Towards Understanding and Optimizing Separation Control Using Microjets

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Flow separation in engine inlets and diffuser ducts and over external aerodynamic surfaces such as wings can significantly compromise performance. In an earlier experimental study, we demonstrated the value of microjets for separation control. In this paper, we significantly broaden the range of conditions and parameters to explore the effects of microjet control on the efficiency of separation control over a backward facing ramp. The parameters explored include: the freestream velocity, ramp angle of attack, microjet pressure, microjet location and their injection angle. Detailed velocity field investigations and unsteady pressure measurements have been conducted to study the effect of flow control over this parametric space. The results indicate that by activating the actuator arrays in the immediate vicinity of the separation location, the control efficiency can be greatly enhanced, reducing the actuator mass flow needed dramatically. By correlating the unsteady surface pressure measurements with the measured velocity field, we demonstrate that, at least in the present geometry, the unsteady pressure alone can be used to a) detect separation, hence identify which actuator(s) to activate and b) estimate the effect of control on a separated flowfield. Finally, based on the response of the flowfield to actuation, we propose some simple scaling laws for detecting and implementing separation control.

Nomenclature:

U_∞ : Freestream velocity
P_{RMS} : root-mean-square value for unsteady pressure
X_s : Separation location
X_{Mj} : Microjet location
X_T : Unsteady pressure transducer location
d_{mj} : Microjet diameter
Ψ_P : $(P_{RMS,Baseline}-P_{RMS,Control})/ P_{RMS,Baseline}$
$\Psi_P(L)$: Scaling factor for the effect of microjet location on P_{RMS}
$\Psi_P(P)$: Scaling factor for the effect of microjet pressure on P_{RMS}
C_μ: Steady momentum coefficient
ρ_∞ : Freestream density
w : Width of the model
N: Number of microjets
$\dot{m}_{in}$: Rate of mass flux supplied through microjets
δ: Boundary layer height
H: Ramp height
U_j : Microjet velocity
MGR : Momentum Gain Ratio
ω_z : Streamwise vorticity

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