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Numerical analysis of a radiated ternary hybrid nanofluid flow and Darcy-Forchheimer term over a rotating 3-D stretching sheet

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ABSTRACT

The rising issues of thermal transfer in heat exchangers need an effective solution. Ternary hybrid nanofluids, which contain three nano species blended into a bulk base fluid, outperform nanofluids regarding thermal efficiency. Ternary hybrid nanofluid consists of Copper Oxide (CuO), Titanium Dioxide (TiO_2), and Silver (Ag) nanoparticles mixed with the base fluid, Ethylene Glycol ($C_2H_6O_2$). This study aims to enhance the fluid's thermal efficiency in a porous medium by suspending these nanoparticles in the base fluid. Thus, the current study investigates the heat transmission properties of a 3D rotating Ternary hybrid nanofluid using Darcy-Forchheimer and thermal radiation effects on a porous bi-stretched surface. The governing equations of the flow problem are expressed as partial differential equations, these partial differential equations (PDEs) are converted into ordinary differential equations (ODEs) using a feasible similarity transformation. The linearized mathematical equations are numerically solved using the MATLAB solver "bvp4c". The variations in the velocity and temperature profiles due to the Magnetic field, Darcy-Forchheimer, and thermal radiation effects are presented graphically. The results revealed that the impact of these nanoparticles in the base fluid has increased the thermal efficiency of the fluid. The outcomes of this work will be beneficial in the cosmetic manufacturing industry, Hydraulic fluid, and the manufacture of fiberglass.

RESEARCH AIM

The current study examines the heat transmission features of a 3D rotating Ternary hybrid nanofluid employing Darcy-Forchheimer and thermal radiation effects on a porous bi-stretched surface.

LITERATURE SURVEY

- Shah and Awan in 2022 investigated the significance of magnetized Dacy-Forchheimer effects on a rotating Williamson hybrid nanofluid flow over a 3D stretching sheet.
- Karthik et.al examined the effect of endothermic/exothermic chemical reactions on heat and mass transfer of nanofluid flow across an inclined cylinder in 2024.
- Lone et.al explored the convective conditions on 3D rotating ternary hybrid nanofluid flow over an extending sheet in 2020.

PROBLEM FORMULATION

The following are the governing equations for a 3D rotating Ternary Hybrid nanofluid flow over a porous bi-stretched surface

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \tag{1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}-2\Omega_1 v=u_e\frac{du_e}{dx}+\vartheta_{thnf}\frac{\partial^2 u}{\partial z^2}-\frac{1}{\rho_{thnf}}\left[\frac{\mu_{thnf}}{k_p}+\sigma_{thnf}{B_0}^2\right](u-u_e)-F(u^2-{u_e}^2) \tag{2}$$

$$u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial w}{\partial z}-2\Omega_1 \mathrm{u}=\vartheta_{thnf}\frac{\partial^2 v}{\partial z^2}-\frac{1}{\rho_{thnf}}\left[\frac{\mu_{thnf}}{k_p}+\sigma_{thnf}{B_0}^2\right]v-Fv^2 \tag{3}$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}=\alpha_{thnf}\frac{\partial^2 T}{\partial z^2}+\frac{(\rho_f)\varepsilon}{(\rho C_p)_{thnf}}Kr^2 exp\left(-\frac{E_A}{KT}\right)\left(\frac{T}{T_\infty}\right)^m(C-C_\infty)+\frac{16\sigma^*}{3k^*}\frac{{T_\infty}^3}{(\rho C_p)_{thnf}}\frac{\partial^2 T}{\partial z^2} \tag{4}$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}+w\frac{\partial C}{\partial z}=D_F\frac{\partial^2 C}{\partial z^2}-Kr^2 exp\left(-\frac{E_A}{KT}\right)\left(\frac{T}{T_\infty}\right)^m(C-C_\infty) \tag{5}$$

SOLUTION METHODOLOGY

The obtained partial differential equations (PDEs) are converted to ordinary differential equations (ODEs) using similarity transformations. A MATLAB “bvp4c” solver resolves the transformed ordinary differential equations (ODEs). This software provides accurate numerical solutions for linearized ordinary differential equations.

CONCLUSIONS

Concerning heat and mass transfer rate, the effects of thermal radiation, and Darcy-Forchheimer effects are depicted graphically using MATLAB “bvp4c” solver. There is a reduction in the velocity rate due to the drag force offered by the Darcy-Forchheimer effect. Thermal radiation boosts the energy profile of ternary hybrid nanofluid.

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