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Three-Dimensional Effects in Visualization Experiments of Vortex Breakdown

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A vortex breakdown is a secondary flow structure associated with a main vortex. Vortex breakdown may affect the stability of the flow as well as the mixing properties. Several types of vortex breakdown have been observed, including the bubble (or B-) type, where a counter-rotating recirculation zone appears on the main vortex. A convenient set-up to study flows with this topology is a fluid-filled cylinder where the main vortex is created by rotating one of the end-covers. Depending on the aspect ratio of the cylinder and the Reynolds number, one or more vortex breakdown bubbles may appear in the steady regime. Numerical simulations assuming the axisymmetry imposed by the geometry of the experiment reproduce the overall flow structure very well, but high-resolution visualization experiments reveal details in the flow which are incompatible with the assumption of axisymmetry.

In this talk I will discuss different ways to resolve the apparent paradox that the steady flow can in fact be axisymmetric but still appear not to be so in a visualization experiment. A key observation is the axisymmetric flow structure of B-type vortex breakdown is structurally unstable, and hence very sensitive to perturbations in the experiment. I will show that imperfections in the equipment well below realistic experimental accuracy are sufficient to explain the observed asymmetric distribution of tracer particles or dye. Furthermore, the combination of misalignment of dye injection and diffusion of the dye will give rise to quite complex patterns in the flow which do not reflect the underlying flow structure, but only depends on the visualization technique.

The talk will be based on joint work with W.Z. Shen, J. N. Sorensen, W. J. Zhu (Technical University of Denmark) and M. C. Thompson, K. Hourigan (Monash University, Australia).

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