Primary bifurcation of a thin-layer flow driven by a rotating disk in a fixed open cylindrical cavity: flat free surface

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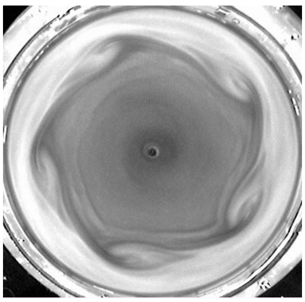
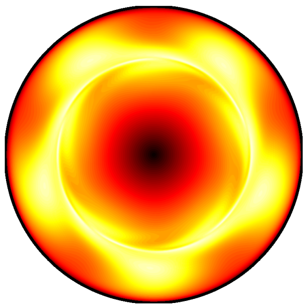
ABSTRACT

The flow driven by a rotating disk of a thin layer of fluid in a fixed cylindrical cavity is studied numerically and experimentally. Such flow is of interest from a geophysical and industrial point of view as it involves shear layer, centrifugal force and a free surface.

The characteristics of the axisymmetric base flow is briefly analyzed with the help of numerical simulation but the focus of this work is to predict and understand the first transition to instability. The primary bifurcation, always three dimensional, is investigated mostly by experimental visualizations and a linear stability analysis. We have first studied six aspect ratios such that the mean fluid layer height to its radial extension varies between $1/14$ to $1.5/14$. In this range, the critical Reynolds numbers and the azimuthal wave numbers predicted by the linear stability analysis match those found in the experiment. In some particular cases, direct numerical simulations using a pseudo-spectral method are also provided.

Figure: Flow structure for an aspect ratio $1/14$ at a Reynolds number slightly above threshold. An azimuthal mode 5 is dominant in the experiment (left) and reproduced by the linear stability analysis (right).





For an aspect ratio smaller than $1/14$, the linear stability results differ substantially from the experiment. The difference is attributed to the strong hypothesis of a fixed flat free surface in the numerical computation [1]. The upper bound of the aspect ratio range is given by the experimental set up [2]. Within these bounds, our analysis allowed us to understand the angular phase velocity of the three dimensional structures and to shed some light on the mechanism of the instability.

REFERENCES

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[2] Sébastien Poncet, Marie-Pierre Chauve *Shear-layer instability in a rotating system*, J. Flow Visualization & Image Processing **14 (1)**, 85-105, 2007.