

EXPERIMENTAL STUDY OF NONLINEAR AEROELASTIC RESPONSE IN A HIGHLY FLEXIBLE WING CONFIGURATION

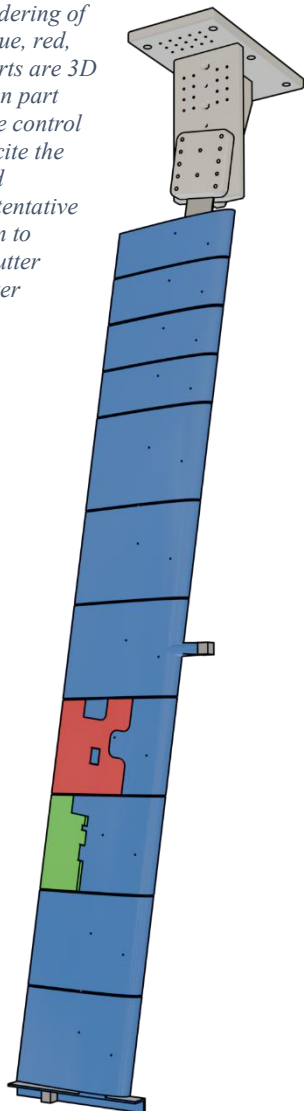
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ABSTRACT

The increasing adoption of high aspect ratio and ultra-flexible lifting surfaces in future aircraft concepts requires experimental validation frameworks capable of capturing strongly nonlinear aeroelastic phenomena. This work will present results from an upcoming experimental campaign focused on the aeroelastic behaviour of a highly flexible swept wing model, to be tested in the 7x5 ft low-speed wind tunnel at the University of Bristol in late February 2026. The primary objective is to investigate flutter onset, limit cycle oscillations, and modal interaction in configurations characterized by large static and dynamic deformations, with wing tip deflections reaching up to 50% of the semi-span.

Figure 1 Rendering of the model. Blue, red, and green parts are 3D printed. Green part represents the control surface to excite the structure; red represents a tentative spoiler design to investigate flutter behaviour after deployment.



The wind tunnel model was developed to simplify manufacturability and numerical modelling, it consists of an 8° swept wing with constant chord and uniform structural properties along the span. The half-span is 1.15 m and the wing is mounted in a ceiling-hung configuration using a custom-made clamping support. Aerodynamic panels are interchangeable, opening the possibility to a test where the spanwise position of control surfaces can be modified.

Model sizing was completed using an aeroelastic model based upon the modal intrinsic beam (MIB) method and unsteady strip theory augmented with three-dimensional lifting-line corrections. The dual-objectives were a) to achieve 50% tip deflection at 30 m/s and an angle of attack of 8 degrees, and b) to exhibit a deformation-dependent flutter instability between 25 to 30 m/s. Provisional V_g - V_f results show the chosen model parameters (sweep angle and chord length) achieve a desired result.

In the final paper, a comprehensive ground vibration testing campaign will be presented to identify modal frequencies, mode shapes and structural damping characteristics. Results will be used to establish baseline dynamic properties and to assess the influence of mass distribution on the aeroelastic response. In particular, two adjustable lumped masses are incorporated into the design: one located at the wing tip, and one positioned at mid-span. The idea is to be able to influence the first two bending modes and the first torsional model, in order to obtain different flutter mechanisms and LCOs,

possibly.

Installed instrumentation will consist of accelerometers to identify flutter, strain gauges to measure the root bending moment, a 3D camera tracking system to measure displacements, and a series of pressure tapping to capture dynamic variations in spanwise loading. A control surface (shown in green in Fig. 1) will be used to excite the model for modal identification. Wind tunnel testing will focus on flutter boundary identification and post-flutter response characterization across a range of angles of attack. Flutter onset is expected to occur at wind speeds on the order of 30 m/s, enabling safe exploration of the instability region well within the operational envelope of the facility. Special attention will be given to the detection of limit cycle oscillations, which are anticipated to arise due to nonlinear effects associated with large deflections. Distinct flutter mechanisms should arise depending on angle of attack and mass distribution.

