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Unsteady aerodynamics modeling for flight dynamics application

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Abstract In view of engineering application, it is practicable to decompose the aerodynamics into three components: the static aerodynamics, the aerodynamic increment due to steady rotations, and the aerodynamic increment due to unsteady separated and vortical flow. The first and the second components can be presented in conventional forms, while the third is described using a one-order differential equation and a radial-basis-function (RBF) network. For an aircraft configuration, the mathematical models of 6-component aerodynamic coefficients are set up from the wind tunnel test data of pitch, yaw, roll, and coupled yaw-roll large-amplitude oscillations. The flight dynamics of an aircraft is studied by the bifurcation analysis technique in the case of quasi-steady aerodynamics and unsteady aerodynamics, respectively. The results show that: (1) unsteady aerodynamics has no effect upon the existence of trim points, but affects their stability; (2) unsteady aerodynamics has great effects upon the existence, stability, and amplitudes of periodic solutions; and (3) unsteady aerodynamics changes the stable regions of trim points obviously. Furthermore, the dynamic responses of the aircraft to elevator deflections are inspected. It is shown that the unsteady aerodynamics is beneficial to dynamic stability for the present aircraft. Finally, the effects of unsteady aerodynamics on the post-stall maneuverability are analyzed by numerical simulation.

Keywords: Unsteady aerodynamics High angle of attack Mathematical model Flight dynamics Bifurcation analysis Post-stall maneuver

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