Flow instabilities for an edgewise flow over hollow cylindrical cavities

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Shrouded rotors are a promising solution for rotorcraft and VTOL vehicles to improve thrust and noise performance. The dynamical nature of the shrouded rotor flow requires investigation into instability mechanisms generated to minimize structural damage and optimize for aerodynamic performance. The edgewise rotor inflow condition provides thrust improvement compared to the rotor in a hover but generates unsteady loads due to the inflow direction. In particular, regimes that contain spontaneous flow instabilities should be avoided, as they generate fluctuating pressure drag loads, shear layer excited acoustic modes, and unsteady rotor inflow, all of which may negatively impact rotor thrust production and acoustic trace. The objective of this study is to parametrically investigate hollow cylindrical cavities of diameter d and height h, in the geometric range of $0.1 \leq h/d \leq 0.6$. These h/d ratios are representative of those found in air vehicle applications. Of particular interest is to determine if a self-sustained oscillation (SSO), which has been observed in closed cavity flows, is present in open cavities. The SSO is a hydrodynamically and acoustically coupled flow instability mechanism that produces resonance and large-scale recirculating structures. A series of plates with h/d ratios of 0.1, 0.2, 0.3, 0.4, 0.5, and 0.6, with fixed thickness and elliptical leading and trailing edges, are tested in a wind tunnel. Hot-wire anemometry with an X-wire probe is conducted near the cavity opening on both sides to obtain time-series velocity data and mean-flow fluid entrainment profile of the streamwise plane. Power spectral density (PSD) analysis is performed on the time series data to obtain characteristic flow oscillation frequencies for different cavity geometry ratios. We shall show that for $0.1 \leq h/d \leq 0.5$, a clear vortex shedding phenomenon is observed at a reduced frequency of $St = 0.2$. Moreover, the turbulent kinetic energy across the inlet of the cavity increased as h/d increased. Further insights into the dynamical modes will be presented during the talk.

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