INVESTIGATION OF SOUND AND VIBRATIONAL PERFORMANCE OF SANDWICH COMPOSITE STRUCTURES THROUGH WAVE NUMBER ANALYSIS

J. Sargianis (MSME), H.I. Kim, J. Suhr

University of Delaware . Center for Composite Materials . Department of Mechanical Engineering

MOTIVATION

- Capitalizing on their high stiffness and strength- to-weight ratio, *aerospace structures utilize composite and sandwich structures* in their design.
- While these structures are mechanically superior, their acoustic properties are undesirable since they *radiate noise more efficiently at lower vibrational frequencies (1000-2000Hz)* compared to homogenous metals (>4000Hz).
- Therefore it is critical to *fundamentally understand wave speeds in sandwich structures* in order to *develop new structures* to mitigate noise propagation.

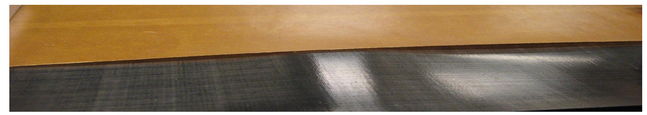
MATERIALS AND APPLICATIONS

(Courtesy of Boeing)

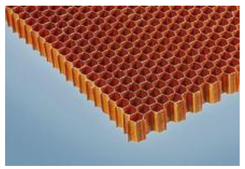
- Engine blade rotation, turbulent air flow, and wing flapping are the primary causes for vibrations.
- Since these vibrations reach frequencies well over 2000Hz*, noise radiation is a problem on commercial aircraft, as well as other applications*

- Common materials* in sandwich structures are:

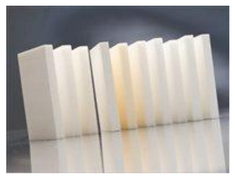
Carbon Fiber and Glass Fiber Epoxy Face Sheets



Nomex™/Kevlar Honeycomb Core



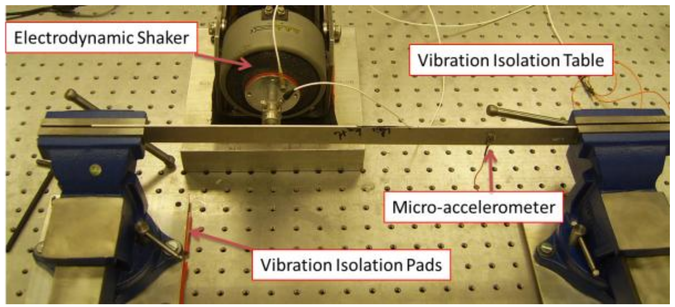
Rohacell® Foam



*Materials provided by Boeing/M.C. Gill Corp

EXPERIMENTAL SETUP

- System utilizes a vibration isolation table to mitigate environmental vibrations.
- The goal is to measure the *coincidence frequency*, where the *structural wave speeds become supersonic and radiate noise efficiently*
- A micro-accelerometer measures the output acceleration, while an impedance head measures the input force.



WAVE NUMBER DOMAIN METHOD

- The *Frequency Response Function* is measured at 64 equidistant points along the beam.
- Using a Fourier Transform, this data transforms to the wave number (k) domain, yielding a *dispersion curve.*
- The *relation* between *wave number* and *wave speed* is seen below:

$$k = \frac{\omega}{c}$$

k = Wave number
ω = Frequency (Hz)
c = Wave speed

- The *coincidence frequency* is where the *dispersion curve intersects the speed of sound.*

