A discontinuous Galerkin analysis of entropy generation due to free convection of hybrid-nanofluid in a partially heated tilted porous enclosure with wavy wall

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1. INTRODUCTION & OBJECTIVE

Porous cavities are extensively utilized in the construction of diverse heat transfer-related devices. This numerical investigation examines the phenomenon of entropy generation in a $Al_2O_3 - Cu$/Water hybrid nanofluid within a tilted porous cavity. The cavity is subjected to partial heating, while the opposite cold side exhibits a wavy pattern. The obtained results were acquired using a discontinuous Galerkin method. The present analysis is centered on investigating the effects of governing parameters, namely the Rayleigh-Darcy number ($10 \leq Ra \leq 10^3$), nanoparticle volume fraction ($0.1\% \leq \sigma \leq 2\%$), wall undulations (a, N), angle of inclination ($0 \leq \phi \leq \pi/2$) and length of the heat source ($0.25 \leq \epsilon \leq 1.0$). The acquired results are analyzed to determine the relevant parameters, and a novel assessment of irreversibility and Bejan number is conducted. The non-dimensional governing equations and boundary conditions for the investigation are obtained from Kumar [1] as:

$$\Delta\Psi = -S_1(\sigma) Ra \left(\frac{\partial\Theta}{\partial X}\cos\phi - \frac{\partial\Theta}{\partial Y}\sin\phi\right) \tag{1}$$

$$\Delta\Theta = S_2(\sigma)\left(\frac{\partial\Psi}{\partial Y}\frac{\partial\Theta}{\partial X} - \frac{\partial\Psi}{\partial X}\frac{\partial\Theta}{\partial Y}\right) \tag{2}$$

Here, S_1 and S_2 are special functions to balance thermophysical properties of hybrid-nanofluid. The thermophysical properties of hybrid nanofluid are obtained from Biswas et al. [2].

The boundary conditions are:

Bottom (Γ_0) and top wall (Γ_2): $\Psi = 0,\ \partial\Theta/\partial Y = 0$

Right wavy wall (Γ_1): $\Psi = 0, \Theta = 0$

Left wall (Γ_3): $\Psi = 0, \frac{\partial T}{\partial X} = \begin{cases} -k_f/k_{hnf}, & 0.5 - \frac{\epsilon}{2} \leq W \leq 0.5 - \frac{\epsilon}{2} \\ 0, & \text{Otherwise} \end{cases}$

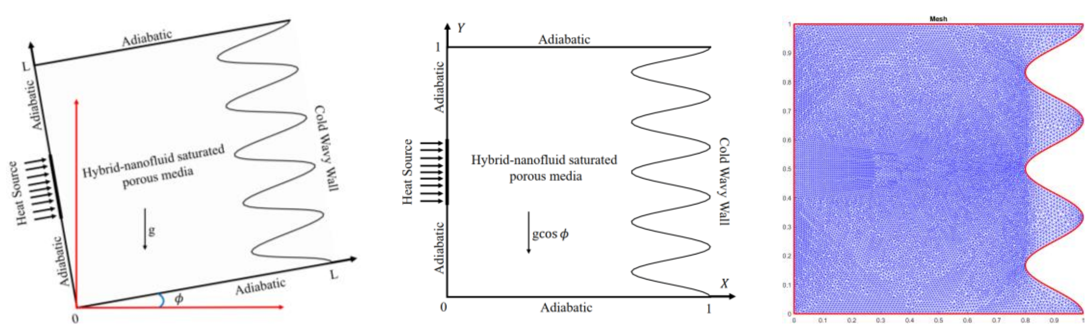

Fig 1: Domain of Computation (left), domain of computation after rotation and non-dimensionalization (middle), and triangular mesh distribution (right).

The governing equations with boundary conditions are solved by a discontinuous Galerkin method given following Rivière [3].

