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A Theoretical and Numerical Study of Flexible Flapping Dynamics in a Uniform Flow RAJEEV JAIMAN, PARDHA GURUGUBELLI, JIE LIU, National University of Singapore — This work presents a numerical and theoretical study of fluid-elastic instability exhibited by a linear elastic plate immersed in a mean flow. Using the Euler-Bernoulli model for the plate and a 2D viscous potential flow model, a generalized closed-form expression of added-mass force has been derived for a flexible plate oscillating in fluid. We present an analytical formulation for predicting critical velocity for the onset of flapping instability. In the second part, a high-order finite element one-field scheme is employed for simulating flapping motion of a thin flexible body in a uniform flow with strong added-mass effects. Through our direct fluid-structure simulations, we study flapping results for a wide range of mass ratios and varying Reynolds numbers while maintaining relatively low bending rigidity. As a function of mass ratio, the flapping dynamics reveals three distinct regimes: fixed-point stability, limit-cycle flapping, and chaotic flapping. The changes associated with regime transition with increasing mass ratio are analyzed by vortex wake patterns, tip displacements, and force coefficients. Dependencies of stability predicated by the theoretical analysis are confirmed by the nonlinear fluid-structure simulations.

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