The Energy Extraction Performance of an Oscillating Rigid and Flexible Foil

By Alexander Totpal

Candidate for Master of Science in Thermal-Fluid Sciences

Major Professor: Dr. James Liburdy

Abstract

The aerodynamic performance of an oscillating pitching and plunging foil operating in the energy harvesting mode is investigated. Experiments are conducted in a closed-loop recirculating wind tunnel at Reynold's numbers of 24,000 to 48,000, and reduced frequencies (*k=fc/u)* of 0.04 to 0.08. Foil kinematics are varied through the following parameter space: non-dimensional heaving amplitude (*h=h0/c)* of 0.3, pitching amplitudes of 45, 60, and 75 degrees, as well as phase lag between sinusoidal pitching and heaving motions of 30 to 120 degrees. Aerodynamic force measurements are collected to show the energy extraction performance of the foil. Coupled with the force measurements, flow fields are collected around the foil using particle image velocimetry (PIV). The flow field characteristics are used to supplement the force results, shedding light into flow features that contribute to more efficient flow energy extraction at these lower reduced frequencies. In addition, inertia-induced passive chord-wise flexibility at the leading edge (LE) of the foil is investigated in order to assess its feasibility in this application. Results indicate that optimal energy extraction (in terms of power coefficient and efficiency) occurs near pitching amplitudes of 45 degrees, at a pitch-heave phase of 90 degrees and k = 0.08. When k is decreased (through increased *Re*) to k = 0.04, overall extraction performance becomes insensitive to the pitching amplitude and motion phase. This is supported by the flow field measurements, which show premature leading edge vortex (LEV) evolution and detachment from the foil surface. However, these results indicate that a proper tuning of the LE may be used to delay the LEV detachment time, resulting in increased energy harvesting at this otherwise inefficient operating parameter space.

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