Abstract:

Massively separated flows about moving bodies, especially with high accelerations and large variations in incidence angle between the body and the flow, are among the last remaining areas in fluid mechanics where even the fundamentals leave much room for acquisition of further knowledge. Questions remain about vorticity production and peak circulation of shed vortices, circulation-dependent vs. acceleration-dependent aerodynamic forces, and the role of 3D effects such as interaction between leading edge vortices and tip vortices for planar 3D bodies, Reynolds number effects at transitional Reynolds numbers and below – to name just a few examples. The motivating problems are geometrically simple: plates of various shape, or possibly airfoils, executing motions such as pitching to high incidence, or flapping fore and aft. Applications include the currently fashionable field of “Micro Air Vehicles”, where we seek to elucidate closed-form aerodynamic models for eventual engineering analysis of flight vehicles. Another example is the study of flyers in nature – birds, bats and insects.

Our approach is primarily experimental, using a water tunnel with a 3 degree of freedom electric rig to produce various periodic and transient motions. We also compare with a range of computations, and with analytical results.

We will focus on four examples. The first is a generalization of classical dynamic stall, where 2D airfoils or 3D wings execute harmonic periodic oscillations in two dimensions, with a resulting angle of attack that moves into and out of the static stall range. Massive dynamic stall, where flow separation is dominated by a leading edge vortex, is seen to be relatively Reynolds number independent and not difficult to predict. Less aggressive motions, however, are paradoxically more difficult to analyze, because the flow separation is dependent on the extent of laminar to turbulent transition.

The second example is pitch ramp-hold-return problem, where the lift history of a flat plate is compared with quasi-steady models, and one seeks to explore the limits of linear superposition.

The third example is a “perching” motion, intended to abstract the wing rotation of bird executing a precision landing, where the reduced frequency describing the wing motion is a function of time, as the flight speed is reduced during the maneuver. We will consider a parameter study of the resulting aerodynamic forces vs. various parameter such as reduced frequency, and will relate peaks in aerodynamic force to the pinch-off and shedding of leading edge vortices.

The final example is of a flat plate in sinusoidal fore-aft motion and constrained free-to-pivot pitch, as a model for flapping. We will compare a translational and rotational motion, and 2D vs. finite aspect ratio plates. The overall conclusion is that at high rates of motion, details of geometry are relatively unimportant, and there is good outlook for a simple scaling of aerodynamic forces as a second-order system with incidence angle as the kinematic variable.

Biography:

Dr. Michael OL is a government employee at the US Air Force Research Lab in Dayton, Ohio. He obtained his Ph.D. from Caltech and his M.S.E. and B.S.E. from the University of Michigan, all in Aeronautics. His current activities include operation of a water tunnel facility with focus on unsteady aerodynamics at low speeds, with application to flight vehicle engineering.