SHAPE AND SIZING AEROELASTIC GUST OPTIMIZATION OF A X-56 PLANFORM WITH STRESS CONSTRAINTS

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ABSTRACT

Conceptual design and even early phases of preliminary design typically do not include the effects of aeroelastic gust loads. While a loads team may incorporate quasi-steady loads, it is vital for future aircraft design that transient gust loads are included earlier in the design process. A way to bring gust loads into the early design process is to leverage developments in multi-disciplinary optimization and utilize efficient gradient-based design methods. Commercial aeroelastic solvers such as Nastran do not include the required sensitivities for aeroelastic gust optimization for either shape or sizing design variables. This works presents a method for including aeroelastic gust optimization for shape and sizing design variables and stress constraints for an X-56 type planform as well as the sensitivity equations based on the linear aeroelastic equations of motion.

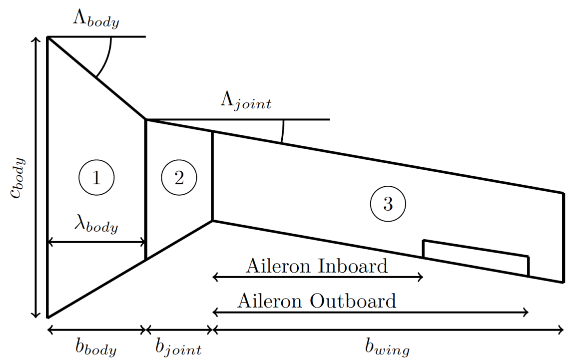

Figure 1: X-56 type Planform.

Figure 1 highlights key design features of the X-56 type planform. For this design problem, the shape design variables will include sweep angles Λ_{body} and Λ_{joint}, taper ratio of the center body λ_{body}, and shell thicknesses for the plate FEM. Figure 2 shows preliminary verification weight and von Mises stress response sensitivities subject to an aeroelastic gust. The fourth-order accurate central difference shows strong agreement for the sensitivity verification and are suitable for design optimization.

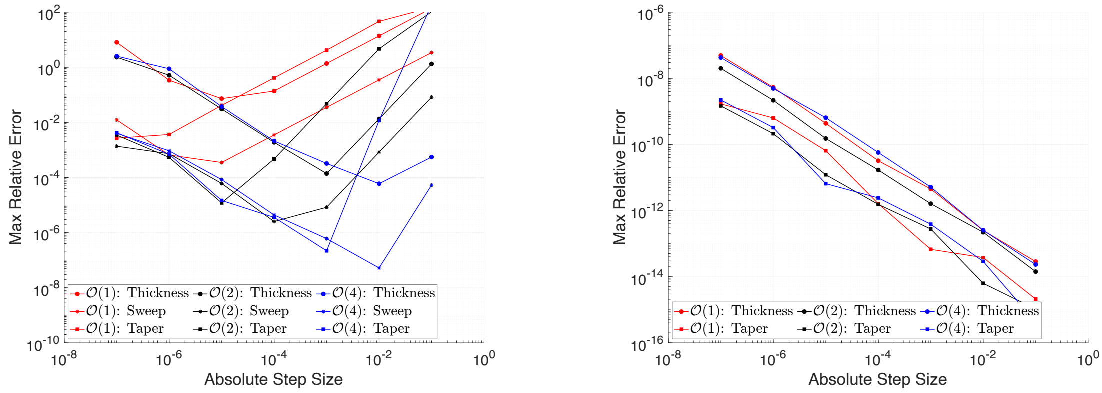

Figure 2: Initial Verification of Design Sensitivities for Aeroelastic Gust Responses.

The design optimization problem of interest would subject the wing to multiple gusts at different frequencies. Table 1 details the design optimization problem which will be conducted. The goal of including multiple gust frequencies is to capture different critical elastic modes. While the spectrum of gust is continuous, the one-cosine profiles provide a way to excite the rigid-body modes and specific elastic modes which are deemed critical.

	Variable/Function	Description	Qty.
Minimize	GTOW	Gross Takeoff Weight (lbs)	1
With respect to	Λ_{body}	Centerbody Leading Edge Sweep (degrees)	1
	Λ_{joint}	Joint Leading Edge Sweep (degrees)	1
	λ_{body}	Centerbody Taper Ratio (-)	1
	t_i	Shell Element Thickness (in)	30
Subject to	$-\sigma_{yield} < \sigma_{vm}$	Von Mises Stress for Gust Response (3 Hz) at each time step (psi)	30+
	$-\sigma_{yield} < \sigma_{vm}$	Von Mises Stress for Gust Response (5 Hz) at each time step (psi)	30+
	$-\sigma_{yield} < \sigma_{vm}$	Von Mises Stress for Gust Response (7 Hz) at each time step (psi)	30+

Table 1: Design Optimization Problem Definition

Analysis of the design optimization study will focus on the change in shape of the planform as well as the stiffness distribution. The sensitivity of the structural response for each gust will also be examined to determine the critical design loads and the corresponding mode shapes.