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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

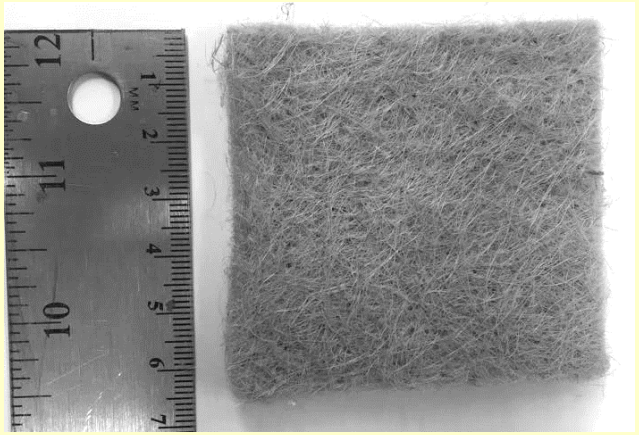
Jute Felt

Treated Jute Felt

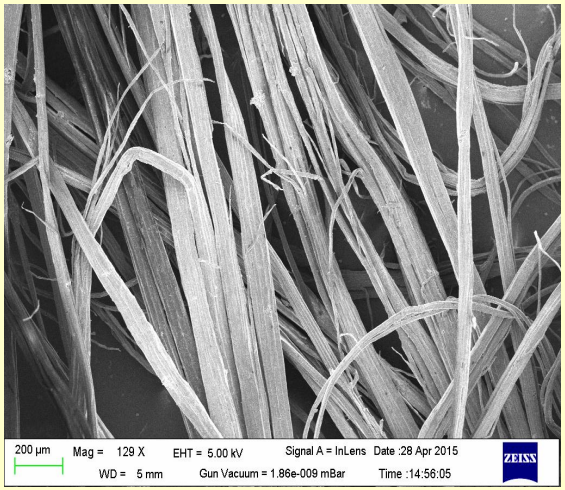
Jute Composite

A. R. Mohanty and S. Fatima, "Biocomposites for Industrial Noise Control" in the book "Biocomposites: Fundamentals to Industrial Applications" Editors V. K. Thakur and M. Kessler, CRC Press (ISBN: 9781771880329) 2014.

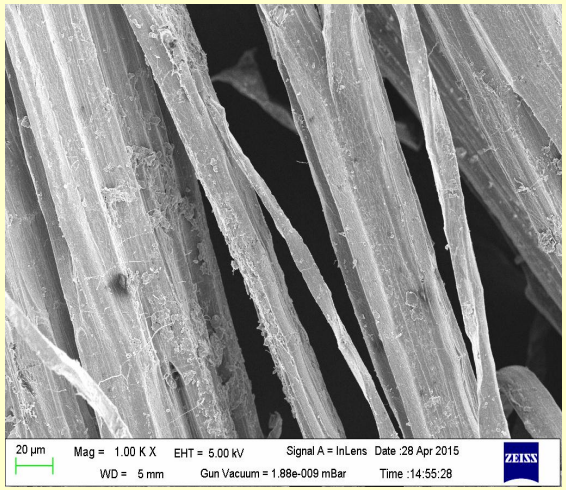
View of jute felt



SEM images of jute felt



(a) under 129 x magnification



(b) under 1000 x magnification

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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.**

Objectives

To explore the important physical properties of engineered natural materials for noise control and optimize them.

