

SAFL SEMINAR SERIES

WEDNESDAY, SEPT. 16, 2009, 3:30PM

ST. ANTHONY FALLS LABORATORY ~ AUDITORIUM

Biologically inspired impulsive starting and maneuvering for solitary and aggregate systems

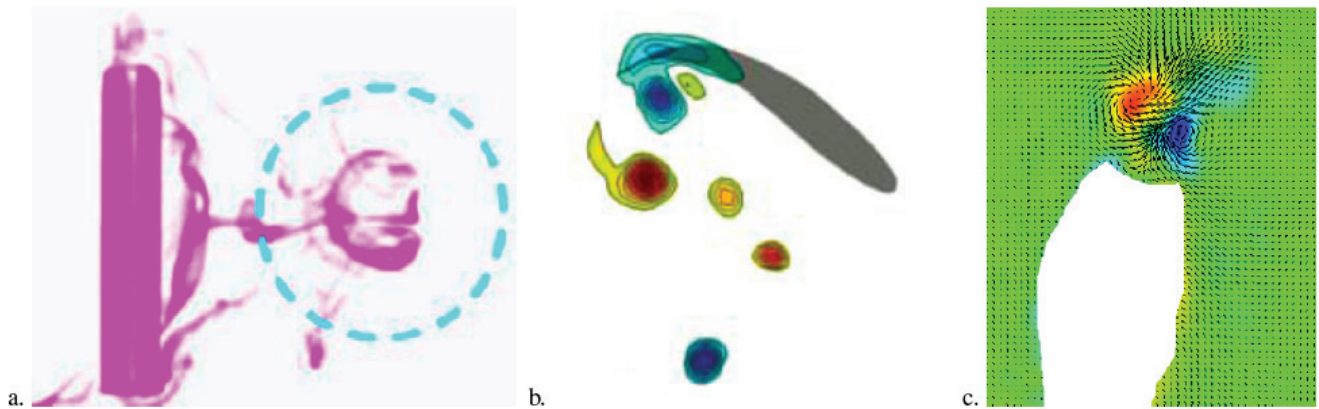


Figure 1: (a) Dye image of a vortex ring for an impulsively flapping foil; (b) PIV images of the vortex ring formation by a maneuvering fish; (c) PIV of the vortex ring formed by a solitary swimming Salp.

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Fast starting and maneuvering in the aquatic realm typically involve the formation of distinct vortex rings that deliver an impulsive change in the animal's momentum. This enables these aquatic animals to maneuver in smaller spaces than that required by conventional underwater vehicles. Past research has shown that the impulsively started propeller generates a toroidal vortex ring in the first full rotation of the propeller. Unsteady flapping by both plates and foils can also generate similar impulsive forces through short burst cycles, such as a single flap cycle with a fixed amplitude (figure 1a). Fast starting, jumping and maneuvering fish also generate vortex rings (figure 1b). Through the coordinated generation of impulsive forces through vortex ring formation, both solitary and aggregate systems can improve maneuvering performance. Understanding how fish and aquatic animals maneuver can help engineers improve the maneuvering performance of underwater vehicles which often operate in chaotic environments such as the surf zone.

Modeling the wake of a maneuvering fish as a simple vortex ring, with considerations taken for added mass effects, allows for straightforward analysis. Thus, by inspecting the wake generated by a rapidly maneuvering fish one can calculate the impulse imparted on the body during the maneuver. The swimming and maneuvering of aggregate swimmers, e.g. those chained together in series or parallel, can be modeled using a series of distinct vortex rings generated by each individual in the chain, with some phase shift between each individual. Particle imaging velocimetry can be used to gain insight into the mechanisms for vortex ring formation as used in fast-starting escape responses and classical maneuvers in biological animals. Both laboratory and in situ tests using both PIV and dye visualization clearly reveal the vortex ring formation and overall impulse strength over the time of the maneuver.