PECTORAL FIN FUNCTION IN FISHES: HYDRODYNAMICS AND CONSTRUCTION OF A ROBOTIC FIN THRUSTER

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Fishes are noted for their ability to maneuver and position themselves accurately even in turbulent flows [1]. This ability is the result of the coordinated movement of fins which form flexible control surfaces that allow thrust vectoring [2]. We have embarked on a research program designed to understand the dynamics of pectoral fin function in sunfish (*Lepomis macrochirus*) and to construct a biomimetic robotic pectoral fin thruster. We first quantified the motion of sunfish fins during both propulsion and maneuvering in three dimensions using multiple high-speed cameras. We then used digital particle image velocimetry (DPIV) on the fins of freely swimming fishes and computational fluid dynamics (CFD) to calculate flows based on measured 3D kinematic data. DPIV experiments used a stereo configuration, transverse plane orientation, and high sample rate (500 fps) to capture streamwise vorticity and to reconstruct time-dependent fluid momentum changes in three dimensions.

Kinematic analysis shows that during steady propulsion the sunfish fin is deformed considerably in both chordwise and spanwise directions, and also exhibits a spanwise wave that travels from the base toward the tip of the fin. Fin kinematics during maneuvering differ greatly from propulsive fin beats. Both DPIV and CFD data demonstrate that the fin can generate thrust throughout the fin beat.

Two simultaneous attached leading edge vortices are present as the fin cups laterally during the outstroke. A proper orthogonal decomposition (POD) of fin kinematics allowed identification of three primary modes of fin motion which were used individually and in combination to calculate fin flows and study the relationship between kinematic and hydrodynamic performance. Thrust is generated by a combination of an accelerating spanwise wave, cupping of the fin surface during the outstroke, and area increase during fin movement back toward the body. A first generation robotic model of the sunfish pectoral fin has been developed that can reproduce the complex pectoral fin motion.

References

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