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Fluid-Dynamics of Underwater Flight in Sea Butterflies: Analysis using Tomographic PIV D. ADHIKARI, Georgia Tech, D.W. MURPHY, Johns Hopkins University, D.R. WEBSTER, J. YEN, Georgia Tech — Sea butterflies, *Limacina helicina*, swim in sea water with a pair of gelatinous "wings" (or parapodia). Their unique propulsion mechanism has been hypothesized to consist of a combination of drag-based propulsion (rowing) and lift-based propulsion (flapping). Drag-based propulsion utilizes maximum drag on the wings during power stroke, followed by minimum drag during recovery stroke. Lift-based propulsion, in contrast, utilizes a pressure difference between the top and bottom of the wings. We present the 3D kinematics of a free-swimming sea butterfly and its induced volumetric velocity field using tomographic PIV. Both upstroke and downstroke motions propel the animal (1 – 3 mm) upward in a sawtooth-like trajectory with average speed of 5 – 15 mm/s ($Re = 5 - 45$) and roll the calcareous shell forwards-and-backwards at 4 – 5 Hz. The rolling motion effectively positions the wings such that they stroke downward during both the power and recovery strokes, hence inducing upward motion during both phases. A clap-and-fling mechanism is observed at the beginning of the flapping cycle. As the wings come into contact, the velocity of the organism is 2 mm/s. During fling motion, high (unsteady) lift causes the organism velocity to reach 35 mm/s. Separation vortices are observed during the fling motion, and vortices with an opposite sense of rotation form closer to the base of the wing due to the upward translation of the organism. The separation vortices shed into the wake, as the organism translates upward, in the form of separate vortex pairs.

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