Flow Resistivity

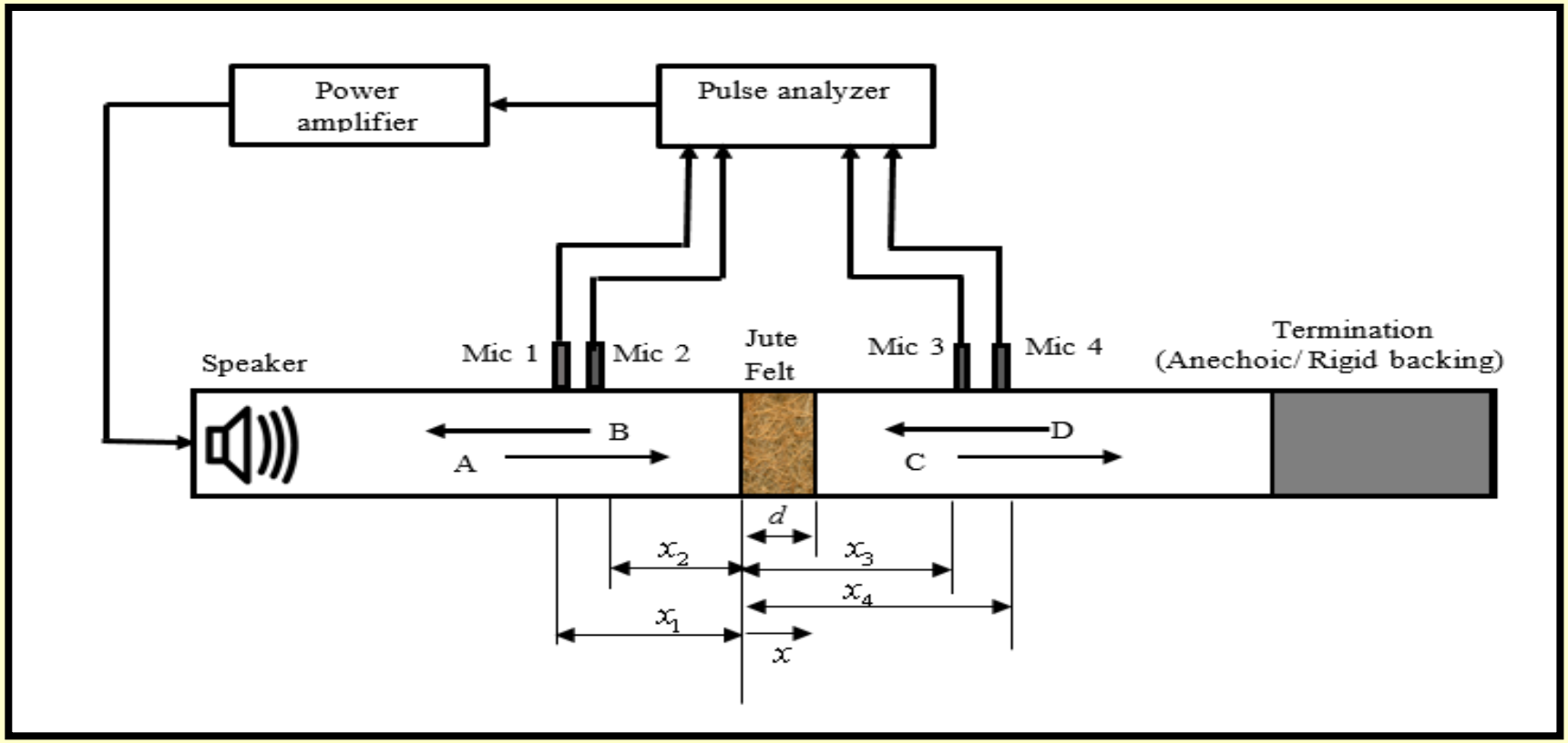
- **The flow resistivity of the jute felt was measured using a Mecanum Sigma-Airflow resistance meter as per ASTM C 522-03.**

- **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

$$P_1 = (Ae^{-jkx_1} + Be^{jkx_1})e^{j\omega t} \qquad P_2 = (Ae^{-jkx_2} + Be^{jkx_2})e^{j\omega t}$$

$$P_3 = (\mathrm{C}e^{-jkx_3} + De^{jkx_3})e^{j\omega t} \qquad P_4 = (\mathrm{C}e^{-jkx_4} + De^{jkx_4})e^{j\omega t}$$

2. Calculate and solve transfer matrix using 2 load methods

$$A = \frac{jP_1e^{jkx_2} - P_2e^{jkx_1}}{2\sin k(x_1 - x_2)} \qquad B = \frac{jP_2e^{-jkx_1} - P_1e^{-jkx_2}}{2\sin k(x_1 - x_2)}$$

$$C = \frac{jP_3e^{jkx_4} - P_4e^{jkx_3}}{2\sin k(x_3 - x_4)} \qquad D = \frac{jP_4e^{-jkx_3} - P_3e^{-jkx_4}}{2\sin k(x_3 - x_4)}$$

