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Competing stability modes in vortex structure formation
STEPHEN GARRETT, J. PAUL GOSTELOW, ALDO RONA, W. ANDREW MCMULLAN, Department of Engineering, University of Leicester, UK — Nose cones and turbine blades have rotating components and represent very practical geometries for which the behavior of vortex structures is not completely understood. These two different physical cases demonstrate a common theme of competition between mode and vortex types. The literature concerning boundary-layer transition over rotating cones presents clear evidence of an alternative instability mode leading to counter-rotating vortex pairs, consistent with a centrifugal instability. This is in contrast to co-rotating vortices present over rotating disks that arise from crossflow effects. It is demonstrated analytically that this mode competes with the crossflow mode and is dominant only over slender cones. Predictions are aligned with experimental measurements over slender cones. Concurrent experimental work on the flow over swept cylinders shows that organized fine-scale streamwise vorticity occurs more frequently on convex surfaces than is appreciated. The conventional view of purely two-dimensional laminar boundary layers following blunt leading edges is not realistic and such boundary layers need to be treated three-dimensionally, particularly when sweep is present. The vortical structures are counter-rotating for normal cylinders and co-rotating under high sweep conditions. Crossflow instabilities may have a major role to play in the transition process but the streamline curvature mode is still present, and seemingly unchanged, when the boundary layer becomes turbulent.

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