

EXPERIMENTAL INVESTIGATION ON THE EFFECT OF PROPELLER PLACEMENT ON THE AEROELASTIC BEHAVIOUR OF FLEXIBLE WINGS

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ABSTRACT

The pursuit of higher performance has driven modern aircraft to increase their aspect ratios, aiming to reduce induced drag and to incorporate composite materials to lessen structural weight. This has resulted in a continued decrease in wing modal frequencies and a nonlinear response in both aerodynamics and structural behaviour.

In this context, aeroelastic research has concentrated on developing nonlinear frameworks that require experimental data for validation. However, obtaining this data is challenging due to the nature of the tests and their inherent nonlinearity. The primary methods used to characterise the structural and aeroelastic behaviour of these flexible structures are wind tunnel tests and Ground Vibration Tests.

This work aims to predict and analyse the behaviour of flexible wings subjected to vibrations induced by a propeller. In addition to addressing common issues like whirl flutter, it seeks to parameterise the position and offset of the propeller axis relative to the wing's elastic axis and to map the wing's aeroelastic response to the propeller's influence.

The work presented in this paper builds on recent research by the two authors, focusing on the application of the Loewner framework with the Natural Excitation Technique (NExT-LF) for modal identification (Dessena et al., 2025) and the newly introduced Propeller-driven Ground Vibration Tests (PVT) for wind-off (Dessena and Pontillo, 2026). The study examines a wing spar with a span of 0.8 m, a uniform thickness of 2.3 mm, and a variable planform. Made from Aluminium 7075-T6, the specimen exhibits typical aluminium properties, including density, Young's modulus, shear modulus, and Poisson's ratio. The spar's planform is divided into four distinct sections, as illustrated in Figure 1. Its dimensions are based on previous work by one of the authors, as documented in Navaratna et al. (2022).

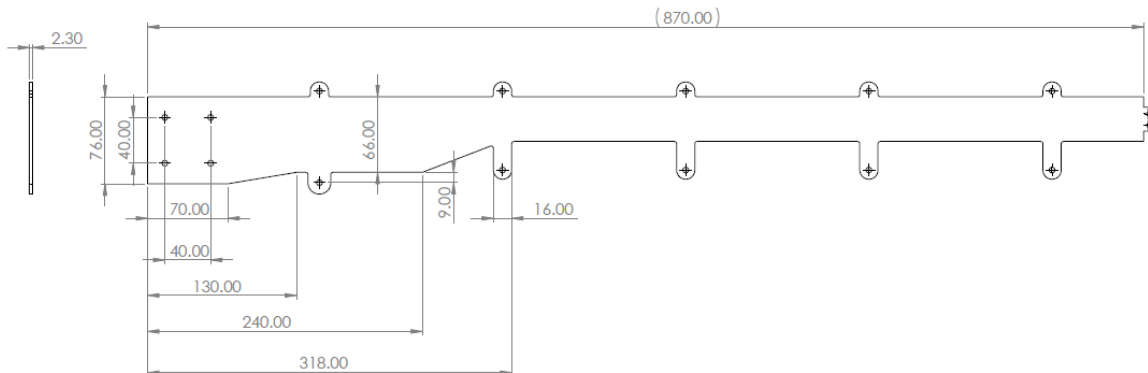


Figure 1 Wing spar planform dimensions

The wing uses a NACA 2412 aerofoil throughout its span. Its chord length remains constant at 0.16 m. An in-house designed motor bracket, which can be mounted at different sections of the wing spar. This bracket is 3D printed from carbon-reinforced nylon filament. A TMOTOR AS2317 electric motor, equipped with an 8-inch two-blade propeller, is mounted on the bracket. The motor is powered by a Favourite FVT 50A BLHeli_32 electronic speed controller.