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

3. Obtain

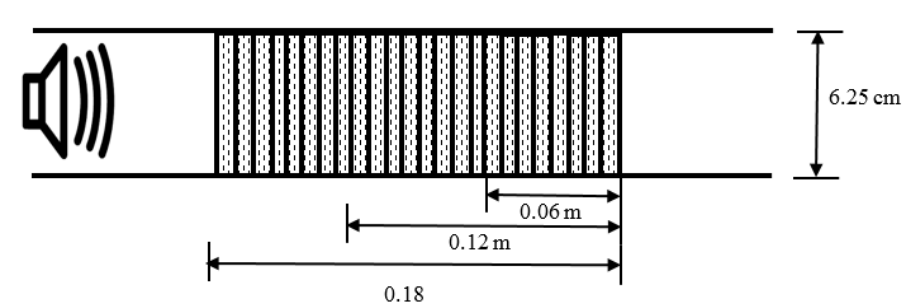
$$R_a = \frac{T_{11} + (T_{12}/\rho c) - \rho c T_{21} - T_{22}}{T_{11} + (T_{12}/\rho c) + \rho c T_{21} + T_{22}} \quad , \quad R_h = \frac{T_{11} + \rho c T_{21}}{T_{11} + \rho c T_{21}}$$

$$TL = 20\log_{10}\left|\frac{1}{T}\right|$$

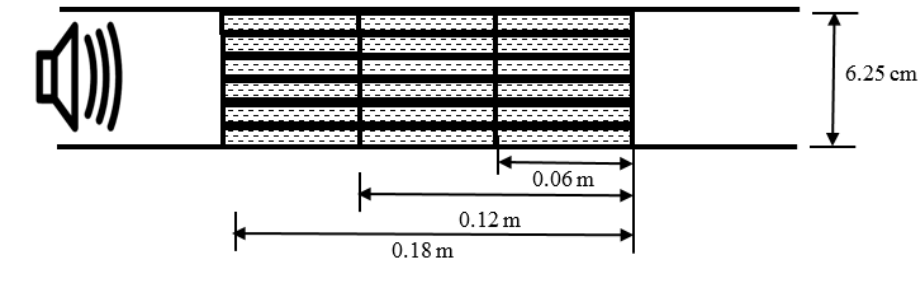
$$\alpha = 1 - |R|^2$$

Orientation of Stack of Jute Felt in two Configurations.

- **Normal incidence**



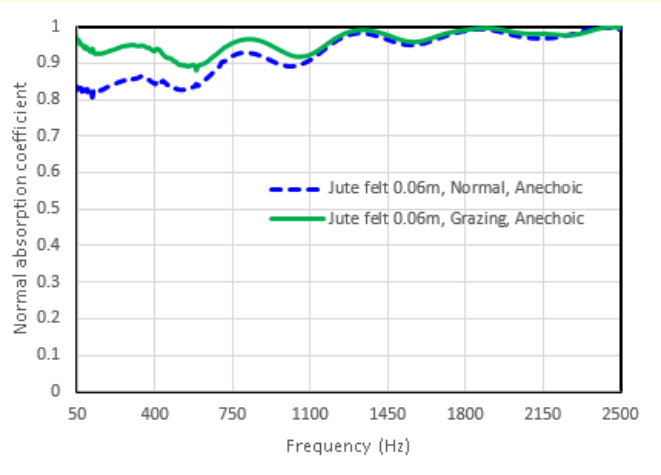
- **Grazing incidence**



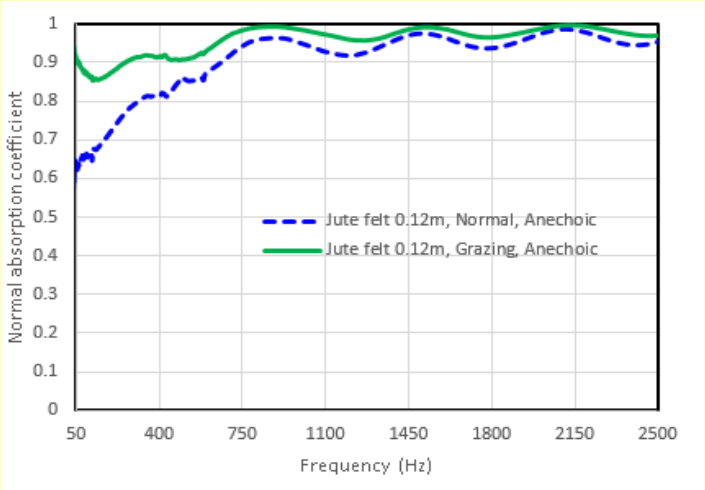
Density and mass of stacked 6.25 cm x 6.25 cm jute felt.

