Conjugate natural convection in a square enclosure in the presence of Cattaneo flux

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1. INTRODUCTION & OBJECTIVE

A computational study of conjugate natural convection in a vertical square enclosure is considered. The bottom enclosure wall is covered with a conducting plate of finite thickness. The temperature of the bottom surface of the plate is maintained isothermally hot whereas the top enclosure wall is isothermally cold. The vertical walls of the set up are insulated. The gravitational force is acting downwards.The relative thickness and thermal conductivity of the bottom plate influence the resulting fluid flow and heat transfer characteristics.

The fluid flow within the enclosure is governed by the Navier-Stokes equation together with the hyperbolic energy equation. The hyperbolicity is incorporated in the energy equation through the Cattaneo-Christov heat flux model. This includes a parameter characterizing the thermal relaxation time. The objective of this study is to determine the influence of Rayleigh number (Ra) on the steady and oscillatory flow, for a fixed value of the Prandtl number (Pr=0.71).

A finite volume based numerical solution is obtained on a uniform staggered grid via the SIMPLE algorithm with the power law scheme. A 200 x 200 grid system is used throughout the computations.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

1) Initially, the thermal conductivity ratio (k_r) and thickness parameter (d) are fixed at 0.5 and 0.2 respectively. For small and moderate values of Ra, almost similar steady state results are obtained for both the Fourier and non-Fouriercases; that is, minimal changes are observed.
2) An increase in the value of Ra beyond $2\text{x}10^6$ leads to a bifurcation that manifests in the form of periodic oscillations. The time histories of the solution show a simple translation between the Fourier and non-Fourier cases. The corresponding isothermal and streamline behaviours during these sustained oscillations are obtained as a function of d.
3) We then determined the effect of k_r on the long-time behaviors in both the cases, by increasing it to k_r=10. It is found that the asymptotic steady state disappears and the solutions start oscillating at a lower value of Ra ($Ra = 5 \text{ x } 10^5$). This is accompanied by a significant change in their amplitudes.
4) A further increase in Ra started showing some complex flow and heat transfer patterns, depending on the value of k_r and d.

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