

Global stability map of the flow in a horizontal concentric cylinder forced by natural convection.

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There are a large number of studies in the literature on natural convection in the annulus between horizontal concentric cylinders. However, not many publications dealing with global stability analysis in this kind of flow have been published¹. For a fixed diameter ratio $L/D_i = (R_o - R_i)/2R_i$, being R_i and R_o the inner and outer cylinder radii respectively, and assuming Boussinesq approximation, the solution only depends on Prandtl ($Pr \equiv \nu/\alpha$) and Rayleigh ($Ra \equiv g \beta L^3(T_i - T_o)/(\nu \alpha)$) numbers. A spectral collocation code has been developed to solve the problem by means of Chebyshev and Fourier differentiation matrices² for $L/D_i = 0.8$ and it has been validated with classical experimental results³. Steady solutions have been sought within the range $Pr \in [10^{-2}, 1]$ and $Ra \in [10^2, 5 \cdot 10^6]$. As a result, a steady solution Pr - Ra map (consisting of 149×75 points) has been traced, where the different families of similar solutions found are detailed, mainly characterized by presenting single or multiple plumes. In addition, two main double-solution regions have been found.

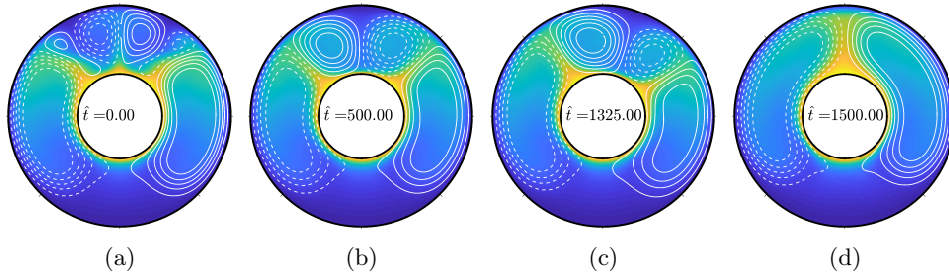


Figure 1: Transient evolution of unstable solution (dimensionless temperature and streamfunction) in a stable-unstable (SU) pair of steady solutions at $Pr = 0.2792$ and $Ra = 7.2 \cdot 10^4$.

A global stability analysis has been carried out and a region of stable steady solutions has been identified in the Pr - Ra map. Double solutions can be classified either as unstable-unstable (UU) or as stable-unstable (SU) solutions. Temporal evolution of the flow has been used in order to verify the instability. It has been found that in case of UU pair of solutions, both evolve towards the same final oscillatory state (vertical flickering plume). In contrast, if SU pairs are analyzed, unstable solution (see Figure 1a) evolves towards the stable one (see Figure 1d). It is worth mentioning that in most of the cases, the unstable solution passes through an intermediate unstable solution (see Figure 1b).

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