No. of layers of jute felt	Sample length (m)	Mass (kg)	Density (kg/m^3)
1	0.06	0.0016	111.1
12	0.06	0.022	95.64
24	0.12	0.38	82.60
36	0.18	0.060	85.71

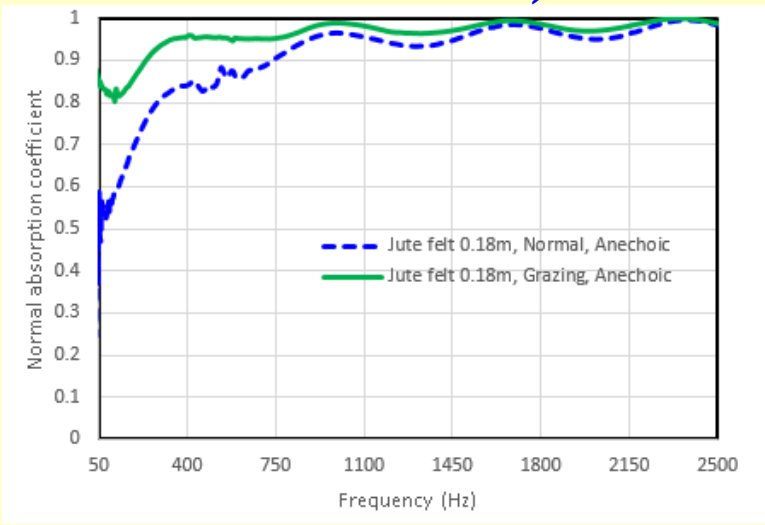
Measured Sound Absorption Coefficient of Jute Felts in Both the Orientations -Anechoic Case.



a) 0.06m



b) 0.12m



c) 0.18m

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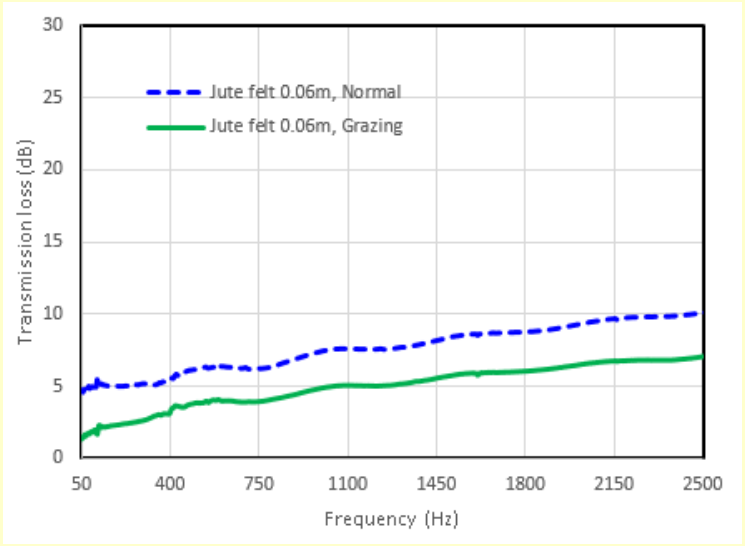
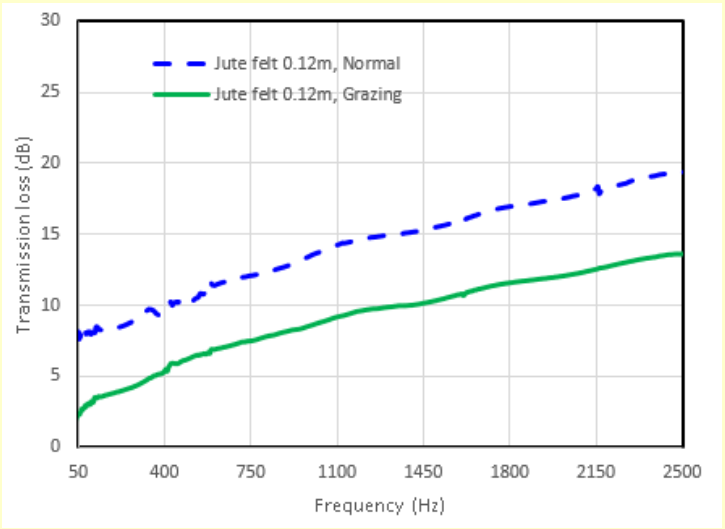
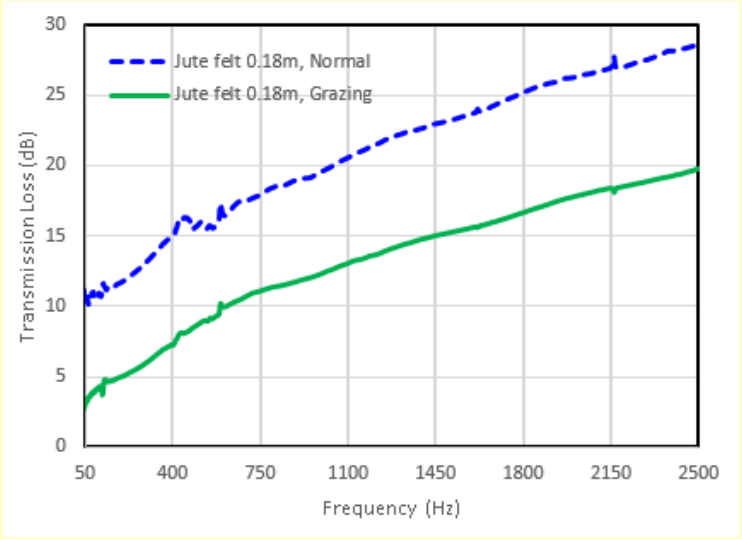
Measured Transmission Loss of Jute Felts in Both the Orientations.



