Development of a Characterization Methodology for Composite Plates in UAV Wing Applications

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NSF NHERI CYBER-PHYSICAL SIMULATION

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Purpose

To develop characterization methodologies for custom composite plates in fixed-wing UAV wing applications

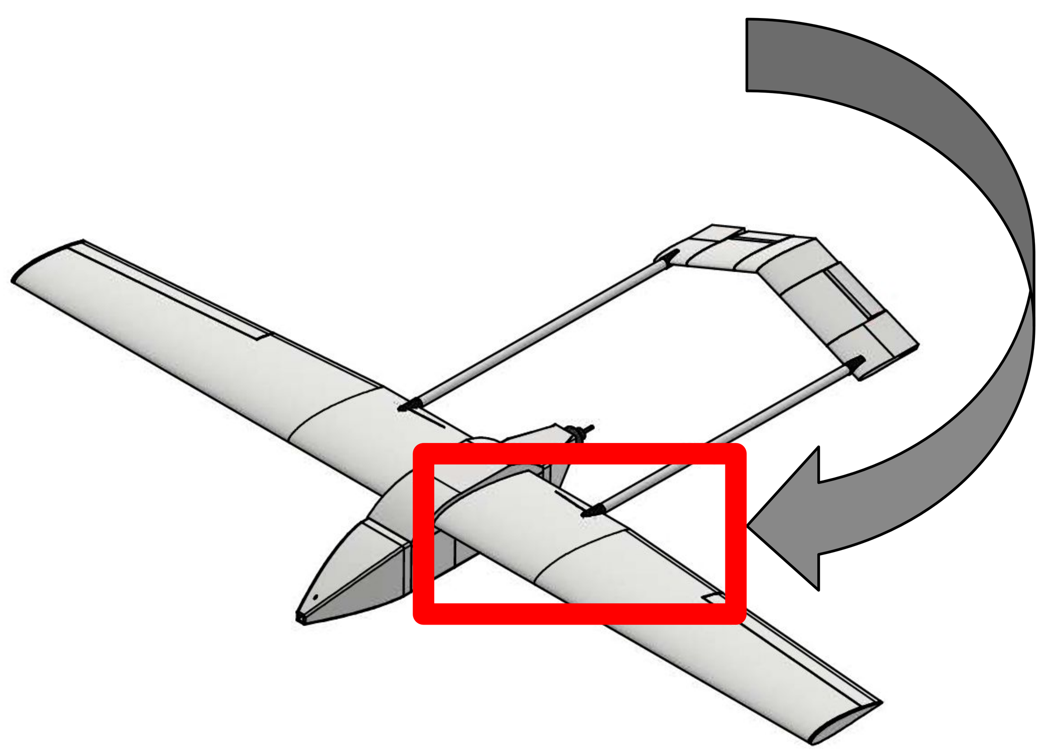

Fig. 1. Fixed-wing UAV model (ARTS-Lab, 2025)

Introduction

- UAVs excel in remote field work (Adawy et al., 2023)
- Composites have increasingly important role in aircraft design optimization
  - Including structural batteries (Jin et al., 2023)
- Aircraft are subject to extensive testing to uphold flight standards (Blasi et al., 2021)
- *A characterization protocol will create a GFRP property database*

Background

- Currently, aerospace composite work is focused on carbon fiber (CFRP)
- Strength-to-weight ratios are key
- Fiberglass (GFRP) composites offer similar properties, but are lower cost and easier to assemble (Ashrith et al., 2023)
- Structural battery composites further aid in design optimization (Jin et al., 2023)

Preliminary Results: *Error of 7.7%!*

STATIC:

