Effect of Symmetric & Asymmetric Span Morphing on Flight Dynamics

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To increase aerodynamic efficiency over the operational flight envelope, span morphing has been proposed as a method to better optimise the aircraft geometry for varying flight conditions. Due to the significant planform change undertaken during span morphing, aerodynamic and structural changes lead to changes in the force, moment and mass property modelled for varying aircraft state. The effect of which on the flight dynamics and control can be significant. A low-fidelity framework is proposed to capture the effect of morphing, to model the change in behaviour such that flight performance and dynamic analysis can be performed. This framework prospectively enables development of morphing concepts, in addition to assessment activities from a conceptual design phase. An example small/ medium Unmanned Air Vehicle (UAV) (mass of 25 kg and nominal aspect ratio of 6.67) is used to demonstrate the tool, presenting results for both symmetric and asymmetric span retraction. The span retraction is performed using the outboard 50% of the main wing, with up to 50% allowable span retraction. Results presented are for a loiter mission. The loiter is at 55 (km/r) where the high speed cruise is from 75-110 km/hr. Span retraction is used to optimise the configuration performance for these flight phases. LTrim and dynamic (both longitudinal and lateral) results are presented for both high speed cruise and loiter for straight and level conditions. Loiter results include lateral coordinated turn with varying strategies, which include using either rudder span retraction, to trim the UAV. Final results show the effect of modelling $\dot{I}_{xx}$ using a reduced model for roll dynamics. This investigation shows that the maximum error occurs where the roll and inertia dynamics are matched.

Nomenclature

α (AoA), β, V_t	Angle of attack, and side-slip angle (deg), Total Velocity (km/hr)
p, q, r	Roll, pitch and yaw rate (deg/s)
ϕ, θ, ψ	Euler angles: Roll, pitch and yaw (deg)
X, Y, Z	Position (m)
L	Rolling moment (N.m)
Δ_{HSTAB}, Δ_{RUDD}, $\Delta_{StarBrdSpan}$	Control angles: Stabiliser, rudder (deg) and spanwise retraction (0 to 1 for full spar
η_{thrust}	Engine thrust (N)
L/D	Aerodynamic efficiency (lift-to-drag ratio)
AR	Aspect Ratio

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