a) 0.06m



b) 0.12m



c) 0.18m

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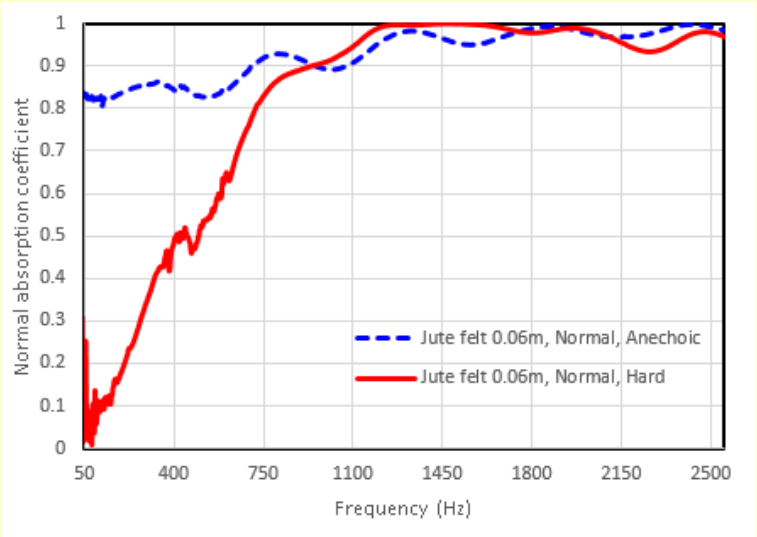
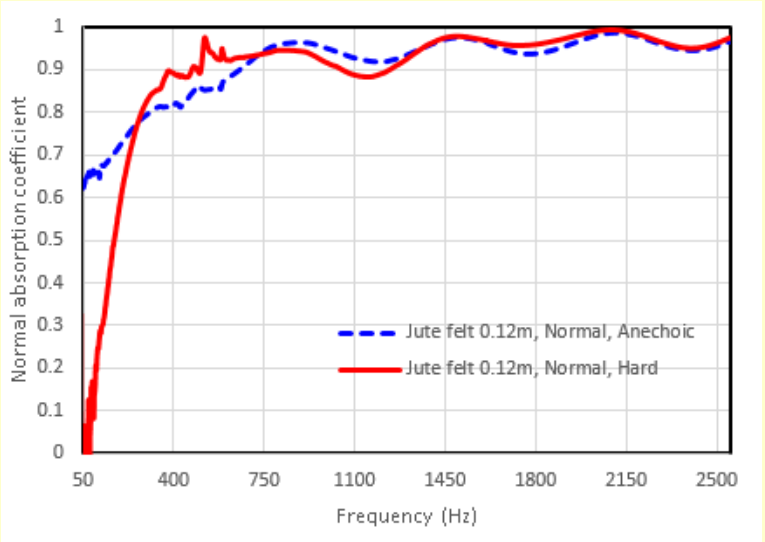
Measured NRC and STC of the Jute Felt Stacks-Anechoic Case.

