Effects of radiation and chemical reaction due to Graphene oxide nanofluid flow in concentric cylinders

Jagadeeshwar Pashikanti [*,a], Susmitha Priyadharshini D R[a]
[a] Department of Science ansd Humanities, Indian Institute of Information Technology Tiruchirappalli
E-mail: [*]jagadeeshwarp@iiitt.ac.in, jagadeeshwar.pashikanti@gmail.com (Corresponding author)

1. ABSTRACT

Aggregated studies of graphene nanoparticles and thermal radiation in nanofluid flow is important for the effective utilization of their striking thermophysical properties and extensive industrial applications. Particularly, in the geometry of concentric cylinders, the nanofluid flow has wide applications including medicine such as the stenosis treatment. This investigation is one such computational study to explore the radiative flow of graphene oxide nanofluids between two concentric cylinders.

2. INTRODUCTION

Studies on graphene nanoparticles and thermal radiation in nanofluid flow is important for the effective utilization of their thermophysical properties in industrial applications. Particularly, in the geometry of concentric cylinders, nanofluid flow has applications including medicine such as the stenosis treatment. Classical studies on fluid flow between concentric cylinders such as the study on two dimensional natural convections for low Rayleigh numbers by Mack and Bishop [1] and stability analysis of Couette flow by Renardy [2] have paved the ways for further exploration of the geometry. Recently, Pordanjani and Aghakhani [3] presented a numerical investigation of alumina nanofluid in the presence of magnetic field in an inclined channel of concentric cylinders with an inference that the Nusselt number decreases with Hartmann number while there is an increase with radiation parameter.

3. GOVERNING EQUATIONS OF THE PROBLEM

Two vertically aligned infinite concentric cylinders are considered with radii b > a and the outer cylinder is assumed to rotate with an angular velocity Ω. GO nanofluid flows between the cylinders with velocity (0, u, 0) and constant pressure gradient ∂P/∂Θ. The flow is assumed to be fully developed and the temperature and concentration of the fluid is assumed to change along the radial direction. Considering the body force due to gravity, effect of chemical reaction and radiative heat flux, the effects caused by Brownian motion and thermophoresis and adapting the nanofluid model [4], the appropriate governing equations are given by

$$\frac{\partial u}{\partial \Theta} = 0 \tag{2.1}$$

$$\frac{\rho_{nf} u^2}{r} = \frac{\partial p}{\partial r} \tag{2.2}$$

$$\mu_{nf}\Big(\frac{\partial^2 u}{\partial r^2} + \frac{1}{r}\frac{\partial u}{\partial r} - \frac{u}{r^2}\Big) + (1-C_a)(T-T_a)g(\rho\beta)_{nf} - (\rho_p - \rho_{bf})(C-C_a)g - \frac{1}{r}\frac{\partial p}{\partial \Theta} = 0 \tag{2.3}$$

$$\frac{\kappa_{nf}}{(\rho C_p)_{nf}}\Big(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r}\Big) + \tau\Big(D_B \frac{\partial C}{\partial r}\frac{\partial T}{\partial r} + \frac{D_T}{T_a}\Big(\frac{\partial T}{\partial r}\Big)^2\Big) + \frac{1}{(\rho C_p)_{nf}\, r}\frac{\partial (r q_r)}{\partial r} = 0 \tag{2.4}$$

$$D_B\Big(\frac{\partial^2 C}{\partial r^2} + \frac{1}{r}\frac{\partial C}{\partial r}\Big) + \frac{D_T}{T_a}\Big(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r}\Big) - K_C(C - C_a) = 0 \tag{2.5}$$

The corresponding convective no-slip boundary conditions are

$$\begin{aligned} &u = 0, \quad -\kappa_{nf}\frac{\partial T}{\partial r} = h(T_a - T), \quad -D_m\frac{\partial C}{\partial r} = k_m(C_a - C), \quad \text{at } r = a \\ &u = b\Omega, \quad -\kappa_{nf}\frac{\partial T}{\partial r} = h(T - T_b), \quad -D_m\frac{\partial C}{\partial r} = k_m(C - C_b), \quad \text{at } r = b \end{aligned} \tag{2.6}$$

4. METHODOLOGY

The governing equations and the corresponding boundary conditions are initially transformed to ordinary differential equations using a suitable transformation. Then the transformed ODEs along with the boundary conditions are solved using successive quasilinearization method (SQLM) adapted from [5].

Additionally Nusselt number, Sherwood number and skin friction values are tabulated, entropy genration analysis is conducted and the results are discussed.

5. CONCLUSION

Investigating the flow of water based graphene oxide nanofluid in the geometry of concentric cylinders with the impacts of thermal radiation and chemical reaction parameter, we infer the following:

- Mass transfer can be increased by amplifying the values of chemical reaction paramater and concentration Biot number.
- Bejan number is calculated to be $Be > 0.5$ for $\eta > 0.625$, and hence the generated entropy is predominantly due to heat transfer in the vicinity of the outer cylinder.
- Enhancing the radiation parameter depletes the Nusselt number and increases skin friction and enhancing the chemical reaction parameter enhances the Sherwood number and skin friction.

REFERENCES

[1] Mack, L. R. and Hardee, H. C. (1968) Natural convection between concentric spheres at low Rayleigh numbers, International Journal of Heat and Mass Transfer, 11(3), 387-396. doi: 10.1016/0017-9310(68)90083-5.

[2] Renardy, Y. and Joseph, D. D. (1985), Couette flow of two fluids between concentric cylinders, Journal of Fluid Mechanics, 150, 381-394. doi: 10.1017/S0022112085000179.

[3] Pordanjani, A. H. and Aghakhani, S. (2022), Numerical Investigation of Natural Convection and Irreversibilities between Two Inclined Concentric Cylinders in Presence of Uniform Magnetic Field and Radiation, Heat Transfer Engineering, 43(11), 937-957. doi: 10.1080/01457632.2021.1919973.

[4] Buongiorno, J. (2006), Convective Transport in Nanofluids, Journal of Heat Transfer, 128(3), 240-250. doi: 10.1115/1.2150834.

[5] Srinivasacharya, D. and Hima Bindu, K. (2018), Entropy generation due to micropolar fluid flow between concentric cylinders with slip and convective boundary conditions, Ain Shams Engineering Journal, 9(2), 245–255. doi: 10.1016/j.asej.2015.10.016.