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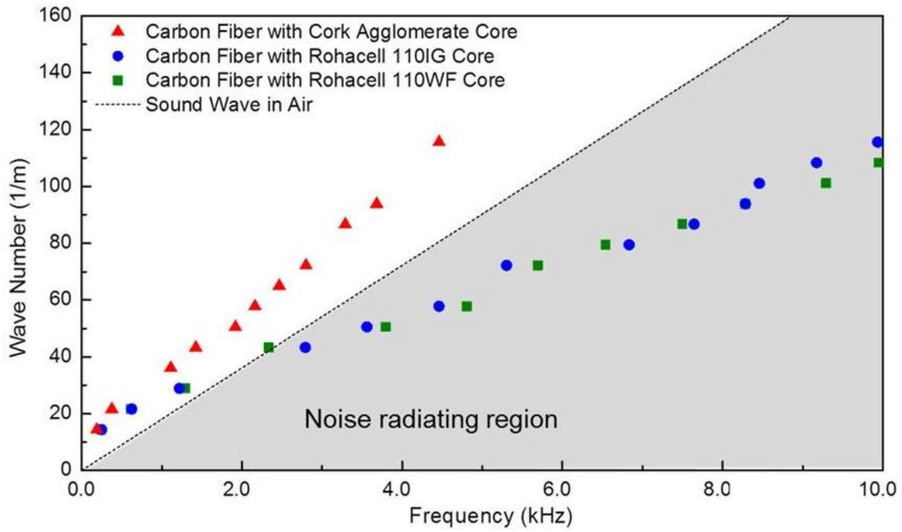
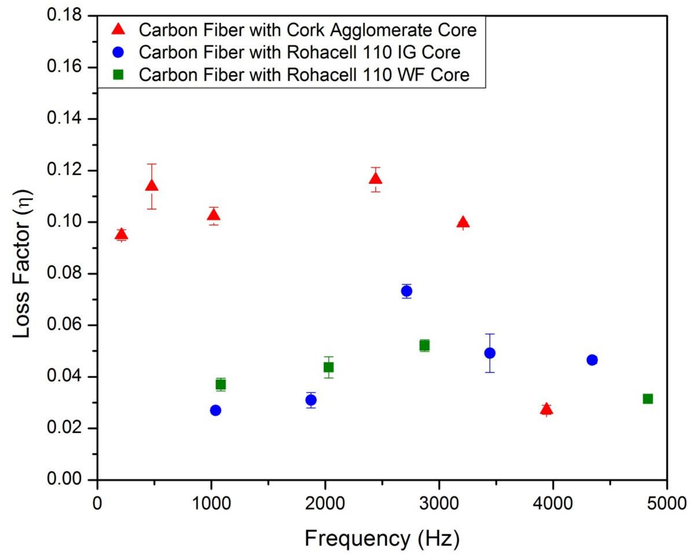
Continued

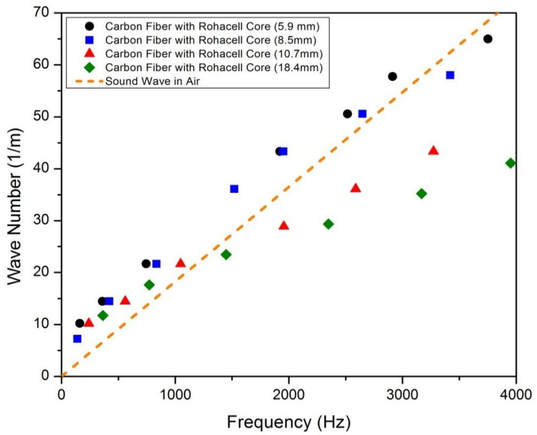
CORK AGGLOMERATE CORE SANDWICH COMPOSITES

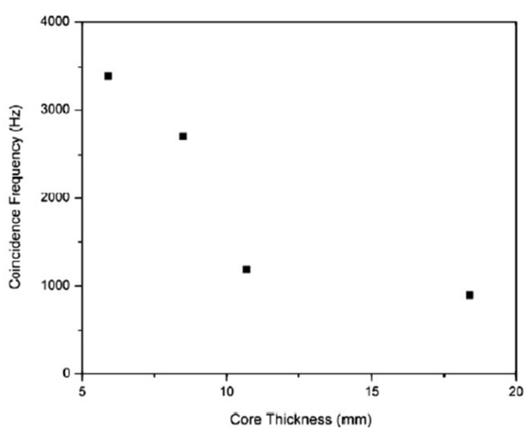




- Utilizing cork agglomerate as a core material in a sandwich structure provides unprecedented improvements in acoustic performance, showing no coincidence frequency in a 10 kHz range.
- Moreover, the cork agglomerate core beam showed up to 200% improvement in structural damping in low frequency ranges. These vibrational responses are often difficult to mitigate.

CORE THICKNESS EFFECT ON COINCIDENCE FREQUENCY





Sargianis, J., Suhr, J. “Effect of core thickness on wave number and damping properties in sandwich composites.” *Composites Science and Technology*, 72:724-730 (2012)

CONCLUSIONS

- The properties and geometry of the core material can have the most drastic effect on the acoustic and vibrational performance of sandwich composites.
- The relationship between core thickness and coincidence frequency is non-linear.
- Cork may provide a solution to the sandwich structure-noise radiation problem due to its unique mechanical properties and energy absorption capabilities.

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