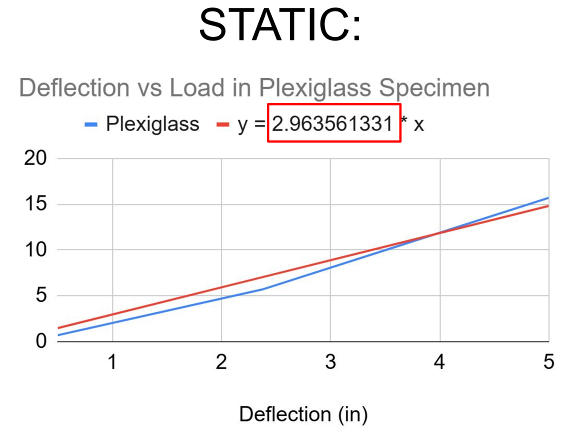

Fig. 2. Graphical least squares estimation of deflection data

DYNAMIC:

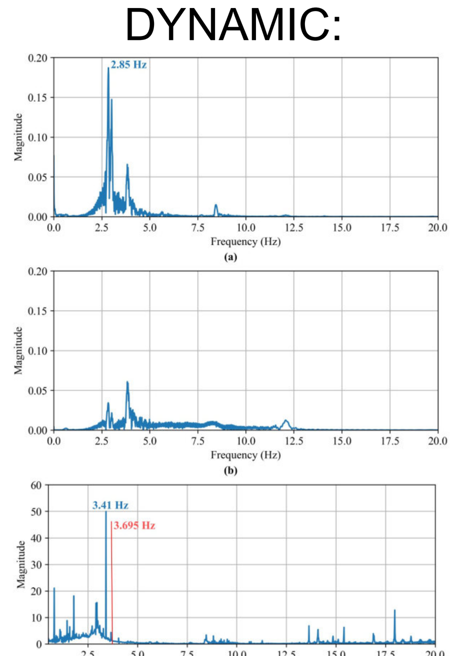

Fig. 3. FFT ratio of plexiglass modal data

Static Characterization

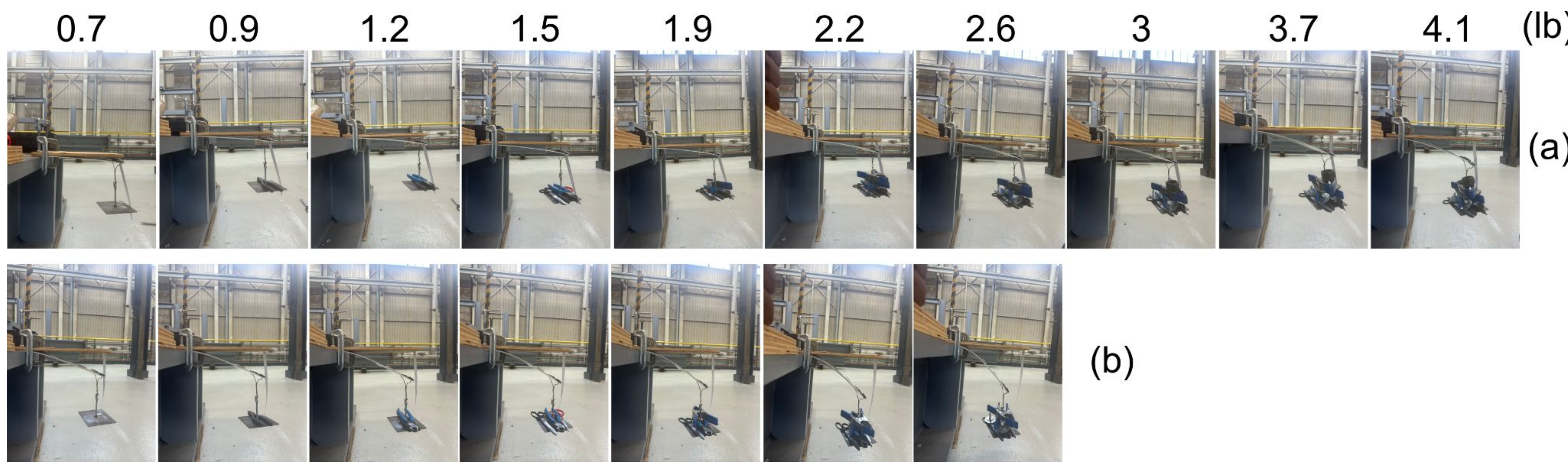

Fig. 4. Sequential load in static characterization set up on (a) control composite and (b) structural battery

