Natural Convection Inside a Laterally Heated Horizontal Cylinder

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ABSTRACT

The numerical study of convective flows of enclosed fluids has attracted much research activity in the past due to its relevance in many engineering applications such as crystal growth of semiconductors. During this process, natural convection may generate defects like striations. For a low Prandtl number fluid contained in a differentially heated horizontal cylindrical cavity, convection always exists, but above a critical temperature difference between the endwalls of the cavity, the flow changes from a stationary to an oscillatory behavior. This passage from one state to another could affect the quality of grown crystal due to the complex dynamics of flow.

In this work, a numerical study for analyzing the main features of the basic flow and the instability of natural convection in a cylindrical enclosure is performed by Direct Numerical Simulation of Navier-Stokes equations [1]. In the vertical mid-plane, we expect to find some agreement with 2D simulations of Mercader et al [2].

We have chosen an aspect ratio $\Gamma = 2$ (Γ= length/diameter) and Prandtl number $\sigma = 0.00715$ as in Mercader et al[2], such that the system maintains a basic single-roll flow configuration. In this basic configuration the fluid flows from the hot to the cold wall in the upper part of the cylinder, and flows back from the cold to the hot wall in the lower part. It is responsible for heat convection, leading to vertical temperature gradients within the central region.

The dependence of the critical values of the Rayleigh number and frequency for the primary instability with the aspect ratio is also studied. The nature of the instability is the same in the range of aspect ratios from 1.5 to 2.5: a supercritical Hopf bifurcation that breaks two reflection symmetries of the basic flow and maintains their product. The instability is characterized by a periodic movement of bubble-like perturbations traveling along the contour of the basic roll.

REFERENCES

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