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Simulation of Quadratic Thermal Radiation on steady flow of Ternary Hybrid Nanofluid (TiO2-SiO2-MoS2/Kerosene oil) Flow over a Rotating Disk with and Cattaneo-Christov Model

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Abstract

The theme of the article is to discuss the impact of the Cattaneo-Christov model and quadratic thermal radiation with convective boundary conditions on ternary hybrid nanofluid (TiO_2-SiO_2-MoS_2/Kerosene oil) flow over a rotating disk. To utilize a porous medium, the Darcy-Forchheimer theory is applied, and suction/injection influence is also considered. The ascendancy of the magnetic field, Forchheimer number, porosity parameter, slip parameter, and radiation parameter are discussed in detail. Higher values of radiation and thermal relaxation parameter increases the heat transmission rate.

1. Introduction

In the present scenario, the researchers aim to explore nanotechnology. It is applicable in the diverse area of the heat transfer process and has elaborated a remarkable surge in energy applications. To improve heat transfer phenomena, the researchers have developed a new kind of hybrid fluid in which three nanoparticles are mixed in one working fluid called ternary nanofluid. Nanofluid is suitable for thermal performance enhancement (Choi [1]).

Heat transfer is a predominant phenomenon in nature due to the temperature gradient. For a long time, heat transfer properties were analyzed by the Fourier law. Cattaneo modified the Fourier law by adding a thermal relaxation time parameter in the classical Fourier law, which says that the heat transfer method allows heat to be transported through the propagation of heat waves at a finite rate.

Some other important attentive points of this paper are:

- The effect of quadratic thermal radiation on velocity and temperature.
- The flow of ternary nanofluid (TiO_2-SiO_2-MoS_2/Kerosene oil) over a rotating disk is inspected in this study.
- A relational study of parameters such as suction/injection, heat generation/absorption, and a magnetic field is discussed for hybrid and ternary hybrid nanofluid.

2. Formulation of the problem [2,3]:

$$u_r + \frac{u}{r} + w_z = 0 \tag{1}$$

$$\rho_{Thnf}\left(uu_r - \frac{v^2}{r} + wu_z\right) + p_r = \mu_{Thnf}\left(u_{rr} + \frac{1}{r}u_r - \frac{u}{r^2} + u_{zz}\right) - \sigma_{Thnf}B_0^2 u + (\rho\beta)_{Thnf}\, g_0\left(T - T_\infty\right) - \mu_{Thnf}\frac{u}{K^*} - \rho_{Thnf}\frac{Fr}{\sqrt{K^*}} \tag{2}$$

$$\rho_{Thnf}\left(uv_r+\frac{uv}{r}+wv_z\right)=\mu_{Thnf}\left(v_{rr}+\frac{1}{r}v_r-\frac{v}{r^2}+v_{zz}\right)-\sigma_{Thnf}B_0^2v-\mu_{Thnf}\frac{v}{K^*}-\rho_{Thnf}\frac{Fr}{\sqrt{K^*}}v^2 \tag{3}$$

$$\rho_{hnf}\left(uw_r+ww_z\right)+p_r=\mu_{hnf}\left(w_{rr}+\frac{1}{r}w_r+w_{zz}\right) \tag{4}$$

$$\begin{aligned}\left(\rho C_p\right)_{Thnf}\left(uT_r+wT_z\right)=k_{Thnf}\left(T_{rr}+\frac{1}{r}T_r+T_{zz}\right)-\left(q_r\right)_z-\Lambda_t\begin{bmatrix}u^2T_{rr}+w^2T_{zz}+2uwT_{zr}\\+\left(uu_r+wu_z\right)T_r+\left(uw_r+ww_z\right)T_z\end{bmatrix}\\+\frac{Q_0}{\left(\rho C_p\right)_{Thnf}}\left(T-T_\infty\right)\end{aligned} \tag{5}$$

Boundary condition:

$$\left.\begin{aligned}&u=L\frac{\partial u}{\partial z},\quad v=r\Omega+L\frac{\partial u}{\partial z},\quad w=w_o,\quad -k_{Thnf}\left(\frac{\partial T}{\partial z}\right)=h_f\left(T_w-T\right)\ \text{at } z=0\\&u\to 0,\quad v\to 0,\quad T\to T_\infty\quad \text{as}\quad z\to\infty\end{aligned}\right\} \tag{6}$$

3. Solution Methodology

The partial differential equations governing the heat transfer problem have been reduced to ordinary differential equations (ODEs). The built-in function "bvp4c" in MATLAB is used to solve the ODEs and to find the missing values of θ. The step size was set as 0.01 with max η = 6.

4. Findings and conclusions

- The radial velocity is diminished by boosting the magnetic parameter, Forchheimer number, velocity slip parameter, Thermal relaxation, and Suction/Injection. At the same time, it accelerates on increasing porosity parameter, radiation parameter, mixed convection, and heat generation/absorption.
- The thermal profile rises on increasing radiation, suction/injection, and heat source/sink parameter.

References

1. Choi SUS. Enhancing thermal conductivity of fluids with nanoparticles. Am Soc Mech Eng Fluids Eng Div FED 1995;231:99–105.
2. Waqas H, Farooq U, Naseem R, Hussain S, Alghamdi M. Impact of MHD radiative flow of hybrid nanofluid over a rotating disk. Case Stud Therm Eng 2021;26.
3. Bhattacharyya A, Seth GS, Kumar R, Chamkha AJ. Simulation of Cattaneo–Christov heat flux on the flow of single and multi-walled carbon nanotubes between two stretchable coaxial rotating disks. J Therm Anal Calorim 2020;139:1655–70.

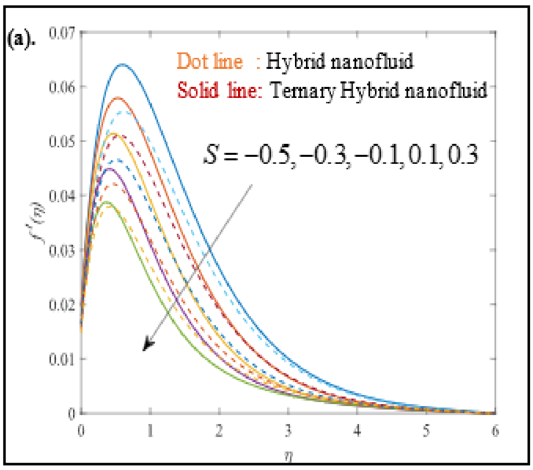

Fig 1. Velocity profile for suction.

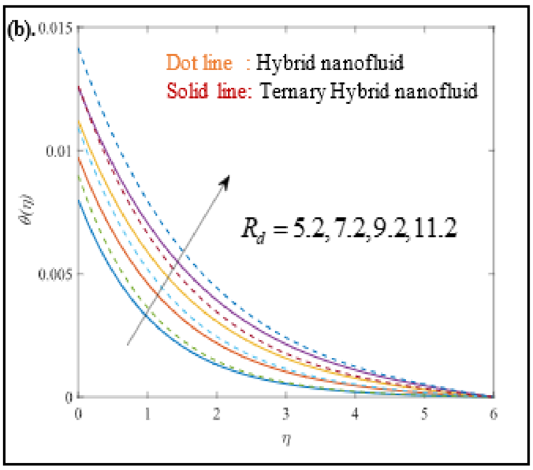

Fig 2. Temperature profile for radiation parameter.