Mitigating Rotorcraft Interior Noise: Stiffened Composite Panels with Integrated Acoustic Black Holes

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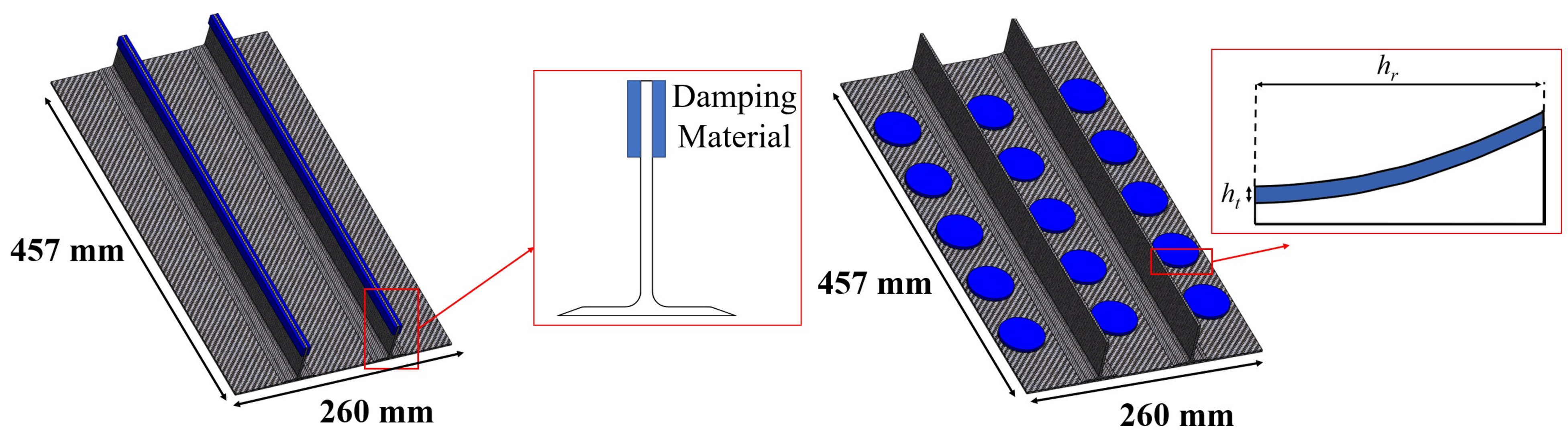
Introduction

Vertical flight vehicles have many high amplitude noise sources (engine/gearbox tones and aerodynamically induced noise), which can be efficiently radiated to the interior of the aircraft through composite airframes, causing hearing damage to pilots or passengers. By incorporating acoustic black holes into the blade stiffened panels used for the fuselage, a passive noise reduction can be attained with minimal tradeoffs to mass or structural integrity.

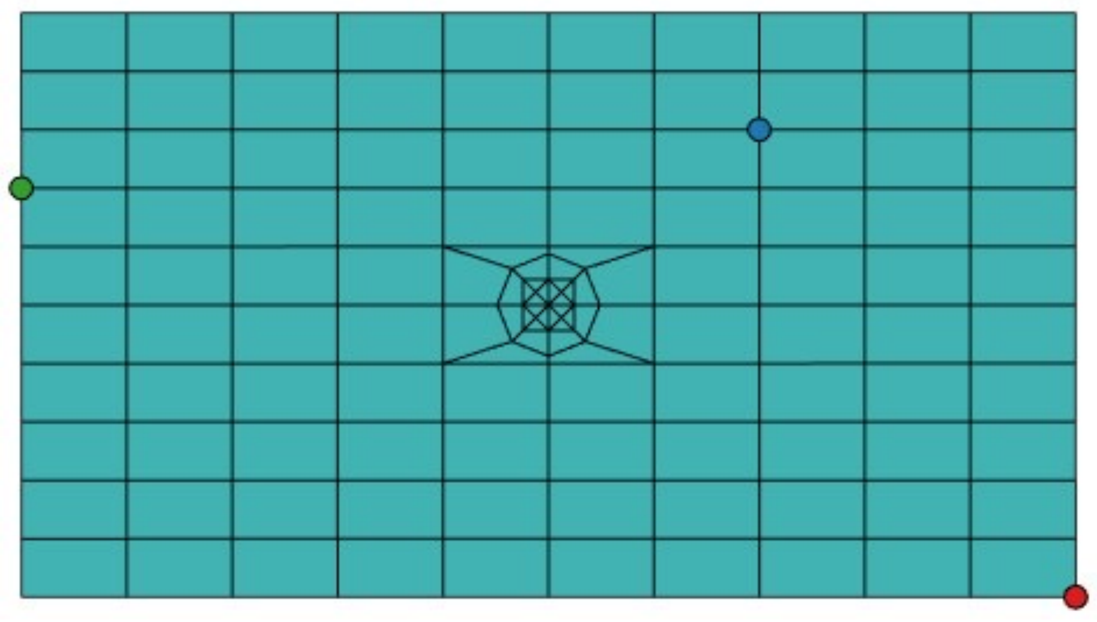
Acoustic Black Hole Designs

Formally, an acoustic black hole (ABH) involves a variation in a structure's geometric properties by a power law taper with a viscoelastic damping material to dissipate elastic energy from the acoustic wave. Several designs of ABHs were considered for the application in blade stiffened panels. For the grid of ABHs implemented in the plate, a parametric study was conducted using finite element analysis to determine an optimal grid spacing, ABH geometry, and viscoelastic layer. Similarly, for the ABH tapered blade stiffener, a study compared different tapers and damping levels to find an ideal design. Panel mass and buckling strength were simulated in addition to the acoustic metric of integrated velocity response (IVR).



