Radiative thermal transport due to nanofluid flow in an inclined channel

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1. ABSTRACT

This paper theoretically studies the entropy generation in radiative flow of graphene oxide (GO) in an inclined channel. Buongiorno nanofluid model is used including the impacts of Brownian diffusion and thermophoresis and chemical reaction effects. Spectral quasilinearization method with Chebyshev's polynomials is adapted to solve the differential equations under convective conditions. The effects of implanted parameters are graphed and interpreted.

Keywords: graphene nanofluids; entropy generation; Buongiorno model

2. INTRODUCTION

Nanofluids are preferred to other conventional viscous and microfluids for their effective heat transfer properties. Additionally, they keep the flow channels from obstruction, deposition and erosion. The performance of nanofluids vary according to the volume fraction, choice of the geometry, base fluids and hybridized nanoparticles and the needs in demand.[1-3] In case of Graphene oxide (GO) nanofluids, the obtained results from computational studies conclude that they aid in maximum heat transfer because of the excellent thermal conductivity. Some of the classical numerical studies on the fluid flow in inclined channels include the study of fully developed laminar flow in the channel of two parallel plates with an inclination angle. The opposing flow was studied under uniform flux conditions with real flow characteristics.[4]
This paper aims at bridging the gap of computationally studying the flow of GO nanoparticles dispersed in water in inclined channel including the effects of thermal radiation and chemical reaction. The flow is modelled and the equations are numerically solved to graph the results.

3. GOVERNING EQUATIONS OF THE PROBLEM

The flow geometry is made up of two parallel plates aligned with an angle of inclination α. Water with dispersed GO nanoparticles flows steadily in the channel. We consider the body forces due to gravity, Brownian motion and thermophoresis effects and the effects caused by thermal radiation and chemical reaction. Thus, the problem is modelled, taking into account the afore-mentioned effects and adapting the Buongiorno nanofluid model[6] as follows:

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

$$\rho_{nf} v_0 \frac{\partial u}{\partial y} + \frac{\partial p}{\partial x} = \mu_{nf} \frac{\partial^2 u}{\partial y^2} + \left((\rho\beta)_{nf} (T - T_a)(1 - C_b) - (\rho_{sp} - \rho_{bf})(C - C_a) \right) g \sin\alpha \tag{2.2}$$

$$\frac{\kappa_{nf}}{(\rho C_p)_{nf}} \left(\frac{\partial^2 T}{\partial y^2} \right) + \tau D_B \frac{\partial T}{\partial y} \frac{\partial C}{\partial y} + \tau \frac{DT}{T_a} \left(\frac{\partial T}{\partial y} \right)^2 + \frac{1}{\left(\rho_{cp} \right)_{nf}} \frac{\partial}{\partial y} \left(q_r \right) = 0 \tag{2.3}$$

$$D_B \frac{\partial^2 C}{\partial y^2} + \frac{D_T}{T_a} \frac{\partial^2 T}{\partial y^2} + K_C \left(C - C_a \right) = 0 \tag{2.4}$$

The corresponding convective no-slip boundary conditions are

$$\begin{aligned} &at\ y=-h, \quad u=0, \quad k_{nf}\frac{\partial T}{\partial y}=h_f\left(T-T_b\right), \quad D_m\frac{\partial C}{\partial y}=k_m\left(C-C_b\right) \\ &at\ y=h, \quad u=0, \quad k_{nf}\frac{\partial T}{\partial y}=h_f\left(T_a-T\right), \quad D_m\frac{\partial C}{\partial y}=k_m\left(C_a-C\right) \end{aligned} \tag{2.6}$$

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 Srinivasacharya and Hima Bindu.[7]

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 inclined channel, we infer the following:

- Velocity can be enhanced by increasing the values of angle of inclination (α), Biot number (Bi_t) and suction/injection parameter (R_{SC}).
- For $-1 < \eta < -0.36$ and $0.61 < \eta < 1, Be < 0.5$. Hence, heat transfer is the primary cause for entropy generation in the middle of the channel.
- Convective heat and mass transfer respectively enhances with radiation and chemical reaction.

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