Samples	Noise reduction coefficient (NRC)	Sound transmission class (STC)[dB]
Jute felt 0.06m,Normal	0.89	6
Jute felt 0.06m,Grazing	0.94	3
Jute felt 0.12m,Normal	0.87	11
Jute felt 0.12m,Grazing	0.94	6
Jute felt 0.18m,Normal	0.88	16
Jute felt 0.18m,Grazing	0.95	9

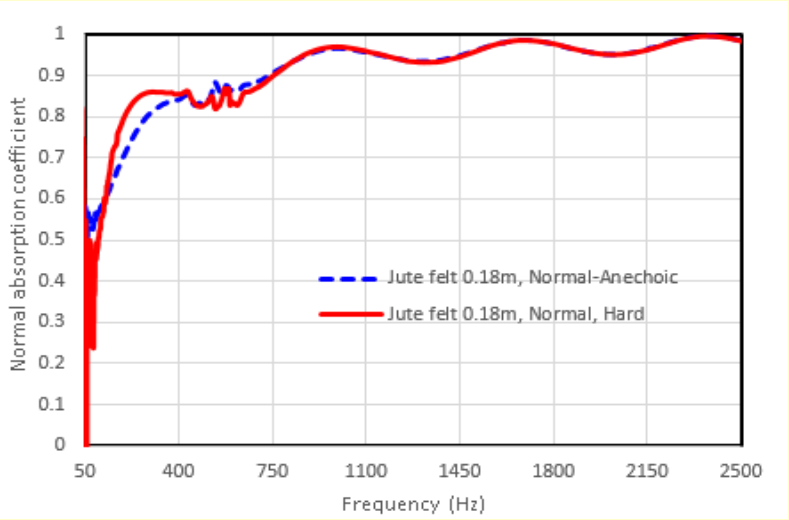
Measured Sound Absorption Coefficient of Jute Felts in Both Termination-Normal Case.



