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Effect of Orientation of Fibers on the Acoustical Properties of a Natural Material

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Effect of Orientation of Fibers on the Acoustical Properties of a Natural Material

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Outline of Presentation

- Introduction
- Objectives
- Experimental Setup and Details
- Results
- Conclusions
- Past Related Research and Major Contributions
- Future Prospects
- Acknowledgements
Introduction

- Environmental noise disrupts the activity or balance of human or animal life.
- Most noise worldwide is due to vehicle, aircraft, rail, industry and indoor machinery.
- Due to increasing concerns over the problems of climate change and global warming, there has been an increased impetus for cleaner and greener technologies.

Green Materials:

- Sisal
- Coir
- Flax
- Hemp
Jute: Natural Acoustical Material

• Jute is a lignin-cellulose fibre which is composed primarily of the plant materials.
  ➢ cellulose (major component of plant fibre) and
  ➢ lignin (major components wood fibre).

• It falls into one of the bast fibre categories (fibre collected from bast or skin of the plant).

• It is specifically cultivated in large quantities in the eastern part of India and in Bangladesh.
Raw Jute to Fabricated Jute Derivatives

Jute Plant  |  Jute Fibre  |  Jute Strand  |  Jute Derivatives

Jute Fiber  |  Jute Felt  |  Treated Jute Felt  |  Jute Composite

View of jute felt

SEM images of jute felt

(a) under 129 x magnification

(b) under 1000 x magnification
Why Jute?

**Key Selection Attributes**
Natural, Eco-friendly, Biodegradable, Cost Effective, Self-Extinguishing

**Possible Applications**
Building Acoustics, Automobiles, Home Appliances, HVAC, Machinery Enclosure

**Physical and Acoustical Properties**
Excellent Fire Retardant Properties, High NRC and STC Values for Sound Attenuation
Motivation

• Jute based materials have a very good potential in noise controlling applications.

• Such materials can also be engineered for good fire retardant properties, structural strength and moisture proofing.

• Jute based materials (fiber, felt and composites) can be successfully used for noise control in household appliances like vacuum cleaner, domestic dryer, washing machine, dishwasher, and clothes dryer.
To explore the important physical properties of engineered natural materials for noise control and optimize them.
Flow Resistivity

- The flow resistivity of the jute felt was measured using a Mecanum Sigma-Airflow resistance meter as per ASTM C 522-03.

- The measured flow resistivity of 3 mm jute felt samples fell within the range of 20000 MKS Rayls/m to 27000 MKS Rayls/m.

- The flow resistivity was measured only in the direction normal to the layer surface.

View of jute felt
Experimental Setup and Details
Transfer Matrix Method

1. Measure sound pressure

\[ P_1 = (Ae^{-jkx_1} + Be^{jkx_1})e^{j\omega t} \]
\[ P_3 = (Ce^{-jkx_3} + De^{jkx_3})e^{j\omega t} \]

2. Calculate and solve transfer matrix using 2 load methods

\[ A = \frac{jP_1e^{jkx_1} - P_2e^{jkx_1}}{2\sin k(x_1 - x_2)} \]
\[ B = \frac{jP_2e^{-jkx_2} - P_1e^{-jkx_2}}{2\sin k(x_1 - x_2)} \]
\[ C = \frac{jP_3e^{jkx_3} - P_4e^{jkx_3}}{2\sin k(x_3 - x_4)} \]
\[ D = \frac{jP_4e^{-jkx_4} - P_3e^{-jkx_4}}{2\sin k(x_3 - x_4)} \]

\[ \begin{bmatrix} P_{(a)} & P_{(b)} \\ V_{(a)} & V_{(b)} \end{bmatrix}_{x=0} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \begin{bmatrix} P_{(a)} & P_{(b)} \\ V_{(a)} & V_{(b)} \end{bmatrix}_{x=d} \]

3. Obtain

\[ R_a = \frac{T_{11} + (T_{12}/\rho c) - \rho cT_{21} - T_{22}}{T_{11} + (T_{12}/\rho c) + \rho cT_{21} + T_{22}} \]
\[ R_h = \frac{T_{11} + \rho cT_{21}}{T_{11} + \rho cT_{21}} \]

\[ TL = 20\log_{10} \left| \frac{1}{T} \right| \]
\[ \alpha = 1 - |R|^2 \]
Orientation of Stack of Jute Felt in two Configurations.

