Adaptive Back Sheet Material for Acoustic Liner Application

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Outline

• Background
• Description of Piezo-electric Composite
• Results to Date
  – Mechanical
  – Acoustic
  – Lessons Learned
• Summary and Conclusions
• Next Steps
The Challenge

Aircraft Engine Nacelle

- Engine size increases
- Frequency of source decreases
- Nacelle treatment area decreases

=> Need to get more performance out of less acoustic liner
NARI

SDOF Liner - Solid Back Plane

⇒ Frequency of peak attenuation fixed by $L_1$
Proposed Liner with Compliant Back Plane

=> Compliant back plane can expand frequency range of attenuation
Objectives of Research

• Build samples coupons with piezoelectric material
• Determine acoustic and mechanical properties
• Estimate effect of material on liner attenuation
Candidate Material

- PBLG Piezoelectric Composite Film
  - Composed of an $\alpha$-helical polypeptide
  - Produced via corona charging to pre-align macroscopic dipoles along helical axis
  - Responds to external force (sensor)
  - Responds to electric field (actuator)
  - Responds at acoustic frequencies
- Developed at Johns Hopkins University Applied Physics Laboratory
Sample Coupons

Unencapsulated sample with electrode

Encapsulated sample (without electrode)
## Samples Evaluated

<table>
<thead>
<tr>
<th>Sample</th>
<th>Description</th>
<th>Electrode</th>
<th>Electrode size</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>JHS1</td>
<td>Composite film, no encapsulate</td>
<td>Cr-Au, evaporated</td>
<td>1”x1”</td>
<td>Functional</td>
</tr>
<tr>
<td>JHS2</td>
<td>Composite film, no encapsulate</td>
<td>Cr-Au, evaporated</td>
<td>1.75”x1.75”</td>
<td>Destroyed</td>
</tr>
<tr>
<td>JHS3</td>
<td>Composite film, encapsulated</td>
<td>No electrode</td>
<td>Na</td>
<td>Functional</td>
</tr>
<tr>
<td>JHS4</td>
<td>Composite film, no encapsulate</td>
<td>Conductive adhesive</td>
<td>1.75”x1.00”</td>
<td>Destroyed</td>
</tr>
<tr>
<td>JHS5</td>
<td>Composite film, encapsulated</td>
<td>No electrode</td>
<td>Na</td>
<td>Functional</td>
</tr>
</tbody>
</table>

**Table 1:** Cumulative list of samples received and the status from evaluating both standard un-encapsulated and encapsulated film samples.
Sample JHS2 after Failure

=> The un-encapsulated film was re-designed to offer samples with greater robustness
Evaluate Properties

• Acoustic Properties
  • Measure acoustic impedance
  • Measure impedance change with voltage excitation

• Mechanical Properties
  • Measure velocity response to voltage excitation
  • Measure velocity response to acoustic excitation
Set-up for Normal Impedance Testing

Normal Incidence Tube

Reference microphone

Sample

Piezo-electric sample in NIT
Impedance results from test set-up with encapsulated sample JHS3 evaluated with two-microphone method using broadband noise at 130 dB overall sound level.
Impedance results from test set-up with encapsulated sample JHS3 evaluated with two-microphone method using broadband noise at 130 dB overall sound level.
Calculated absorption of a perforate-over-honeycomb liner (core 1.50 in) compares rigid back wall to compliant back wall, JHS3.
Calculated absorption of a perforate-over-honeycomb liner (core 1.50 in) compares rigid back wall to compliant back wall, JHS3.

=> Compliant back wall adds to liner absorption
Piezoelectric Film as Sensor

Voltage from electrode of sample JHS1 with acoustic excitation at 1000 Hz

\[ V = 0.00082P \]
Piezoelectric Film as Actuator

Test set up for velocity measurement

Measured velocity of sample JHS1 with voltage excitation at 1500 Hz

=> Velocity response much less than expected acoustic particle velocity
Application of Active Compliant Back Wall

Calculated absorption coefficient of liner (core 1.5 in) with JHS1 backwall, compares power off to power on, 150 volt excitation
Application of Active Compliant Back Wall

Calculated absorption coefficient of liner (core 1.5 in) with JHS1 backwall, compares power off to power on, 150 volt excitation

=> Despite low authority, measurable change in liner absorption is indicated
Conclusions (Part 1 of 2)

• Developed liner samples for evaluation
  • Improved design to provide suitable robustness
• Developed experiments to evaluate the piezoelectric film samples
  • Measured mechanical properties
  • Measured acoustic properties
Conclusions (Part 2 of 2)

- Demonstrated that energizing the piezoelectric changes normal impedance in a controlled way
  - Current design lacks authority to alter impedance significantly.
- Developed mathematical model of liner absorption including compliant back wall
  - Model is semi-empirical
Next Steps – Phase I

• Incorporate piezoelectric into honeycomb structure
  • 2 in x 2 in sample for NIT
  • Estimate absorption of composite structure
  • Measure absorption to validate prediction
• Begin re-design of electrodes for greater authority
• Present results to date at Acoustics Technical Working Group
  • April 2013
  • October 2013
Next Steps – Phase II

• Improve electrode design
  • Increased authority
  • Incorporate in honeycomb structure
• Improve mathematical model of compliant wall effect
• Design, fabricate, and test active wall liner for Grazing Flow Impedance Tube
  • 2 inch x 24 inch liner sample size
  • Flow speed up to Mach 0.500
  • Tone and broadband sound input
Thank You

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