a) 0.06m

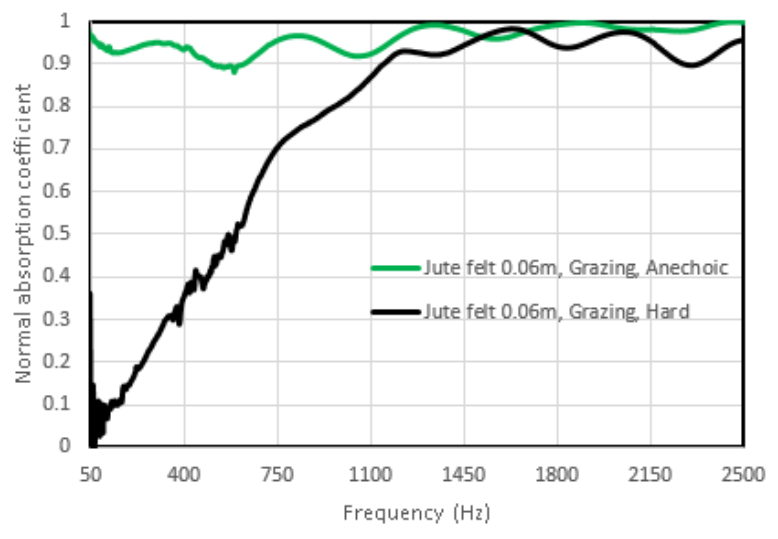


b) 0.12m

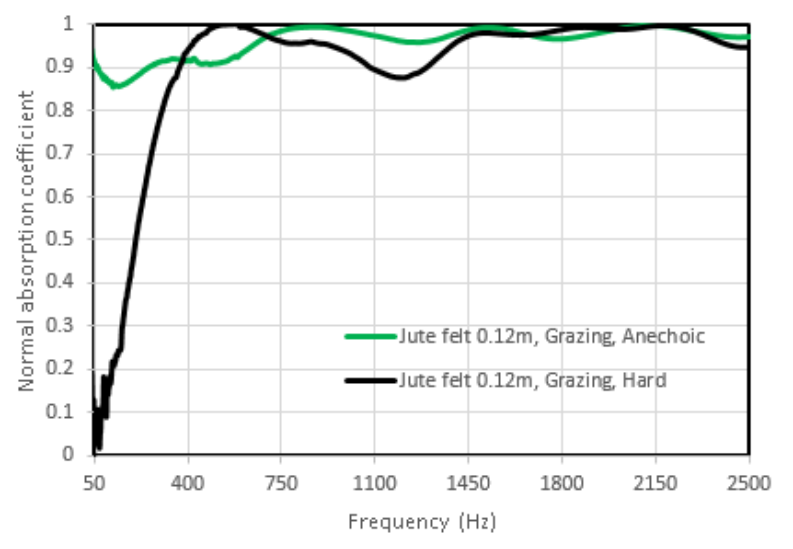


c) 0.18m

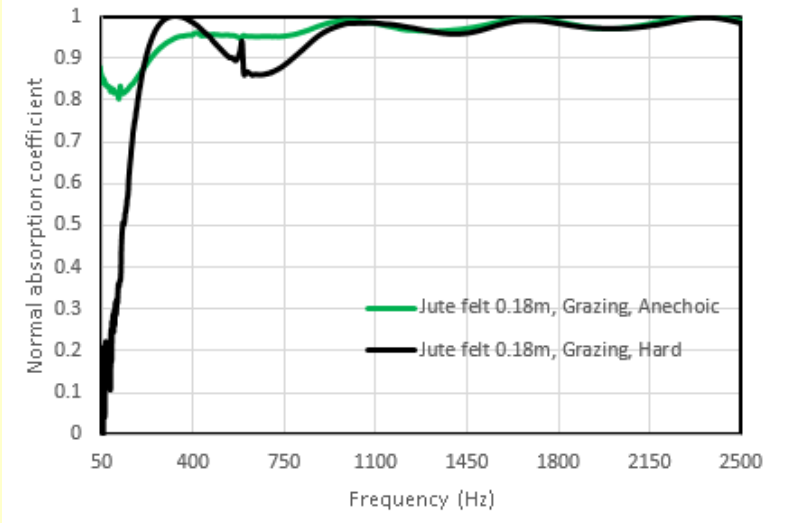
Measured Sound Absorption Coefficient of Jute Felts in Both Termination-Grazing Case.



