Transient response at the onset of steady and time-dependent Taylor vortices

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ABSTRACT

The interpretation of hydrodynamic instabilities in terms of low-order bifurcation events has been a fruitful area for the application of modern mathematical ideas to pattern formation. Boundaries play an important role for the bifurcation structure of a pattern forming system. The effect of boundaries on the 'critical dynamics' at the onset of steady [1] and time-dependent [2] Taylor vortices is investigated.

Numerical calculations of Navier-Stokes equation with 'stress-free' boundary conditions show that Landau amplitude equation provides a good model of the transient dynamics at the onset of steady Taylor vortices. However, it is found that this rapidly breaks down when the 'no-slip' condition is approached. Measurments of the transient response at the onset of Taylor vortices are performed and compared with numerical calculations. The apparatus used had a radius ratio of $\eta = 0.5$ and a continously adjustable system length h. Though in case of physical boundaries the pitchfork bifucation to Taylor vortices is destroyed an apparent critial behaviour is observed in these experiments. However, it shows a surprising dependence on the system length.

Landau amplitude equation is also known to provide a good model for the onset of rotating waves in steady Taylor vortex flow assuming an infinite axial extend of the flow. For systems with $\eta = 0.5$ the classical wavy mode and the so-called small-jet mode are the dominant time-dependent modes. The small-jet mode is an axially subharmonic mode, sometimes labeled 'wavy outflow boundary'. Measurments reveal a departure from Landau dynamics at the onset of small-jet mode in finite systems. While for the onset of wavy mode a good agreement with Landau dynamics is found a low-frequency response could be observed in the amplitude relaxation process of small-jet mode. 'Critical-slowing-down' and 'square-root behaviour' still occur. The role of underlying Taylor vortices and mirror symmetry-breaking for the relaxation process is discussed.

REFERENCES

[1] J. Abshagen, O. Meincke, G. Pfister, K.A. Cliffe, and T. Mullin: *Transient dynamics at the onset of Taylor vortices*, J. Fluid Mech. (2003), vol. 476, pp. 335-343.

[2] J. Abshagen, M. Wrage, and G. Pfister: *Low-frequency response at the onset of wavy Taylor vortices*, in preperation.