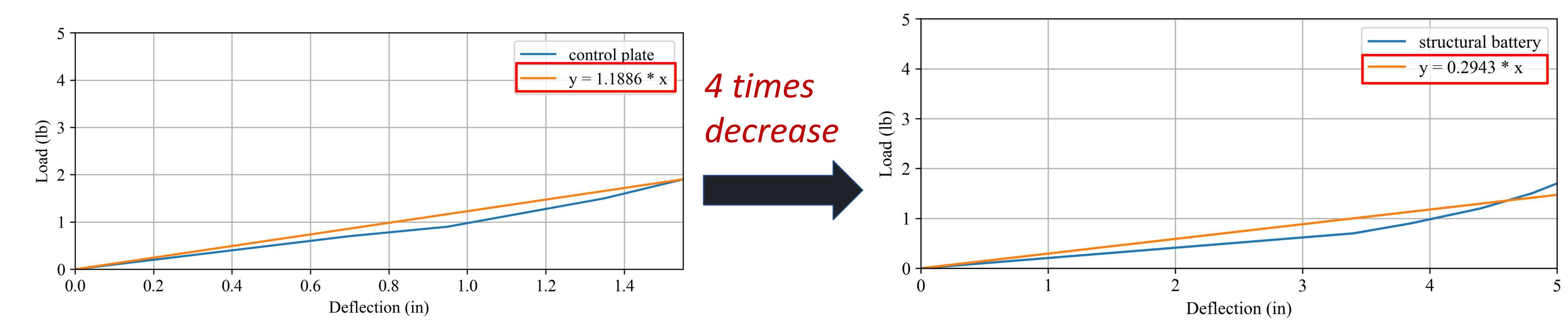

Fig. 5. Stiffness comparison between structural battery and control composite

Methodology

STATIC CHARACTERIZATION

Take weights and measure tip deflections

Generate y=k*x curve using least squares

Identify stiffness, k

Calculate natural frequency

DYNAMIC CHARACTERIZATION

Apply sine wave sweep to shake table

Record base and tip accelerations