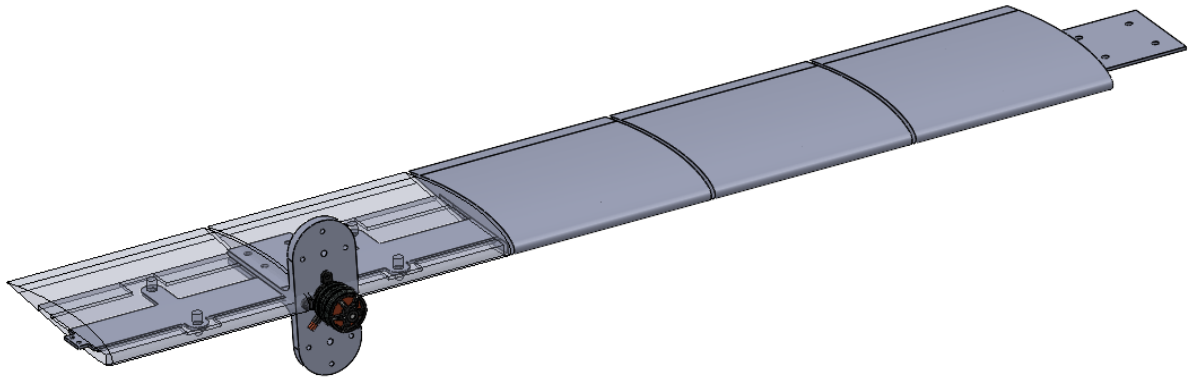


Figure 2 Wing assembly showing the propeller motor and the propeller bracket

Figure 2 presents the assembled CAD model of the wing, showing the skin panels and motor mounting supported by the bracket. The skin consists of five distinct panels designed to accommodate large deflections, estimated to be in the nonlinear range exceeding 20% of the model span during testing. Additionally, in Figure 2, it can be seen that the support bracket is designed to offset the motor vertically relative to the elastic axis. This support offers three positions: the propeller axis aligned with the spar's symmetry plane (neutral), 35 mm above, and 35 mm below the symmetric plane.

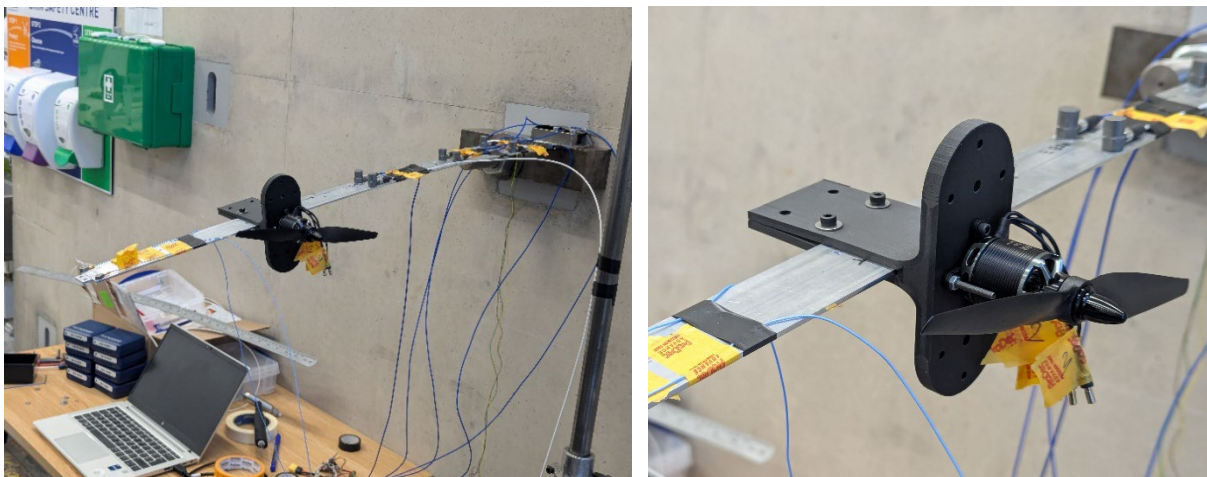


Figure 3 Experimental setup for PVT (left) and detail of the support bracket (right)

This is also illustrated in Figure 3 (right), displaying a photo of the motor and propeller in the neutral position of the support bracket. Preliminary tests have been performed on the spar using the setup shown in Figure 3 (left), which employed 8 accelerometers along the spar to capture the wing's modal response to propeller vibrations, as outlined in the new PVT method.

A preliminary analysis of the model has already been conducted to validate the method. Figure 4 presents the results of the LF identification process on the bare spar caused by propeller vibration input, with the motor positioned at the neutral point relative to the symmetric plane, 320 mm from the tip.

