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UNSTEADY, TRANSONIC FLOW AROUND DELTA WINGS UNDERGOING COUPLED AND NATURAL MODES RESPONSE–A MULTIDISCIPLINARY PROBLEM

by

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ABSTRACT

UNSTEADY, TRANSONIC FLOW AROUND DELTA WINGS UNDERGOING COUPLED AND NATURAL MODES RESPONSE–A MULTIDISCIPLINARY PROBLEM.

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The unsteady, three-dimensional Navier-Stokes equations coupled with the Euler equations of rigid-body dynamics are sequentially solved to simulate and analyze the aerodynamic response of a high angle of attack delta wing undergoing oscillatory motion. The governing equations of fluid flow and dynamics of the multidisciplinary problem are solved using a time-accurate solution of the laminar, unsteady, compressible, full Navier-Stokes equations with the implicit, upwind, Roe flux-difference splitting, finite-volume scheme and a four-stage Runge-Kutta scheme, respectively. The primary model under consideration consists of a 65° swept, sharp-edged, cropped delta wing of zero thickness at 20° angle of attack. In a freestream of Mach 0.85 and Reynolds number of 3.23×10^6, the flow over the upper surface of the wing develops a complex shock system which interacts with the leading-edge primary vortices producing vortex breakdown.

The effect of the oscillatory motion of the wing on the vortex breakdown and overall aerodynamic response is detailed to provide insight to the complicated physics associated with unsteady flows and the phenomenon of wing rock. Forced sinusoidal single and coupled mode rolling and pitching motion is presented for the wing in a

transonic freestream. The Reynolds number, frequency of oscillation, and the phase angle are varied.

Comparison between the single and coupled mode forced rolling and pitching oscillation cases illustrate the effects of coupling the motion. This investigation shows that even when coupled, forced rolling oscillation at a reduced frequency of 2π eliminates the vortex breakdown which results in an increase in lift. The coupling effect for in phase forced oscillations show that the lift coefficient of the pitching-alone case and the rolling-moment coefficient of the rolling-alone case dominate the resulting response. However, with a phase lead in the pitching motion, the coupled motion results in a non-periodic response of the rolling moment.

The second class of problems involve releasing the wing in roll to respond to the flowfield. Two models of sharp-edged delta wings, the previous 65° swept model and an 80° swept, sharp-edged delta wing, are used to observe the aerodynamic response of a wing free to roll in a transonic and subsonic freestream, respectively. These cases demonstrate damped oscillations, self-sustained limit cycle oscillations, and divergent rolling oscillations. Ultimately, an active control model using a mass injection system was applied on the surface of the wing to suppress the self-sustained limit cycle oscillation known as wing rock.

Comparisons with experimental investigations complete this study, validating the analysis and illustrating the complex details afforded by computational investigations.

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