Analyze FFTs for natural frequency, f

Compare experimental vs theoretical value

Identifies stiffness,

$$k = \frac{F}{\Delta} = \frac{3EI}{l^3}$$

Identifies natural frequency,

$$f = \frac{3.5156}{2\pi}\sqrt{\frac{k * g}{3 * W}}$$

Dynamic Characterization

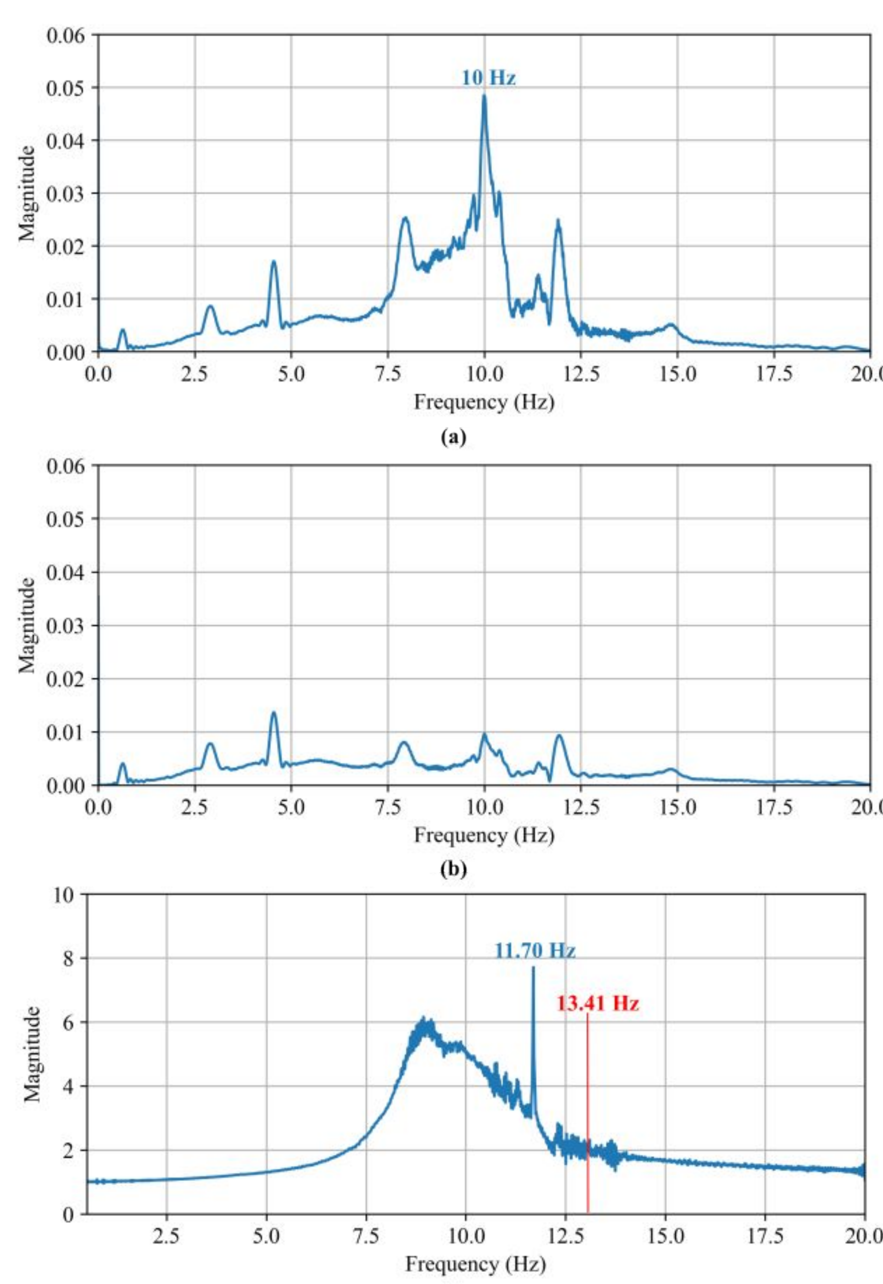

Fig. 9. Control composite FFTs showing (a) plate response, (b) table response, and (c) their ratio with theoretical comparison

