

EXPERIMENTAL BODY FREEDOM FLUTTER TEST CAMPAIGN OF AEROELASTICALLY SCALED X-56 WING

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ABSTRACT

Body freedom flutter is an aeroelastic instability inherent to blended wing body and flying wing aircraft in which an elastic mode couples with a rigid body mode to excite a flutter response. This work describes an experimental campaign to study body freedom flutter to enhance the design of flying wing and blended wing aircraft. The campaign includes design, manufacture, characterization of outer mold line geometry and structural dynamics, and finally wind tunnel testing.

Contrary to traditional wing bending flutter, body freedom flutter requires free motion in at least one rigid body mode such as wing root pitch or plunge. To consider this boundary condition experimentally, several additions to the repertoire of AFRL's low-speed aeroelastic wind tunnel testing paradigm have been made. First, a new pitch-plunge mount was designed, built, and tested for the Parker four-by-four-foot Subsonic Research Facility (SuRF). The mount is designed to plunge vertically such that wings may be trimmed against their own weight under gravity, with 12 inches of free movement. The pitch motion may be controlled via a DC brushless motor or allowed to rotate freely. Second, a new 30-inch (18% scale) wing was designed to match the reduced frequencies of the full-scale X-56 aircraft [1]. Static aeroelastic analysis was conducted in MSC Nastran to determine displacements, lift coefficients, and root forces which will act upon the pitch-plunge mount. Dynamic aeroelastic modelling predicted the flutter speed in the tunnel. The wing was additively manufactured from HT23, a polyetherketoneketone material with 23% chopped carbon-fiber infill for material stability and minimal creep [2]. The wing was 3D scanned for geometric accuracy to the as-designed wing, and found to deviate from the source by no more than 1 degree of twist at the wingtip. A shaker test was conducted to determine mode shapes, frequencies, and damping. Model updates at the root boundary condition were necessary to match the frequencies of the finite element model with the printed wing. Finally, the wing was tested in the tunnel. Static testing yielded lift and drag polars from a force balance at the root, along with tip deflection data from laser displacement sensors. Initial dynamic testing included testing the pitch-plunge mount for adequate freedom to move in the rigid body pitch and plunge coordinates.

At the time of writing, the tunnel flutter test has not occurred but is planned for the first quarter of 2026, and will be included in the final paper. Several flutter margin prediction methods will be investigated based on wing deflection data from laser displacement sensors, possibly including Raveh's autoregressive flutter boundary prediction method [3,4] and Kim's progressive flutter boundary prediction method [5]. The flutter boundary will be compared with published data from the full-scale X-56 aircraft[6]. The methods developed will be incorporated into AFRL's wind tunnel testing routines, and the published paper will serve as a benchmark of scaled wing wind tunnel test campaigns. It also serves as a checkpoint to future work on scaled wings with actuated control surfaces for active flutter suppression control law design.

References:

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