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Numerical Investigation of Turbulent Flow Control by Suction and Injection on a Subsonic NACA23012 Airfoil by Proper Orthogonal Decomposition Analysis and Perturbed Reynolds Averaged Navier-Stokes Equations

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Abstract : Separation flow control for performance enhancement over airfoils at high incidence angle has become an increasingly important topic. This work details the characteristics of an efficient feedback control of the turbulent subsonic flow over NACA23012 airfoil using forced reduced-order model based on the proper orthogonal decomposition/Galerkin projection and perturbation method on the compressible Reynolds Averaged Navier-Stokes equations. The forced reduced-order model is used in the optimal control of the turbulent separated flow over a NACA23012 airfoil at Mach number of 0.2, Reynolds number of 5×106, and high incidence angle of 24° using blowing/suction controlling jets. The Spallart-Almaras turbulence model is implemented for high Reynolds number calculations. The main shortcoming of the POD/Galerkin projection on flow equations for controlling purposes is that the blowing/suction controlling jet velocity does not show up explicitly in the resulting reduced order model. Combining perturbation method and POD/Galerkin projection on flow equations introduce a forced reduced-order model that can predict the time-varying influence of the blowing/suction controlling jet velocity. An optimal control theory based on forced reduced-order system is used to design a control law for a nonlinear reduced-order model, which attempts to minimize the vorticity content in the turbulent flow field over NACA23012 airfoil. Numerical simulations were performed to help understand the behavior of the controlled suction jet at 12% to 18% chord from leading edge and a pair of blowing/suction jets at 15% to 18% and 24% to 30% chord from leading edge, respectively. Analysis of streamline profiles indicates that the blowing/suction jets are efficient in removing separation bubbles and increasing the lift coefficient up to 22%, while the perturbation method can predict the flow field in an accurate Manner.

Keywords : flow control, POD, Galerkin projection, separation
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