Methodology

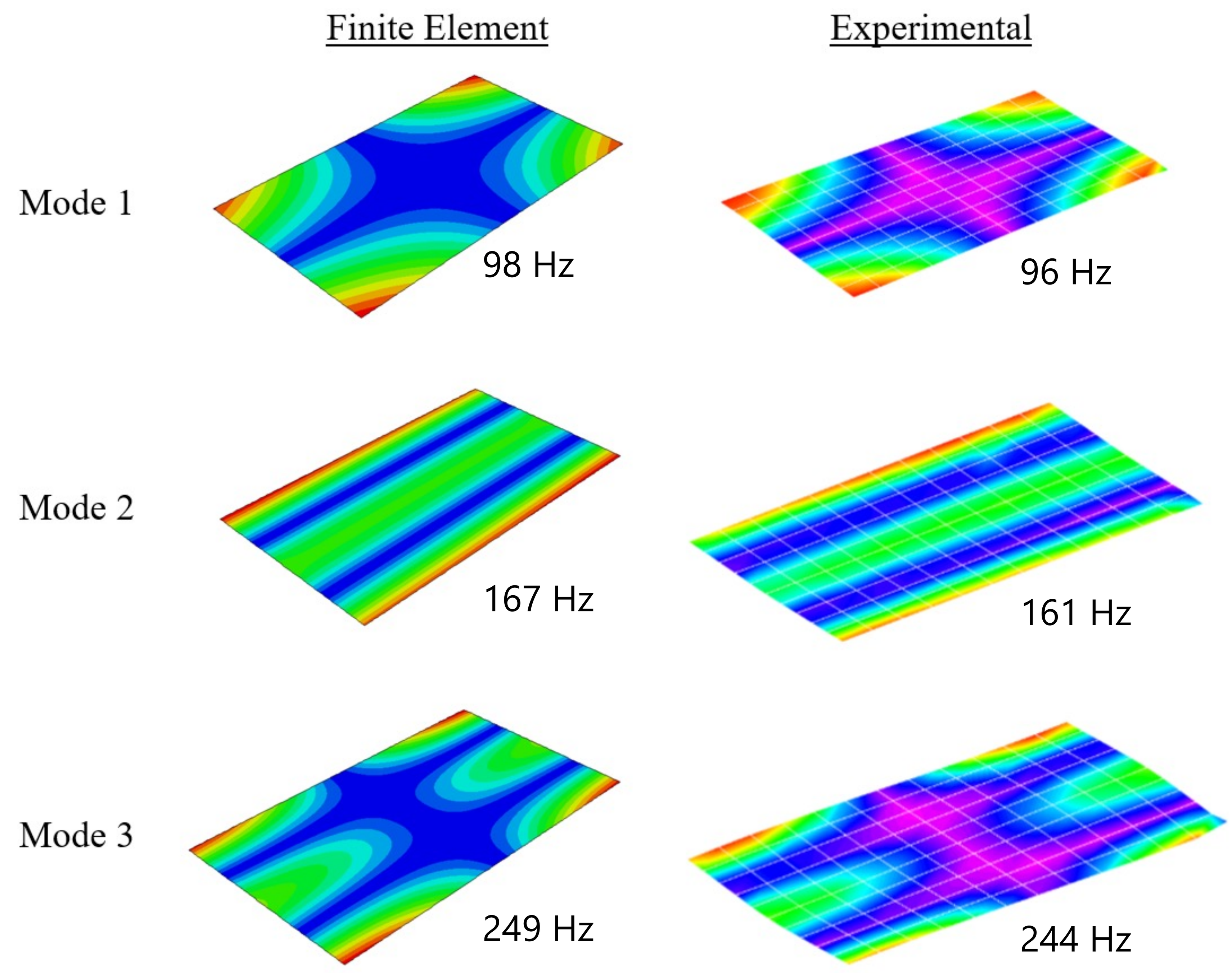
From the finite element geometries, composite panels were manufactured to experimentally validate acoustic results and undergo buckling and fatigue testing. To determine the IVR, modal analysis was performed using an impact hammer and accelerometers corresponding to the hit-point grid below.



