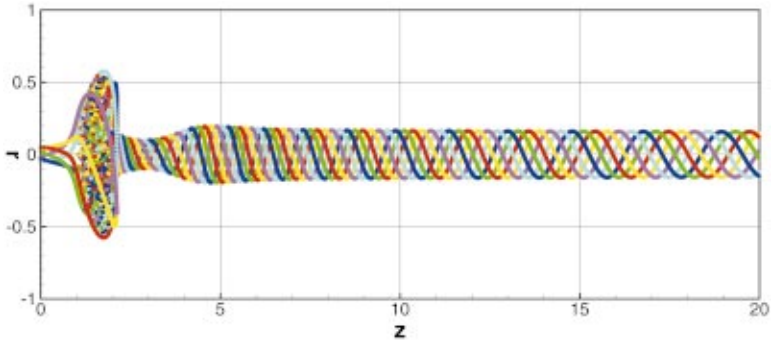

FIG. 1. Swirl parameter $S=1.1$, quasisteady state.

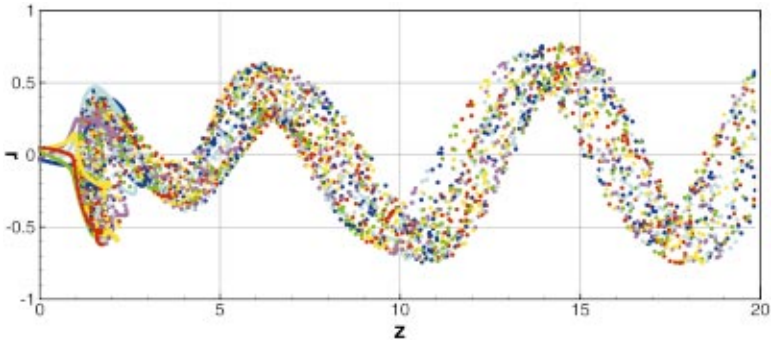

FIG. 2. $S=1.1$, single helical breakdown structure.

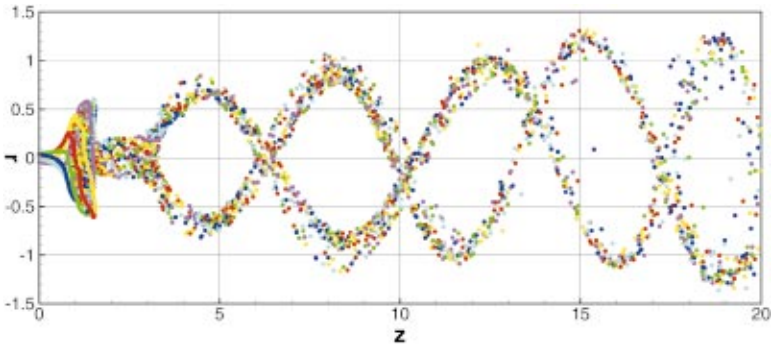

FIG. 3. $S=1.3$, double helical breakdown structure.

Breakdown Modes of Swirling Jets with Coflow

Submitted by
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We present numerical simulations[1] of vortex breakdown modes of spatially growing, swirling jets with coflow in infinite domains at Reynolds number $\mathrm{Re}=200$ based on the vortex core radius. A fixed inflow velocity profile[2] with uniform axial flow and an azimuthal velocity component represented by the swirl parameter S is prescribed at the left boundary. Here S represents the ratio of the azimuthal velocity at the core edge to the axial velocity at infinity. Particles are released at the inflow plane close to the axis to display streaklines of different color.

For small values of S (not shown), a stable, axisymmetric flow evolves that is characterized by a closed recirculation bubble. At larger values of S, an axisymmetric quasisteady state develops that displays a pronounced swelling in the wake of the bubble (Fig. 1). Here an azimuthal instability develops, which ultimately yields a helical breakdown (Fig. 2). Increasing the swirl number to $S=1.3$ replaces the single helix with a double helical breakdown mode (Fig. 3).

[1]M. R. Ruith, P. Chen, and E. Meiburg, Comput. Fluids (submitted).
[2]W. Grabowski and S. Berger, J. Fluid Mech. **75**, 525 (1976).