Aeroelastic Analysis of Unrestrained Aircraft Wing with External Stores Under Roll Maneuver

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This paper discusses our study on the flutter of an unrestrained aircraft wing carrying a fuselage at its semispan and arbitrary placed external stores under roll maneuver. Maneuver terms are combined in the governing equations which are obtained using the Hamilton's principle. The wing is represented by a classical beam and incorporates bending-torsion flexibility. Theodorsen unsteady aerodynamic pressure loadings are considered to simulate the aeroelastic loads. The Galerkin method is subsequently applied to convert the partial differential equations into a set of ordinary differential equations. Numerical simulations are validated against several previous published results and good agreement is observed. In addition, simulation results are presented to show the effects of the roll angular velocity, fuselage mass, external stores mass, and their locations on the wing flutter of an aircraft in free-flight condition. Parametric studies show that the predicted flutter boundaries are very sensitive to the aircraft rigid body roll angular velocity, fuselage mass and external stores mass and locations.

NOMENCLATURE

b	Wing semi chord
e_F	Distance between the fuselage center of gravity and wing elastic axis
e_p	Distance between the store center of gravity and wing elastic axis
E	Young's modulus
G	Shear modulus
I	Wing cross-section moment of inertia
J	Wing cross-section polar moment of inertia
l	Wing length
L	Wing sectional lift
m	Mass of the wing per unit length
M	Aerodynamic moment
$\mathbf{R}_{w_i}$	Displacement vector of an arbitrary point of wings
T	Kinetic energy
U	Strain energy
v_f	Nondimensional flutter speed
w_i	Bending displacement
x_e, y_e, z_e	The external mass location in x, y and z directions, respectively
δ	Variational operator
ε_{ij}	Strain component
Λ	Sweep angle
θ_i	Twist angle
ρ	Density of the wing
ρ_∞	Air density
σ_{ij}	Stress component
ω_f	Flutter frequency
ω_θ	Torsional frequency
Ω	Roll angular velocity

1. INTRODUCTION

The flutter prediction of an unrestrained aircraft wing with stores is of paramount importance for the analysis and design of an aircraft. Clearly, estimating the aeroelastic instabilities of such aircraft with different wing configurations is critical to establish the flight envelope of newly designed aircrafts.

Many of the previous efforts made to simulate wing flutter have considered uniform straight wings with external stores. One of the first works devoted to the aeroelasticity of aircraft wings with external store is the paper by Goland and Luke on the determination of the flutter speed of a uniform cantilever wing with tip mass.[1] They verified the flutter speed by integration of the differential equations of the wing motion. Harry and Charles[2] analyzed the flutter of a uniform wing and made a comparison between the analytical and the experimental results. Lottati considered the aeroelastic stability of a swept wing with tip weights for an unrestrained vehicle.[3] In his work, a composite wing has been studied, and it was observed that flutter occurs at a lower speed as compared with a clean wing configuration. Gern and Librescu have made some efforts to show the effects of externally mounted masses on the static and dynamic aeroelasticity of advanced swept cantilevered wings.[4,5] The dynamic response of adaptive cantilevered beams carrying externally mounted stores and exposed to time-dependent external excitations has been con-