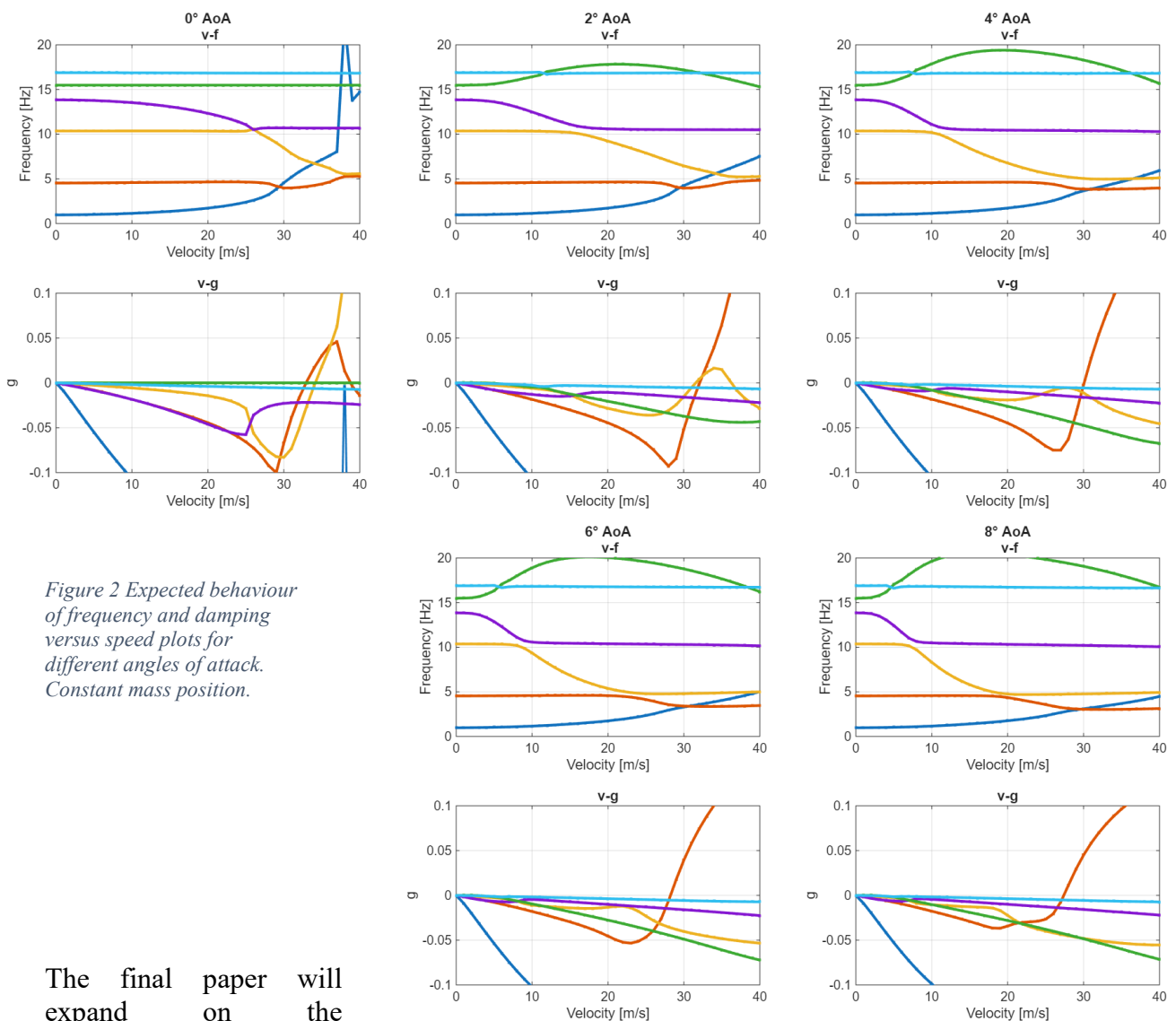


Figure 2 Expected behaviour of frequency and damping versus speed plots for different angles of attack. Constant mass position.

The final paper will expand on the methodology used to design the model, its construction, results from the ground vibration testing and present the experimental data obtained during the test campaign. These results will provide a valuable benchmark for the validation of nonlinear aeroelastic models targeting highly flexible lifting surfaces. In addition, the dataset will contribute to improved understanding of mass distribution effects on flutter behaviour in swept flexible wings. The results will also inform future design strategies for large deformation aeroelastic experiments.