Taylor Couette Flow with Imposed Radial and Axial Flows- A Weakly Nonlinear Analysis

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The linear stability analysis of Taylor-Couette flows where axial and radial through-flows are superimposed is extended to consider the weakly nonlinear behavior of convective-type instabilities using a fifth-order amplitude equation and numerical simulations. Special attention is paid to the influence of the radius ratio η, particularly as the gap increases to become very wide (η increases from top to bottom in Figure 1), which magnifies the impact of the radial Reynolds number α. The instabilities take the form of pairs of counter-rotating

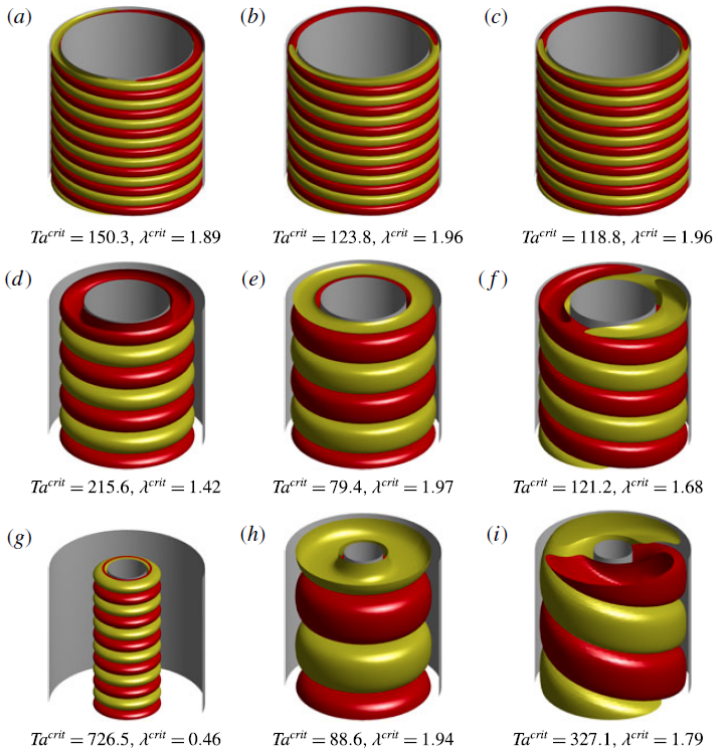

Figure 1: Modes of instabilities for $\beta = 20$ and (a) $\eta = 0.85$ and α = -10, (b) $\eta = 0.85$ and $\alpha = 0$, (c) $\eta = 0.85$ and $\alpha = 10$, (d) $\eta = 0.55$ and α = -10, (e) $\eta = 0.55$ and $\alpha = 0$, (f) $\eta = 0.55$ and $\alpha = 10$, (g) $\eta = 0.25$ and α = -10, (h) $\eta = 0.25$ and $\alpha = 0$, (i) $\eta = 0.25$ and $\alpha = 10$. Isosurfaces of the radial velcoity of the instability are shown at 0.2 (red) and -0.2 (yellow) of the maximum value. The critical Taylor number and wavelength are indicated. Reprinted with permission [1].

toroidal vortices superseded by helical ones as the axial Reynolds number β is increased. Increasing the radial inflow (negative α) draws the vortices toward the inner cylinder, where they shrink relative to the annular gap when the gap is wide (Figure 1(d, g, h)). Strong axial and radial flows lead to steeply sloped helical vortices. Strong radial outflow (positive α) in a wide annular gap results in very large helical vortices (Figure 1(i)). In addition, radial inflows or outflows can change the supercritical bifurcation from laminar to vortical flow to become a subcritical bifurcation. The radial flow above which this change occurs decreases as the radius ratio decreases.

References

[1] D. Martinand, E. Serre, R. M. Lueptow, *Linear and weakly nonlinear analyses of cylindrical Couette flow with axial and radial flows*, J. Fluid Mech. **824**, 438-476, 2017.

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