Model-based stabilization of self-excited fluid-structure interaction systems in uniform laminar flow

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The flow around a slender body at high incidence has fascinated researchers for over five decades and has since been studied extensively. Even though the body geometry is simple, the flow around it is intricate and even early wind tunnel experiments have indicated that measurements were not repeatable. This can be partly answered by the explanation that the body is not symmetric and at high angles-of-attack the formation of vortex asymmetry is enough to generate a steady side force and corresponding yawing moment. Experimentalists thus encountered the problem of flow instability at high angles-of-attack culminating in self-excited oscillations. In this research, we investigate the stabilization of an elastically restrained slender body undergoing self-excited oscillations in uniform compressible laminar flow. We formulate a fluid-structure interaction problem where a pointed rigid cylindrical body incorporates an internal controllable inertia wheel. The structural model is augmented with a nonlinear wake oscillator representing the formation of asymmetric vortices along the body. An asymptotic multiple-scale analysis of a reduced-order configuration enables estimation of the rotating inertia wheel feedback control gains which are then implemented in a second-order accurate finite difference computational fluid dynamics framework. The latter confirm the reduction of both periodic and nonstationary limit-cycle oscillations for medium and high angles-of-attack respectively.