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Rich 3-Tori Dynamics in Small-Aspect-Ratio Highly Counter-Rotating Taylor-Couette Flow with Reversal of Spiraling Vortices

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Abstract : We present numerical simulations concerning the reversal of spiraling vortices in short highly counter-rotating cylinders. Increasing the differential cylinder rotation results in global flow-inversion is which develops various different and complex flow dynamics of several quasi-periodic solutions that differ in their number of vortex cells in the bulk. The dynamics change from being dominated of the inner cylinder boundary layer with ’passive’ only responding outer one to be dominated by the outer cylinder boundary layer with only responding inner one. Solutions exist on either two or three tori invariant manifolds whereby they appear as symmetric or asymmetric states. We find for either moderate and high inner cylinder rotation speed the quasiperiodic flow to consist of only two vortex cells but differ as the vortices has opposite spiraling direction. These both flows live on 2-tori but differ in number of symmetries. While for the quasi-periodic flow (q^a_2) at lower rotation speed a pair of symmetrically related 2-tori T2 exists the quasi-periodic flow (q^s_2) at higher rotation speeds is symmetric living on a single 2-torus T2. In addition these both flows differ due to their dominant azimuthal m modes. The first is dominated by m=1 whereas for the latter m=3 contribution is largest. The 2-tori states are separated by a further quasi-periodic flow (q^a_3) living on pair of symmetrically related 3-tori T3. This flow offers a ’periodical’ competition between a two and three vortex cell states in the bulk. This flow is also an m=1 solution as for the quasiperiodic flows living on the pair of symmetrically-related 2-tori states. Moreover we find hysteresis resulting in coexisting regions of different quasiperiodic flows q^s_2 and q^a_3 with increasing and decreasing the differential rotation.

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