the numerical values of the skin friction and the rate of heat transfer are entered in tables.

Keywords: Rotating disk; Ohmic heating; Viscous dissipation; Shooting method

1. Introduction

The study of flow and (or) heat and mass transfer over rotating bodies is of considerable interest due its occurrence in many industrial, geothermal, geophysical, technological and engineering applications. Such a study is important in the design of turbines (gas or marine) and turbo-machines, in estimating the flight path of rotating wheels and spin-stabilized missiles and in the modeling of many geophysical vortices.

The hydrodynamic flow due to an infinite rotating disk was first introduced by von Karman [1]. He formulated the problem in the steady state and used similarity transformations to reduce the governing partial differential equations to ordinary differential equations. Asymptotic solutions were obtained for the reduced system of ordinary differential equations [2]. The extension of the steady hydrodynamic problem to the transient state was done by Benton [3]. The influence of an external uniform magnetic field on the flow due to a rotating disk was studied [4] without considering the Hall effect. More applications can be found in [5–7].

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Nomenclature

u	radial velocity, m/s
P	pressure, N/m^2
g	gravitational acceleration, m/s^2
L	characteristic length, m
w	axial velocity, m/s
Nu	Nusselt number
T	fluid temperature, K
B_0	magnetic flux density
c_p	specific heat at constant temperature, J kg^{-1} K^{-1}
Pr	Prandlt number, $=\mu_0 c_p / k_0$
T_w	wall temperature, °C
M	magnetic interaction parameter, $=\sigma B_0^2/(\rho_0 \Omega)$
W	uniform suction/injection, $= w/\sqrt{v_0 \Omega}$
U_t	target velocity, m/s
v	tangential velocity, m/s
r	radial axis, m
z	vertical axis, m
Kn	Knudsen number
Re	Reynolds number, $=\Omega r^2 / v_0$
Re_m	magnetic Reynolds number
n	normal direction to the wall

Greek symbols

v_0	uniform kinematic viscosity, m^2/s
δ	unsteadiness parameter
ϕ	vertical angle of the disk
η	normal distance from the disk, $=z(\Omega / v_0)^{1/2}$
Ω	angular velocity, m/s
μ	dynamic viscosity, N s/m^2
κ	thermal conductivity coefficient
ρ	fluid density, kg/m^3
σ	electrical conductivity
$\sigma*$	Stefan–Boltzmann constant
$\kappa*$	absorption coefficient
ε	relative temperature different parameter, $=\triangle T / T_0$
v	kinematic viscosity, m^2/s
η	dimensional normal distance
τ_t	tangential skin friction
τ_r	radial skin friction
ψ	target momentum accommodation coefficient
γ	slip factor, $[(2-\psi)\lambda\Omega^{1/2}]/[\psi v^{1/2}]$

Subscripts

i	initial condition
w	condition of the wall
0	condition at free stream