a) 0.06m

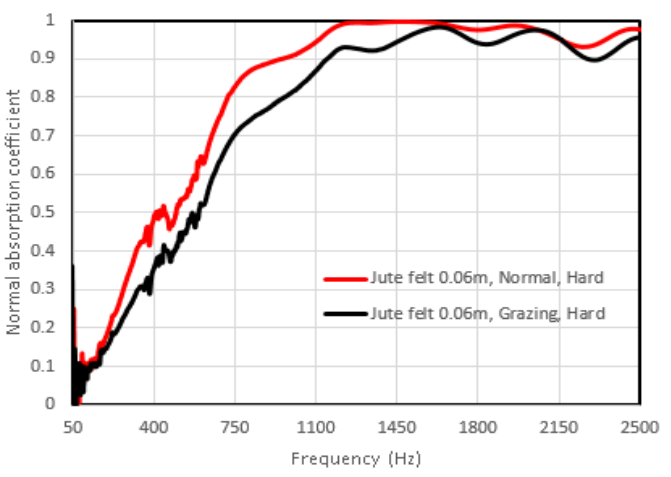


b) 0.12m

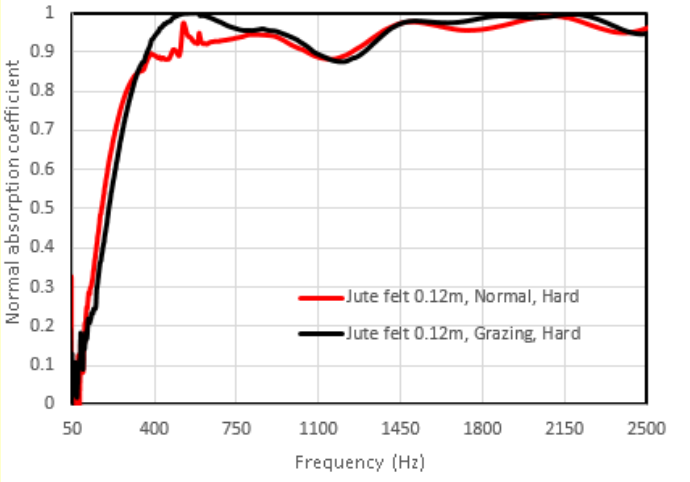


c) 0.18m

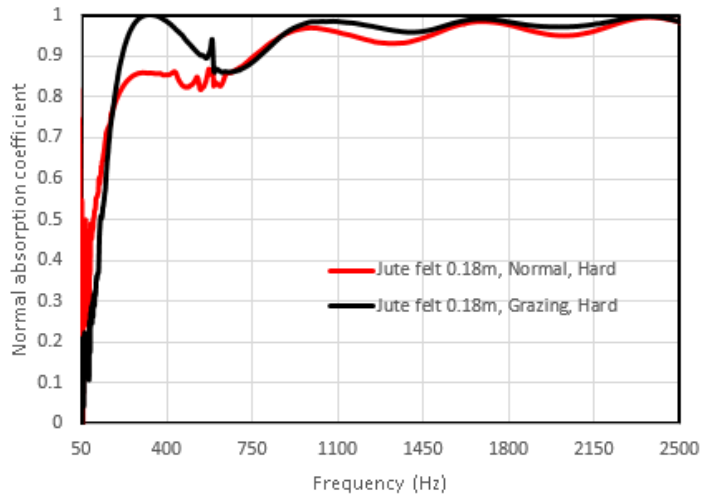
Measured Sound Absorption Coefficient of Jute Felts in Both the Orientations -Hard Case.



a) 0.06m



b) 0.12m



c) 0.18m

Measured NRC of the Jute Felt Stacks in Both Termination.

Samples	Noise reduction coefficient (NRC), Anechoic backing	Noise reduction coefficient (NRC), Hard backing
Jute felt 0.06m,Normal	0.89	0.69
Jute felt 0.06m,Grazing	0.94	0.61
Jute felt 0.12m,Normal	0.87	0.88
Jute felt 0.12m,Grazing	0.94	0.88
Jute felt 0.18m,Normal	0.88	0.89
Jute felt 0.18m,Grazing	0.95	0.94

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.

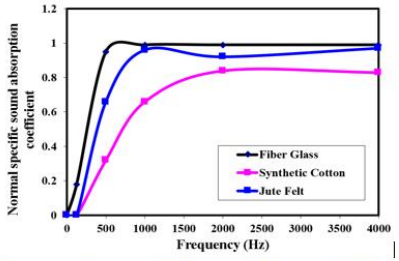
Noise Control of Domestic Appliances by Jute Based Materials

Measured properties of jute

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

Pilot trials done on household appliances

- Vacuum cleaner
- Dryer



Measured sound absorption coefficient


Various forms of developed jute material used for noise control


Sound Power Measurement of Vacuum Cleaner


Jute Lined enclosure for noise control of clothes

- *S. Fatima and A. R. Mohanty, 2012, Home Appliance Noise Control – The Green Way, Journal of Noise and Vibration Worldwide, Vol 43(7), pp. 26-34.*
- *S. Fatima and A. R. Mohanty, 2011, Acoustical and Fire-retardant Properties of Jute Composite Materials, Applied Acoustics, Vol 72(2-3), pp. 108-114.*
- *S. Fatima and A. R. Mohanty, 2009, Jute as an Eco-Friendly Noise Control Material – A Case Study, Journal of the Acoustical Society of India, Vol 36(1).*

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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- Taewook Yoo of the 3M Company for help with flow resistance measurements.
- Indian Institute of Technology Kharagpur, India, for providing the materials to test.

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- Standard Test Method for Airflow Resistance of Acoustical Materials, ASTM C522-03.

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