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NEW THEORETICAL AND NUMERICAL DEVELOPMENTS FOR ADDED-MASS EFFECTS AND FLAPPING DYNAMICS

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ABSTRACT

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 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 developed for simulating flapping motion of a thin flexible body in a uniform flow with strong added-mass effects. In the first part, we study flapping results of a single cantilevered plate for a wide range of mass ratios and varying Reynolds numbers while maintaining relatively low bending rigidity through our direct nonlinear fluid-structure simulations. 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. As a further extension, two parallel cantilevered plates will be investigated as a function of spacing between the parallel plates to assess the flapping motion, vortex dynamics, and the load/energy transfer. The flow-induced vibrations of this kind of coupled system have a potential to extract energy from the surrounding fluid flow for generation of electric power.

References

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