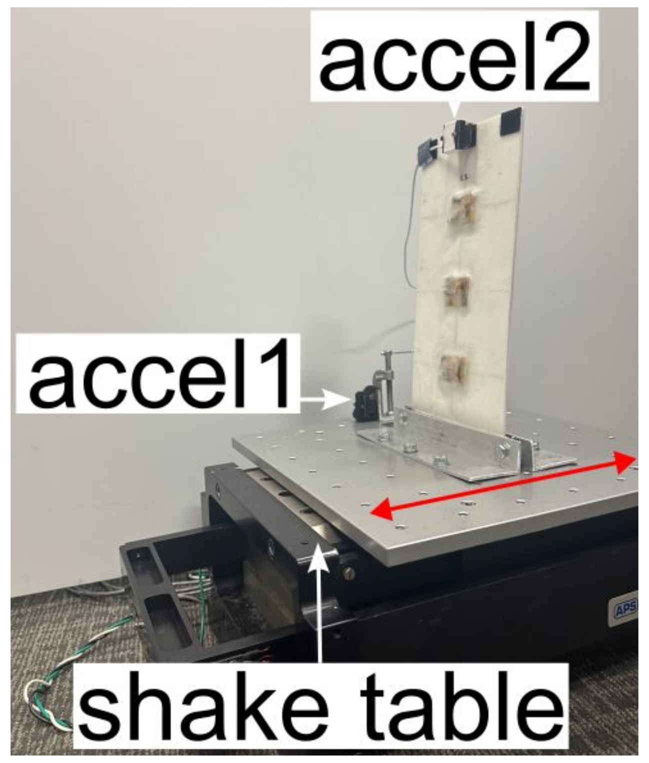

Fig. 7. Labeled modal characterization set up

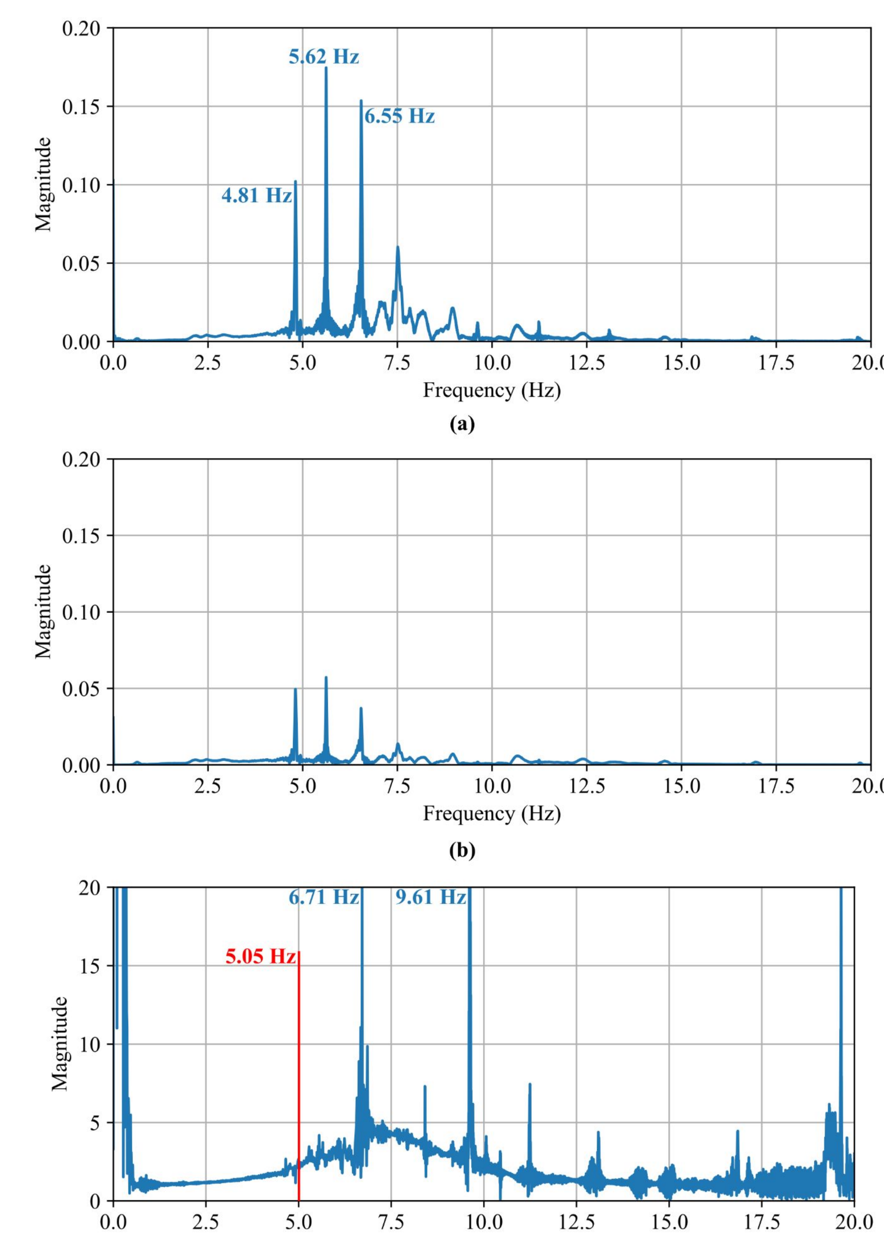

Fig. 10. Structural battery composite FFTs showing (a) plate response, (b) table response, and (c) their ratio with theoretical comparison

Conclusion

- Method validated by accurate results
- Groundwork for future testing & UAV design
- Additional testing needed
  - Reasons for false peaks, frequency leakage
  - Effects of composite composition, delamination

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Acknowledgments

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