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Numerical analysis of unsteady squeezing MHD flow of a ternary hybrid nanofluid between parallel rotating disks with Hall current and heat transfer reversal

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Abstract

This paper investigates the three-dimensional unsteady squeezing flow of a magnetized ternary hybrid nanofluid ($\text{Cu-Al}_2\text{O}_3\text{-TiO}_2/\text{water}$) between two parallel rotating disks. The mathematical model incorporates the effects of Hall current, Joule heating, viscous dissipation, and Arrhenius activation energy. Using appropriate similarity transformations, the governing partial differential equations are reduced to a system of coupled nonlinear ordinary differential equations. These equations are solved numerically via the Shooting Method combined with the Runge-Kutta-Fehlberg (RK45) algorithm. A comprehensive parametric study is conducted to analyze the influence of the Squeeze number (S), Magnetic parameter (M), Hall parameter (m), and Eckert number (Ec) on the velocity, temperature, and concentration profiles. A critical finding of this study is the occurrence of heat transfer reversal (negative Nusselt numbers) at the disk surface, driven by dominant internal heat generation from viscous and Ohmic dissipation. The results indicate that the Hall current effectively reduces the surface drag in the swirl direction by decreasing the effective electrical conductivity. Furthermore, the squeezing force significantly modifies the radial flow topology compared to steady-state configurations. This research provides essential insights for the design of high-performance thermal systems in aerospace and industrial lubrication.

Keywords Ternary hybrid nanofluid, Squeezing flow, Shooting method, Hall effect, Joule heating, Heat transfer reversal

1 Introduction

The relentless demand for high-efficiency thermal management systems in modern industrial processes, encompassing aerospace engineering, nuclear reactor cooling mechanisms, and micro-electromechanical systems, has catalyzed the exploration of advanced heat transfer fluids. Traditional coolants, such as water, ethylene glycol, and mineral oils, are fundamentally limited by their inherently low thermal conductivities. To circumvent these limitations, the scientific community introduced the concept



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