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M. Vanierschot

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M. Vanierschot[a]

[a]KU Leuven, campus Group T, Andreas Vesaliusstraat 13, B-3000 Leuven, Belgium.
Email: Maarten.Vanierschot@kuleuven.be

Abstract

This paper reports on novel features found in the dynamics of the transition to vortex breakdown in inviscid axisymmetric flows with swirl. These features are revealed by a transient simulation of an open ended pipe flow where the inlet swirl is suddenly increased from a swirl number just below the onset of vortex breakdown to a swirl number just above the onset of vortex breakdown. To eliminate the numerous parameters influencing breakdown, the axisymmetric Euler equations with swirl are used as a fluid flow model and solutions are obtained by means of numerical simulation. It is shown that as the step response has died out, the flow evolves to a quasi-static state where time derivatives of variables are negligible small. Stability analysis of this state shows that it can support standing waves in a small region of the flow domain. These standing waves are observed in the simulations as an imbalance in the axial momentum equation which slows down the flow near the central axis. The amplitude of this imbalance grows exponentially in time with a dimensionless growth rate of 0.83 scaled with the flowthrough time. Eventually, the axial velocity along the central axis becomes negative in a small part of the flow, leading to an axisymmetric recirculation zone,

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