Magnetoconvection in a Ternary Hybrid Nanofluid with Melting Boundary Condition

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ABSTRACT

This study explored the thermal and fluid dynamic behavior of a ternary hybrid nanofluid composed of copper oxide (CuO), multi-wall carbon nanotubes (MWCNTs), and single-wall carbon nanotubes (SWCNTs) suspended in water. Hybrid nanofluids, which combine multiple types of nanoparticles in a base fluid, have been shown to offer enhanced thermal properties, making them promising candidates for improving heat transfer in advanced thermal systems. The fluid dynamics and heat transfer characteristics of this ternary hybrid nanofluid are investigated in a semipermeable channel with a porous bottom wall, incorporating suction, injection, and melting conditions at the upper surface. These conditions represent practical situations in heat exchangers or energy storage systems, where heat dissipation and fluid flow need to be optimized. The primary aim of this study is to assess the effects of various factors, such as magnetoconvection, radiation, and Joule heating, on the thermal and fluid dynamic performance of hybrid nanofluids. This study uses the Differential Transformation Method (DTM) to solve the governing dimensionless equations, providing a detailed parametric study of key factors, such as the Hartmann number (representing the effect of magnetic fields), Reynolds number (fluid flow dynamics), Eckert number, nanoparticle volume fraction, skin friction coefficient, and Nusselt number. By conducting this analysis, this study aims to provide insights into the influence of these parameters on heat transfer and fluid flow, with the ultimate goal of enhancing thermal management and energy storage applications.

RESULT

This study reveals several key findings that highlight the potential of ternary hybrid nanofluids in thermal management systems. Increasing the Hartmann number leads to a decrease in fluid velocity due to the stronger Lorentz force exerted by the magnetic field. However, this results in an enhanced temperature distribution because a slower fluid flow allows for more efficient heat retention and distribution. The introduction of a melting condition at the upper surface significantly alters the thermal boundary layer, improving heat dissipation. This effect is particularly beneficial for systems in which effective cooling or energy storage is crucial, as it allows for better heat transfer at the surface. Both radiation and Joule heating further optimize the heat-transfer process. Radiation enhances the dissipation of heat from the surface, whereas Joule heating, induced by the electrical conductivity of the nanofluid, raises the temperature and boost the thermal performance.

In summary, this study underscores the potential of ternary hybrid nanofluids to enhance thermal management in advanced systems, demonstrating their utility in applications that require efficient heat dissipation and energy storage.

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