- Normal incidence

- Grazing incidence

Density and mass of stacked 6.25 cm x 6.25 cm jute felt.

<table>
<thead>
<tr>
<th>No. of layers of jute felt</th>
<th>Sample length (m)</th>
<th>Mass (kg)</th>
<th>Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.06</td>
<td>0.0016</td>
<td>111.1</td>
</tr>
<tr>
<td>12</td>
<td>0.06</td>
<td>0.022</td>
<td>95.64</td>
</tr>
<tr>
<td>24</td>
<td>0.12</td>
<td>0.38</td>
<td>82.60</td>
</tr>
<tr>
<td>36</td>
<td>0.18</td>
<td>0.060</td>
<td>85.71</td>
</tr>
</tbody>
</table>
Measured Sound Absorption Coefficient of Jute Felts in Both the Orientations - Anechoic Case.

a) 0.06m

b) 0.12m

c) 0.18m
Measured Transmission Loss of Jute Felts in Both the Orientations.

a) 0.06m

b) 0.12m

c) 0.18m
Measured NRC and STC of the Jute Felt Stacks-Anechoic Case.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Noise reduction coefficient (NRC)</th>
<th>Sound transmission class (STC)[dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jute felt 0.06m,Normal</td>
<td>0.89</td>
<td>6</td>
</tr>
<tr>
<td>Jute felt 0.06m,Grazing</td>
<td>0.94</td>
<td>3</td>
</tr>
<tr>
<td>Jute felt 0.12m,Normal</td>
<td>0.87</td>
<td>11</td>
</tr>
<tr>
<td>Jute felt 0.12m,Grazing</td>
<td>0.94</td>
<td>6</td>
</tr>
<tr>
<td>Jute felt 0.18m,Normal</td>
<td>0.88</td>
<td>16</td>
</tr>
<tr>
<td>Jute felt 0.18m,Grazing</td>
<td>0.95</td>
<td>9</td>
</tr>
</tbody>
</table>
Measured Sound Absorption Coefficient of Jute Felts in Both Termination-Normal Case.

a) 0.06m

b) 0.12m

c) 0.18m
Measured Sound Absorption Coefficient of Jute Felts in Both Termination-Grazing Case.

a) 0.06m

b) 0.12m

c) 0.18m
Measured Sound Absorption Coefficient of Jute Felts in Both the Orientations - Hard Case.

a) 0.06m

b) 0.12m

c) 0.18m
# Measured NRC of the Jute Felt Stacks in Both Termination.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Noise reduction coefficient (NRC), Anechoic backing</th>
<th>Noise reduction coefficient (NRC), Hard backing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jute felt 0.06m,Normal</td>
<td>0.89</td>
<td>0.69</td>
</tr>
<tr>
<td>Jute felt 0.06m,Grazing</td>
<td>0.94</td>
<td>0.61</td>
</tr>
<tr>
<td>Jute felt 0.12m,Normal</td>
<td>0.87</td>
<td>0.88</td>
</tr>
<tr>
<td>Jute felt 0.12m,Grazing</td>
<td>0.94</td>
<td>0.88</td>
</tr>
<tr>
<td>Jute felt 0.18m,Normal</td>
<td>0.88</td>
<td>0.89</td>
</tr>
<tr>
<td>Jute felt 0.18m,Grazing</td>
<td>0.95</td>
<td>0.94</td>
</tr>
</tbody>
</table>
Conclusions

• Jute and its derivatives in the form of chopped pieces, fibers, felts, yarns, textile and composite panels can be used in various noise control applications.

• Jute felt composed of natural fibers is anisotropic and so the felt’s sound absorption coefficient and transmission loss differ for the case of grazing and normal incidence—significant in duct lining applications.

• This study can help the analytical model developer to make appropriate acoustical models for studying the sound absorption and transmission loss of jute-like natural fiber materials.
Past Related Research and Major Contributions so Far.

Noise Control of Domestic Appliances by Jute Based Materials

Measured properties of jute
- Characteristics of jute
- Physical properties
- Fire retardant properties
- Acoustical properties

Pilot trials done on household appliances
- Vacuum cleaner
- Dryer

Future Prospects

• It will open a new paradigm in eco-friendly materials for noise control application.

• Application of these materials will increase the market share and help the farmers cultivating such plants.

• This research can be taken forward to use materials from bio-waste and plant waste in making acoustical materials for noise control.
Acknowledgments

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References


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THANK YOU!