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ACTIVE FLOW AND AEROELASTIC CONTROL OF LIFTING SURFACES

K. O'Donnell[1], A. Milanese[1], C. Hoover[1], M. Stolk[1], L. Miller[2]
P. Marzocca[1], R. Jha[1], G. Armadi[1], E. Bollt[2]

[1]Department of Mechanical and Aeronautical Engineering
[2]Department of Mathematics and Computer Sciences
Clarkson University, Potsdam, NY 13699-5725

Abstract

Active flow control devices such as zero-net-mass-flux actuators have broad aeronautical applications. Among them, low power and lightweight Synthetic Jet Actuators (SJAs) can be used to improve the performance of flight vehicles, expand their flight envelope and prevent catastrophic failure by flutter instability. Numerical and experimental investigations are proving that SJAs are effective in actively altering the boundary layer and influencing the flow separation. Furthermore, the effect of the momentum exchange due to the SJAs leads to a rearrangement of streamlines around the wing, thus modifying the unsteady aerodynamics forces. Incompressible Reynolds-Averaged Navier-Stokes (RANS) computations are performed with FLUENT® to estimate the efficiency of the SJAs in modifying pressure distribution, and consequently the aerodynamic forces on the lifting surface to which they are hosted. Simulations accounts for the SJA diameter, location, oscillation frequency and its strength. The computational simulations show that SJAs produce sufficiently large aerodynamic forces to expand the flutter boundary and to counteract self sustained limit cycle oscillations (LCOs), e.g. non-linear aeroelastic vibrations, due to the inherent structural and aerodynamic nonlinearities present in the wing structure and flow field respectively. Although LCOs do not produce immediate failure of the wing, the self sustained vibrations can lead to premature failure due to fatigue and for this reason a carefully designed LCO suppression mechanism is of interest to the aeronautical community. Two phases of experimental tests are under investigation. First, a two degree-of-freedom plunging and pitching wing apparatus, representing a wing structure with elasticity concentrated in elastic springs has been designed and characterized. Stiffness and damping characteristics have been estimated along with the flutter and LCO analysis. Once the apparatus characterization is complete, accurate analytical models can be proposed and used to help the development of active flow control systems and their associated control laws. Second, active flow control devices (SJAs) will be installed on a wing section and a proper feedback control law will be implemented to demonstrate the suppression of LCOs. The final paper will present experimental and numerical results showing the effectiveness for suppressing aeroelastic vibrations. The combination of experimental and numerical simulations will provide the aerospace industry with design guidance for flow and aeroelastic control devices, insight into flow phenomena, and feasibility analysis of SJAs for specific applications.