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Quenching of vortex breakdown oscillations via Harmonic forcing

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Abstract

Vortex breakdown is a phenomenon inherent to many practical problems, such as leading-edge vortices on aircrafts, atmospheric tornadoes, and flame-holders in combustion devices. The breakdown of these vortices is associated with the stagnation of the axial velocity on the vortex axis and the development of a near-axis recirculation zone. For large enough Reynolds number, the breakdown can be time-dependent. The unsteadiness can have serious consequences in some applications, such as tail-buffeting in aircrafts flying at high angles of attack. There has been much interest in controlling the vortex breakdown phenomenon, but most efforts have focused on either shifting the threshold for the onset of steady breakdown or on altering the spatial location of the recirculation zone. There has been much less attention paid to the problem of controlling unsteady vortex breakdown. In this talk, recent results from a combined experimental and numerical investigation of vortex breakdown in an enclosed cylinder will be present in which low amplitude modulations of the rotating endwall that sets up the vortex are used as an open-loop control. As expected, for very low amplitudes of the modulation, variations of the modulation frequency reveals typical resonance tongues and frequency lockings, so that the open-loop control allows us to drive the unsteady vortex breakdown to a prescribed periodicity within the resonance regions. For modulation amplitudes above a critical level that depends on the modulation frequency (but still very low), the result is a periodic state synchronous with the forcing frequency over an extensive range of forcing frequencies. But what is particularly of interest is the spatial form of this forced periodic state: for modulation frequencies less than about twice the natural frequency of the unsteady breakdown, the oscillations of the near-axis recirculation zone are amplified, whereas for modulation frequencies larger than about twice the natural frequency the oscillations of the recirculation zone are quenched, and the near-axis flow is driven to the steady axisymmetric state.