

Conceptual Design Prediction of the Buffet Envelope of Transport Aircraft

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This paper describes a methodology that inexpensively predicts the buffet envelope of new transport airplane wing geometries at the conceptual design stage. The parameters that demonstrate a strong functional sensitivity to buffet onset were identified and their relative effect was quantified. To estimate the buffet envelope of any target aircraft geometry, the method uses fractional change transformations in consort with a generic reference buffet onset curve provided by the authors or the buffet onset of a known seed airplane. The explicit design variables required to perform buffet onset prediction are those describing the wing planform and the wingtip section. The mutually exclusive nature of the method's analytical construct provides considerable freedom in deciding the scope of free-design-variable complexity. The method has been shown to be adequately robust and flexible enough to deal with a wide variety of transport airplane designs. For the example transport airplanes considered, irrespective of aircraft morphology and en route flight phase, the relative error in prediction was found to be mostly within $\pm 5.0\%$, with occasional excursions not exceeding a $\pm 9.0\%$ bandwidth. The standard error of estimate for the lift coefficient at 1.0 g buffet onset at a given Mach number was calculated to be 0.0262.

Nomenclature

AR	= reference wing aspect ratio	x_n	= arbitrary independent or dependent variable or design parameter
a	= arbitrary coefficient of proportionality or exponent	α	= exponent that establishes a relationship between wing sweep and the maximum permissible operating lift coefficient at buffet onset for a given Mach number
b	= arbitrary coefficient of proportionality or exponent	β	= exponent that establishes a relationship between wing section thickness-to-chord ratio and the maximum permissible operating lift coefficient at buffet onset for a given Mach number
b	= wingspan, m or ft	γ	= exponent that establishes a relationship between wing section camber and the maximum permissible operating lift coefficient at buffet onset for a given Mach number
C_L	= operating lift coefficient	ε	= error function, applicable for absolute or relative values
C_{LB}	= lift coefficient at the onset of 1.0 g buffet for a given Mach number	η	= given wing spanwise buttock line normalized by wing semispan
\tilde{C}_{LB}	= lift coefficient at the onset of 1.0 g buffet decoupled from the influence of reference wing taper ratio	Θ	= generic function representing the buffet onset of an unswept taper ratio of unity flat-plate representation of a wing
c	= wing section camber, m	ϑ	= constant of proportionality that establishes a relationship between wing section camber and the maximum permissible operating lift coefficient at buffet onset for a given Mach number
c	= local wing planform chord length, ft	κ	= linear correlation used for establishing wing thickness-to-chord sensitivity to operating lift coefficient at buffet
k_n	= constant of proportionality or exponent that establishes a relationship between flow regime, primary wing design variables, and the maximum permissible operating lift coefficient at buffet onset for a given Mach number	Λ	= reference wing sweep, rad or deg
M	= Mach number	λ	= taper ratio for individual trapezoidal panel, original or reference wing taper ratio
\tilde{M}	= Mach number at the onset of 1.0 g buffet decoupled from the influence of reference wing sweep	ξ	= set of ancillary design parameters that influence the maximum permissible operating lift coefficient at buffet onset for a given Mach number
M_B	= Mach number at the onset of 1.0 g buffet for a given attainable lift coefficient	ρ	= ambient density at altitude, kg/m ³ or slugs/ft ³
S_W	= reference wing area, m ² or ft ²	τ	= constant of proportionality that establishes a relationship between wing sweep and the maximum permissible operating lift coefficient at buffet onset for a given Mach number
t/c	= wing section thickness-to-chord ratio at a given wing spanwise buttock line or at the wingtip	Ω	= generic function representing the influence of ancillary design parameters on the maximum permissible operating lift coefficient at buffet onset for a given Mach number
W	= all-up weight, kg		
W	= instantaneous gross weight, lb		
X	= longitudinal position along wing section from leading-edge datum, normalized by chord length		

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