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Towards Effective ZNMF Jet Based Control of a Canonical Separated Flow

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Three dimensional numerical LES simulations and companion of synthetic jet based control of a canonical separated flow at chord Reynolds number of 1×10^5 are investigated. Aft chord separation on the upper surface of a flat plate with a 4:1 elliptical leading edge and blunt trailing edge is created by implementing zero-net steady suction and blowing on the top boundary of both the computational and experimental domains. This study shows that even this simple canonical separated flow is dominated by nonlinear interactions between the shear layer, separation bubble, and wake instabilities in a manner that is representative of more complex airfoil separation. These interactions produce complex flows characterized by various lock-on states in which the oscillations in these regions are coupled in a complex nonlinear fashion. Numerical simulations of spanwise uniform ZNMF sinusoidal forcing shows that active control can move the separated flow system to other lock-on states that either reduce or enhance separation.

Nomenclature

C_f = skin friction coefficient, $C_f = \frac{\tau_w}{q_\infty}$
C_μ = ZNMF jet momentum coefficient, $C_\mu = 2(d/c)(l/W)(\overline{V}_J/U_\infty)^2$
c = flat plate chord
d = steamwise extent of the ZNMF jet exit
f = jet or actuator frequency
f_n = natural frequency of uncontrolled flow
f_{sep} = separation bubble frequency
f_{SL} = shear layer frequency
f_{wake} = wake vortex shedding frequency
H_{LE} = height of minor axis of elliptic leading edge
H_{sep} = height of separation bubble

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