Transition to turbulence in the rotating disk boundary layer of a rotor-stator cavity

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The transition to turbulence in the rotating disk boundary layer is investigated in a closed cylindrical rotor-stator cavity via direct numerical simulation using spectral vanishing vistocity method (DNS-SVV) and linear stability analysis (LSA). As shown in the Figure 1,

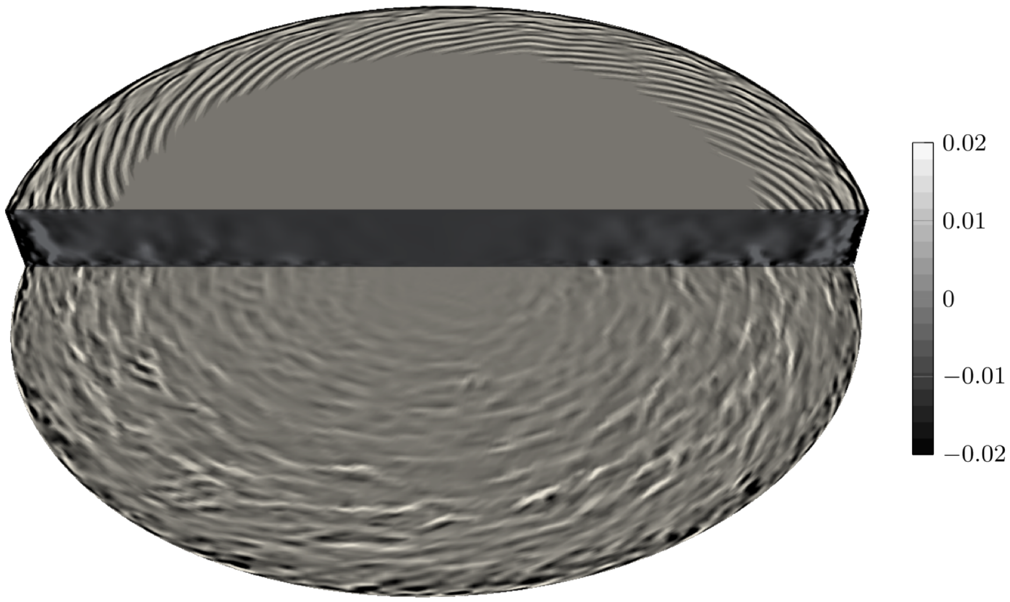

Figure 1: Instantaneous flow pattern in the whole cavity for $Re = 4 \times 10^5$. The stator is below. Iso-surfaces and iso-contours of the instantaneous axial velocity w. Three dimensional view. The rotor and stator boundary layers are shown for $z = \pm 0.97H$, respectively.

the stator boundary layer (lower part) is already turbulent while the rotor boundary layer (upper part) remains stable until very high Reynolds number $Re = U/\nu R$ then shows an organised behaviour followed by incipient turbulence. We focus on the global stability and the transition to turbulence of the rotor boundary layer. The mean flow in the rotor boundary layer is qualitatively similar to the von Kármán self-similarity solution [1]. The mean velocity profiles, however, slightly depart from theory which is developed on the infinite disk assumption [2] as the rotor edge is approached. Such meanflow modification near the edge seems to affect the stability behaviour of the system [3, 4]. Shear and centrifugal effects lead to a locally more unstable mean flow than the self-similarity solution, which acts as a strong source of perturbations. Fluctuations start rising there, as the Reynolds number is increased, eventually leading to an edge-driven global mode, characterized by spiral arms rotating counter-clockwise with respect to the rotor (see Figure 1). At larger Reynolds numbers, fluctuations form a steep front, no longer driven by the edge, and followed downstream by a saturated spiral wave, eventually leading to incipient turbulence. Numerical results show that this front results from the superposition of several *elephant* front-forming global modes, corresponding to unstable azimuthal wavenumbers m, in the range $m \in [32,\ 78]$. The spatial growth along the radial direction of the energy of these fluctuations is quantitatively similar to that observed experimentally on the infinite single disk [5]. This superposition of *elephant*-modes could thus provide an explanation for the discrepancy observed in the single disk configuration, between the corresponding spatial growth rates values measured by experiments on the one hand, and predicted by LSA and DNS performed in an azimuthal sector [6], on the other hand.

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