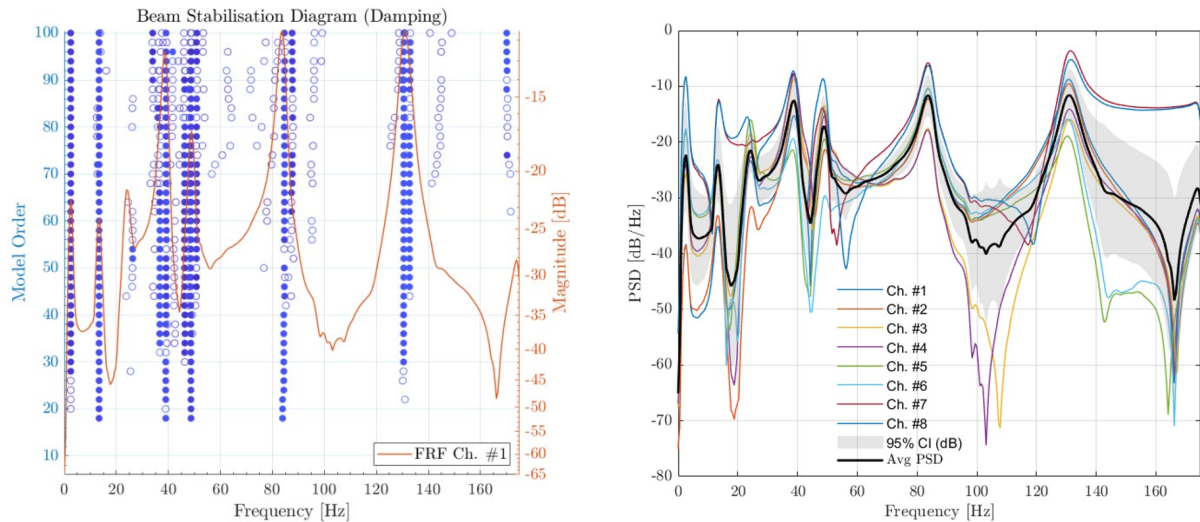


Figure 4 Preliminary results: PVT modal identification with the motor at 320 mm from the tip and propeller axis in neutral position

Future work and materials that will be presented in the final paper

The final paper will expand on the previous work to validate the PVT method. A new PVT campaign will be conducted to analyse the wing's modal response, including the skin. Specifically:

- The set of results will be extended to different positions of the propeller along the spar and to different vertical offsets of the motor
- The PVT will also include different motor RPMs to study the sensitivity of the method to the magnitude of the input

A wind tunnel test campaign is scheduled for February 2026 at UWE Bristol's 7x5 ft subsonic wind tunnel. The wing's aeroelastic response will be analysed across various velocities, motor RPMs, and positions. Typically, such analyses utilise algorithms like ERA to determine modal properties, but for this test, a novel (within wind tunnel testing) approach using the NExT-LF method will be employed. The modal results will also help define an experimental flutter boundary for the wing, applying LF to the flutter margin method as outlined by Zimmerman (Zimmerman et al., 1964) Figure 5 presents a preliminary estimate of the flutter speed for a 2-DOF model, approximately 64.4 m/s.

References:

G. Dessena, M. Civera, A. Yousefi, and C. Surace, 'NExT-LF: A Novel Operational Modal Analysis Method via Tangential Interpolation', *Int Journal of Mech Sys Dyn*, vol. 5, no. 3, pp. 401–414, May 2025, doi: 10.1002/msd2.70016.

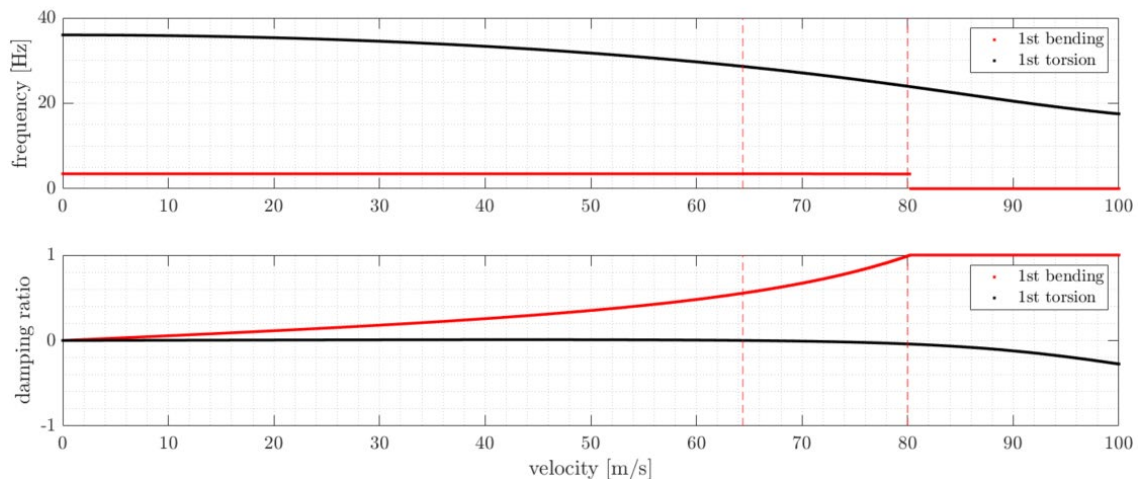


Figure 5 Wing flutter estimation based on a 2-DOF system

G. Dessena and A. Pontillo, 'Modal Parameter Extraction via Propeller-Driven Vibration Testing', 2026, arXiv. doi: 10.48550/arXiv.2601.08123.

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