James Buchholz

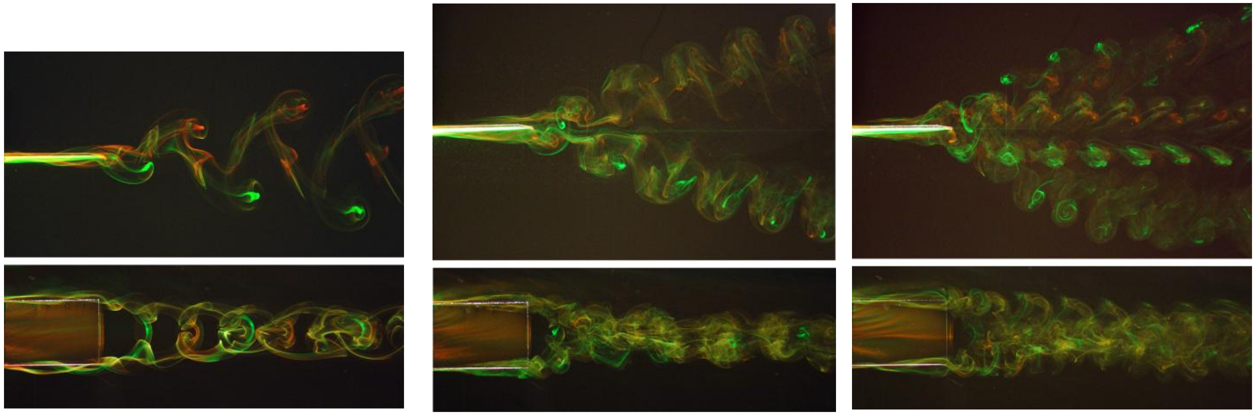
Mechanical Engineering

james-h-buchholz@uiowa.edu

AFOSR YIP 2011

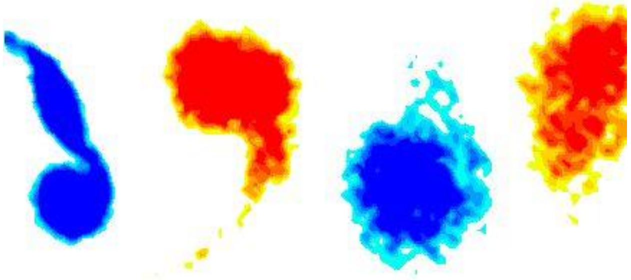
The University of Iowa

Flow Structure and Aerodynamic Performance Of Unsteady Biomimetic Propulsors



Birds, insects, and aquatic animals articulate their appendages in unsteady motions to produce forces for propulsion and maneuvering. This results in highly complex, unsteady, three-dimensional flow fields such as those shown in the images above. Despite significant changes in the appearance of these vortex wakes with variation of the forcing parameters, the vortex topology appears to be robust, and consistent with the wake patterns observed in other, highly disparate unsteady flows such as co-flowing jets and the wakes of oscillating spheres.

The robustness of the qualitative structure suggests that there may also exist robust scaling laws governing the strength of the vortices shed by these oscillating bodies. These parameters can be used to quantify existing wake models, enhance the prediction of aerodynamic forces on flapping appendages., and better inform aerodynamic control models for locomotion in multi-vehicle shoals and other turbulent environments.