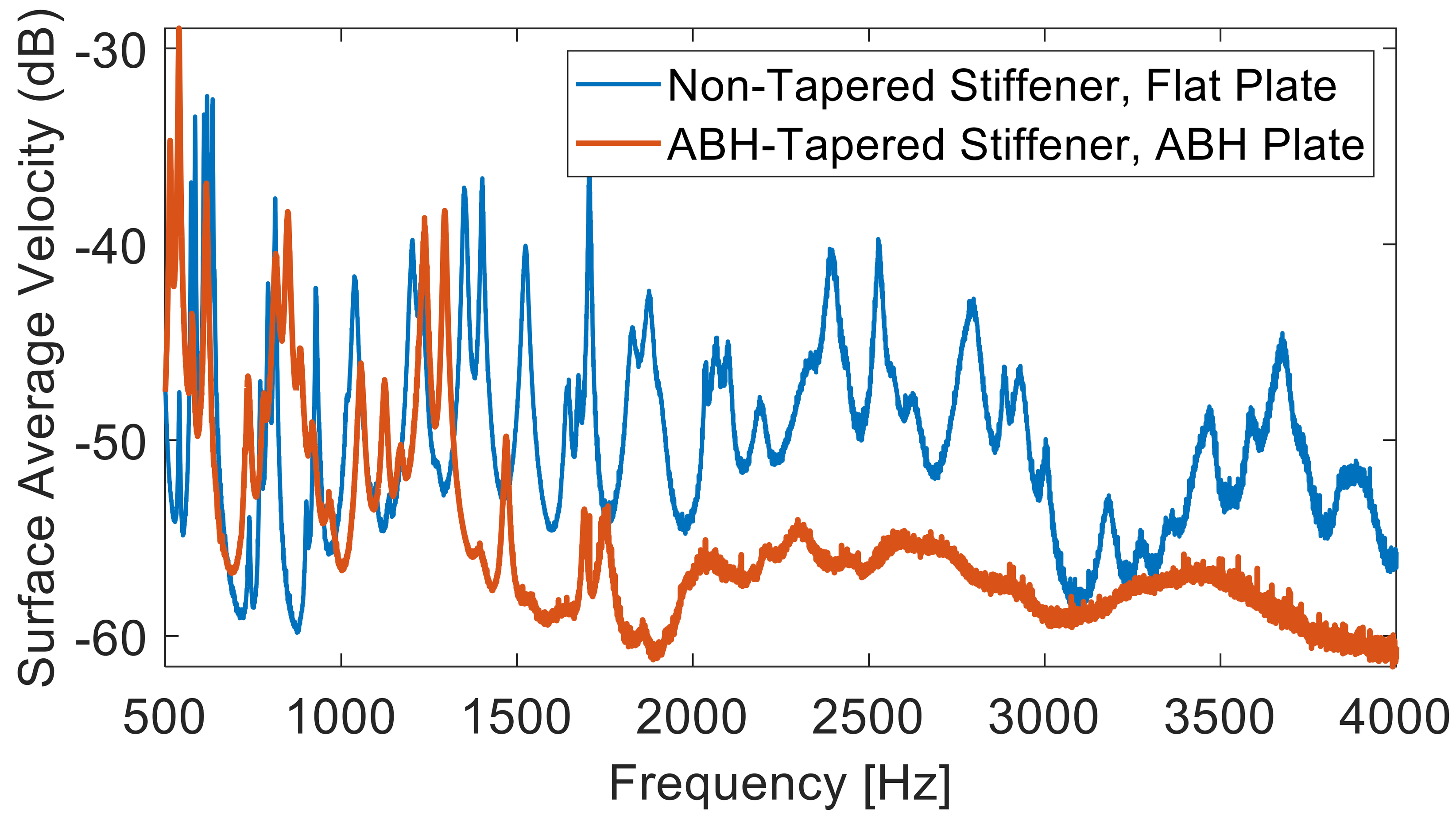
With the modal testing data, the mode shapes, resonance frequencies, surface averaged mobility, and IVR could be compared to determine the design's acoustic effectiveness.

Results

A comparison of finite element and experimental mode shapes (and their corresponding resonant frequencies) demonstrates a high level of correlation that extends through the first ~8 modes.



The surface averaged velocity allows the damping effect of the ABHs to be visualized. Above 1500 Hz, distinct peaks can no longer be seen in the ABH design, and the mobility can be ~15 dB lower at certain frequencies.



The ABH designs gave varying IVR improvements with the best performing case reaching a ~6 dB reduction. The buckling strength improved by up to 2.9% for certain tapered blade stiffener designs and the mass across all panel designs was maintained below a 5% increase.

Future Objectives

- Explore panel designs which target certain narrowband frequencies and tones specific to rotorcraft noise
- Experimentally test panels using an excitation system that simulates flight conditions

Acknowledgements

This work was partially supported by the **PIPELINE**: **P**enn State **I**ntern **P**ipelin**E** **LI**nks to **N**avy **E**ngineering program, ONR grant #N000142312656. The Penn State PIPELINE Program motivates and connects students and faculty to careers and research opportunities with the Navy technical workforce.