Also, the entropy generation (E_T) and Bejan number (Be) in a porous medium are calculated for the porous domain by using:

$$E_T = E_{convection} + E_{fluid\ flow} = \frac{k_{hnf}}{k_f}(\nabla\Theta)^2 + \chi\frac{\mu_{hnf}}{\mu_f}(\nabla\Psi)^2 \quad (3)$$

$$Be = \frac{E_{convection}}{E_T} \quad (4)$$

The in-house CFD code based on dG-FEM are validated and by comparisons and grid sensitivity.

2. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

The obtained results for a wide range of governing parameters are presented and analysed. Fig. 2, 3 represents contour plots of streamlines (Ψ), isotherms (Θ), total entropy generation (E_T).

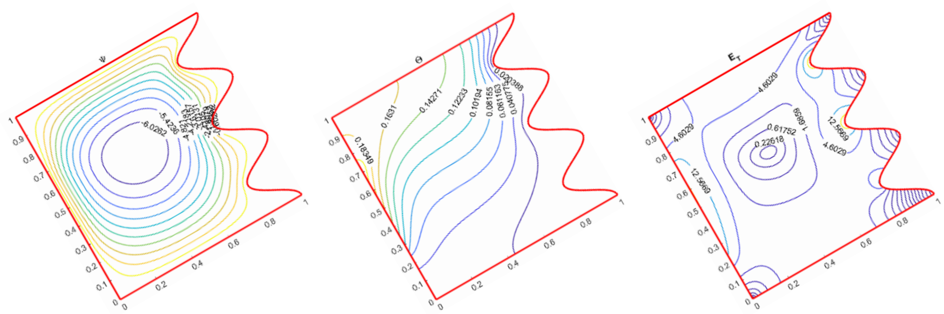

Fig 2: Contour plots of Ψ, Θ, and E_T at $Ra = 10^3, \phi = \pi/6, \sigma = 0.33\%, N = 3, a = 0.10, \epsilon = 0.5$.

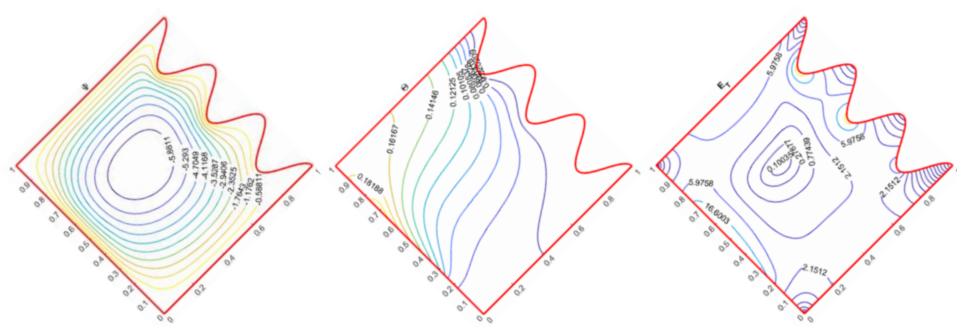

Fig 3: Contour plots of Ψ, Θ, and E_T at $Ra = 10^3, \phi = \pi/4, \sigma = 0.33\%, N = 3, a = 0.10, \epsilon = 0.5$.

Refrrecnces:

[1] B. V. R. Kumar, "A Study of Free Convection Induced by a Vertical Wavy Surface with Heat Flux in a Porous Enclosure," *Numerical Heat Transfer, Part A: Applications*, vol. 37, no. 5, pp. 493–510, Apr. 2000, doi: 10.1080/104077800274181.

[2] N. Biswas, D. K. Mandal, N. K. Manna, R. S. R. Gorla, and A. J. Chamkha, "Magnetohydrodynamic thermal characteristics of water-based hybrid nanofluid-filled non-Darcian porous wavy enclosure: effect of undulation," *HFF*, vol. 32, no. 5, pp. 1742–1777, Apr. 2022, doi: 10.1108/HFF-03-2021-0190.

[3] B. Rivière, *Discontinuous Galerkin Methods for Solving Elliptic and Parabolic Equations: Theory and Implementation*. Society for Industrial and Applied Mathematics, 2008. doi: 10.1137/1.9780898717440.