Abstract Submitted
for the DFD11 Meeting of
The American Physical Society

Hydrodynamic Wake Resonance as an Underlying Principle of Efficient Unsteady Propulsion[1] KEITH MOORED, Princeton University, HOSSEIN HAJ-HARIRI, University of Virginia, PETER DEWEY, BIRGITT BOSCHITSCH, ALEXANDER SMITS, Princeton University — In this study, three dimensional wake structures are generated by an actively flexible robotic elliptical fin. Particle image velocimetry is used to characterize and quantify the wake and to extract time averaged velocity profiles. A linear spatial stability analysis is performed on the velocity profiles to find the frequency of maximum spatial growth, i.e. the resonant frequency of the time averaged jet. It is found that (1) optima in propulsive efficiency occur when the driving frequency of a flapping fin matches the resonant frequency of the jet profile, (2) there can be multiple wake resonant frequencies and modes corresponding to observed multiple peaks in efficiency, (3) observed wake structures are largely linear phenomena and (4) wake patterns are strongly influenced by the nearest resonant mode. Multiple peaks in efficiency and transitions in the wake structure can be explained by this theoretical framework. Surprisingly, the analysis, although one-dimensional, captures the performance exhibited by a three-dimensional propulsor, showing the robustness and broad applicability of the technique.

[1]Supported by ONR MURI

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Date submitted: 05 Aug 2011 Electronic form version 1.4