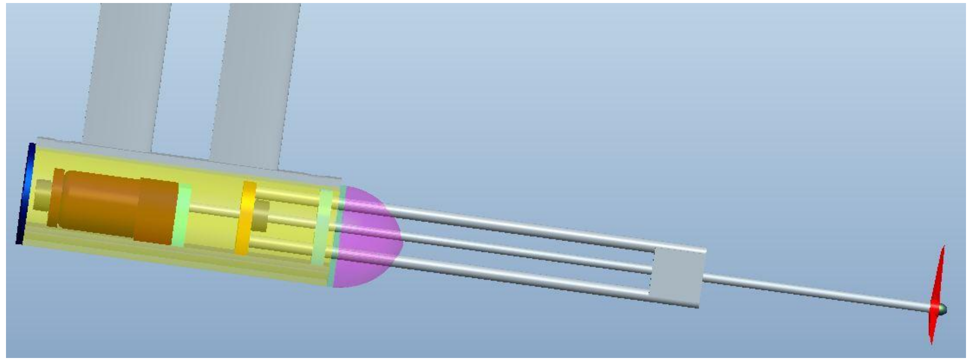
James Buchholz

Mechanical Engineering

james-h-buchholz@uiowa.edu

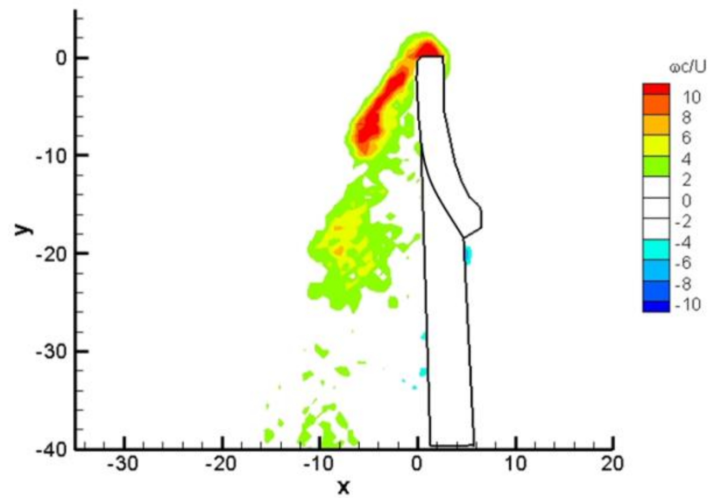
The University of Iowa

The Effects of Wing/Blade Rotation on Flow Structure and Stall

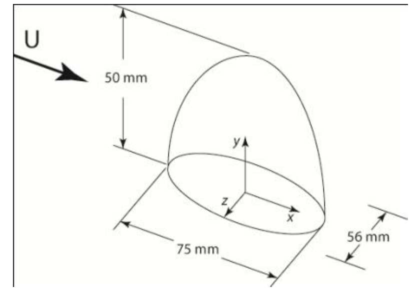


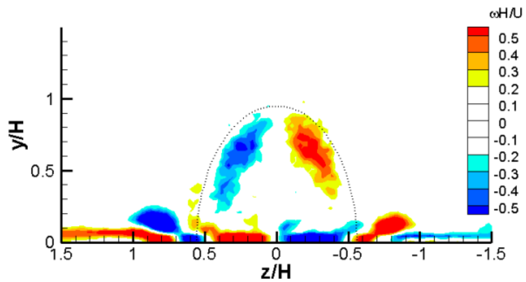
Wing and blade rotation is a key feature of the kinematics of many engineered and biological aerodynamic structures such as wind turbine blades, and bird and insect wings. Analysis of rotating wings and blades often rely on experimental measurements on non-rotating airfoils. In many circumstances, the relation between the rotating and non-rotating cases is not well-understood; however, some (but not all) studies have indicated that rotation yields a significant delay in stall near the hub.

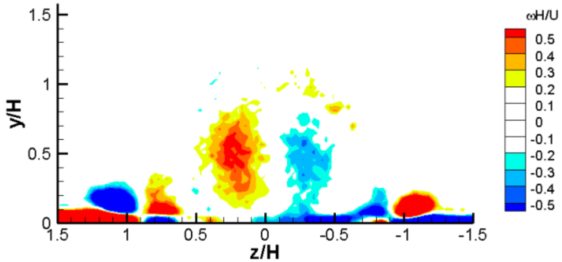
We are interested in understanding the role of rotation on flow structure and aerodynamic performance of rotating wings and blades. In particular, we are conducting fundamental experiments involving rotating blades in a) an otherwise quiescent fluid, b) an axial co-flow, and c) an axial co-flow with yaw misalignment such as to produce a condition of dynamic stall.

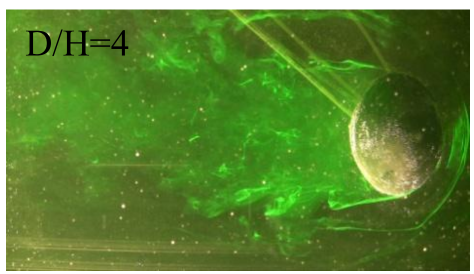


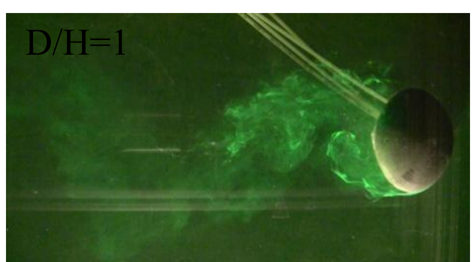
Unsteady Aerodynamics of Wall-Mounted Bluff Bodies











The two figures to the upper left show isocontours of streamwise vorticity in the wake of a wall-mounted semi-ellipsoid in a boundary layer flow. The flow is viewed looking upstream. A 90-degree rotation of the ellipsoid from the *streamlined* (top) orientation to the *transverse* (bottom) orientation results in a distinct reversal in the dominant vortex patterns. A counter-rotating 'tip vortex' pair is observed near the top of the streamlined structure, which induces a downwash in the wake, and is a robust feature in this class of flows. The wake of the transverse semi-ellipsoid exhibits a weak tip vortex, but a strong base vortex that induces upwash in the wake. Our experiments have indicated that relative submergence (the ratio of flow depth *D* to obstacle height *H*) is an important parameter governing this transition. The two lower images also show disparate shedding patterns between the high and low relative submergences.

