Novel Momentum-Injection Techniques for Lift Enhancement and Shear Layer Reattachment on Airfoils in Deep Stall

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The focus of this work is lift enhancement and shear layer reattachment for stalled airfoils through the use of active flow control techniques to introduce a localized source of momentum to the flowfield. Controlling the flowfield and aerodynamic forces over wing surfaces improves their performance, and potential benefits for reducing the possibility of stall include increased safety of commercial flights and increased power output from wind turbines. It is known from previous research that the response to short-duration impulse disturbances at post-stall angles of attack consists of an initial lift reversal phase followed by a transient lift enhancement phase before returning to the baseline state. The goal of this work is to investigate whether a different input signal to the flowfield would reattach the separated shear layer faster. It is also of interest to investigate the physical mechanisms governing the initial lift reversal behavior, and to determine if there is an input signal that would produce an enhancement in the lift response without a lift reversal phase. The use of proper orthogonal decomposition (POD) and dynamic mode decomposition (DMD) is employed on direct numerical simulation (DNS) data to identify a low-dimensional subspace that best describes the flowfield and captures the physics of the interaction of the disturbance with the separated shear layer. To isolate the dynamics of the disturbance with the separated flowfield, the actuation snapshots were projected onto a subspace of POD modes that captures the limit cycle solution. The spectrum of DMD eigenvalues resulting from this constraint gives interesting insight into the stability of the actuated system. The relationship between the POD mode coefficients and the lift response is explored.

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