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Thermal radiation effects on the time-dependent MHD permeable flow having variable viscosity

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ABSTRACT

The present work is devoted to the impacts of thermal radiation on the unsteady laminar convective MHD flow of a viscous electrically conducting fluid having a temperature-dependent viscosity over a rotating porous disk of infinite extend impulsively set into motion. The fluid is subjected to an external uniform magnetic field perpendicular to the plane of the disk. The governing Navier-Stokes and Maxwell equations of the hydromagnetic fluid, together with the energy equation, are reduced into a system of nonlinear ordinary differential equations via the Von Karman similarity transformations. Due to the radiation effect and variable viscosity property the equations are highly coupled. These equations are then solved numerically by using a technique based on the spectral Chebyshev collocation in the direction normal to the disk and forward marching in time. Transient effects are discussed first. Later a parametric study of all parameters involved is performed and a representative set of results incorporating the effects of Prandtl number, the viscosity variation parameter, the magnetic interaction parameter, the radiation parameter, the uniform suction/blowing parameter, the relative temperature difference parameter and the Eckert number on physically meaningful quantities such as the radial and tangential skin friction coefficients, the torque, the vertical wall suction and the rate of heat transfer from the disk surface are illustrated graphically and discussed.

1. Introduction

After the pioneering work of Von Karman [1], the rotating disk flow is still being an intriguingly fresh problem from a mathematical point of view since it is one of the rare fluid flow phenomena in fluid mechanics possessing an exact three-dimensional solution. The magnetohydrodynamic (MHD) fluid flow problem of a rotating disk also finds special places in several science and engineering applications, for instance, in turbomachinery, in cosmical fluid dynamics, in meteorology, in computer disk drives, in geophysical fluid dynamics, in gaseous and nuclear reactors, in MHD power generators, flow meters, pumps, and chemical vapor deposition reactors. Particularly, the thermal radiation influences are taken into account here in the unsteady problem of rotating disk Von Karman fluid flow having a temperature-dependent viscosity with the hydromagnetic, uniform suction/blowing, relative temperature difference, viscous dissipation and Joule heating effects all incorporated.

For a brief survey on the rotating disk flow, pursuing the work of Von Karman [1], the effects of unsteadiness on the Von Karman flow were investigated in [2] and [3]. The recent work by Takeda et al. [4] explored the permeable wall conditions. The analogous heat transfer problem for steady and unsteady flow cases was examined in [5] and [6]. Hossain et al. [7] and Maleque and Sattar [8] investigated the influence of variable properties on the physical quantities of the rotating disk problem by obtaining a self-similar solution of the Navier-Stokes equations along with the energy equation. Kumar et al. [9] and Turkyilmazoglu [10] covered the effects of a uniform external magnetic field on the steady flow over a rotating disk. For the flow and heat transfer characteristics over rotor-rotator and rotating disk systems, one can refer to the books [11–13].

The aforementioned research unfortunately ignored the radiation effects of the Von Karman swirling flow. However, as stressed out by the studies in [14] and [15], when technological processes take place at high temperatures thermal radiation heat transfer become very important and its effects cannot be neglected. Recent developments in hypersonic flights, missile reentry rocket combustion chambers, gas cooled nuclear reactors and power plants for inter planetary flight, have focused attention of researchers on thermal radiation as a mode of energy transfer, and emphasize the need for inclusion of radiative transfer in these processes. Upon this, many studies have appeared concerning the interaction of radiative flux with thermal convection flows. For example, in the context of spacecraft technology Sutton [16] as early as 1956 suggested that for temperatures ranging from 1927 degrees Celsius to 3871 Celsius, as

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