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Three-Dimensional Vortex Breakdown in Swirling Jets and Wakes

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Vortex breakdown of nominally axisymmetric, swirling incompressible flows with jet- and wake-like axial velocity distributions issuing into a semi-infinite domain is studied by means of direct numerical simulations for a two-parametric initial velocity profile. Highly swirling flows at large Reynolds numbers exhibit bubble, helical or double helical breakdown modes. It is shown that a transition from super- to subcritical flow, as defined by Benjamin (1962), accurately predicts the parameter combination yielding breakdown, if applied locally to flows with supercritical inflow profiles. The basic form of breakdown is found to be axisymmetric, and a transition to helical breakdown modes is shown to be caused by a sufficiently large pocket of absolute instability in the wake of the bubble, giving rise to a self-excited global mode. Two distinct eigenfunctions corresponding to an azimuthal wavenumber m=-1 and m=-2 have been found to yield a helical or double helical breakdown mode, respectively.

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