James Buchholz
Mechanical Engineering

james-h-buchholz@uiowa.edu

NSF CBET-1033732

The University of Iowa

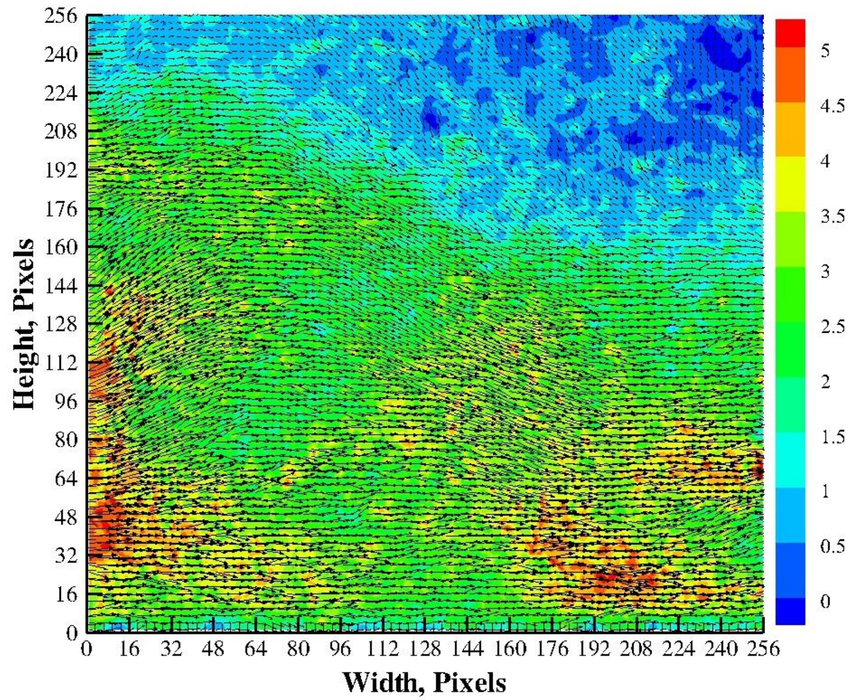
James Buchholz

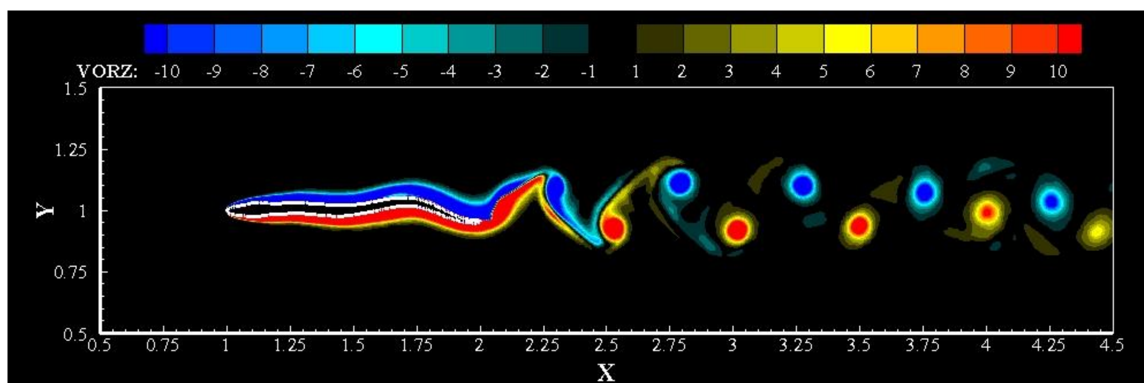
Mechanical Engineering

james-h-buchholz@uiowa.edu

Image-based Velocimetry and Computational Modeling in Moving Boundary Problems

Optical Flow, an Eulerian methodology developed to quantify motion in machine vision applications, is applied to fluid mechanics problems with moving boundaries. Application to images of particle-laden flows can provide dense fluid displacement or velocity fields (right) using multiple images of the particle distributions. Optical-flow-derived velocities are also used to derive boundary conditions for CFD simulations from video data of the moving boundary problem. An example is the two-dimensional simulation of an American eel (shown below) based on a video supplied by Dr. Eric Tytell. This work is being conducted in collaboration with Prof. H. S. Udaykumar.





The University of Iowa