Measurement of Sound Absorption and Impedance

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Measurement of Sound Impedance

Impedance Tube Measurements

ASTM E1050-95 (ISO 10534-2) Test Method

sample

microphones

Transfer function

driver (loudspeaker)
Coordinate System and Microphone Locations

Impedance Tube Measurements

Material sample

Sound source

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Noise and Vibration
Short Course
Plane Wave Theory

Impedance Tube Measurements

Total sound pressure at any point in the tube:

\[ P(x) = Ae^{-jkx} + Be^{jkx} \]

\( +x \) traveling wave \hspace{1cm} \( -x \) traveling wave

The transfer function between points 1 and 2:

\[
H_{12} = \frac{P(x_2)}{P(x_1)} = \frac{Ae^{-jkx_2} + Be^{jkx_2}}{Ae^{-jkx_1} + Be^{jkx_1}} = \frac{e^{-jkx_2} + Re^{jkx_2}}{e^{-jkx_1} + Re^{jkx_1}}
\]

\[ R = \frac{B}{A} \] is the pressure reflection coefficient of the material
Solving for Material Properties

Impedance Tube Measurements

Solving for $R$:

$$R = \frac{e^{-jkx_2} - H_{12}e^{-jx_1}}{H_{12}e^{jkx_1} - e^{jkx_2}}$$

Normalized specific boundary impedance:

$$\frac{z}{\rho_o c} = \frac{1 + R}{1 - R}$$

Sound absorption coefficient of the material for any angle of incidence:

$$\alpha(\varphi) = \frac{4r'\cos\varphi}{(1 + r'\cos\varphi)^2 + (x'\cos\varphi)^2}$$

where

$$r' = \frac{r}{\rho_o c}, \quad x' = \frac{x}{\rho_o c}$$
Two-Microphone Standards

Impedance Tube Measurements

1. ISO 10534-2, Acoustics-Determination of sound absorption coefficient and impedance in impedance tubes - Part 2: Transfer-function method

2. ASTM E1050-10, Standard Test Method for Impedance and Absorption of Acoustical Material Using a Tube, Two Microphones and a Digital Frequency Analysis System
Sound Absorption Measurement

Sample holder with rigid piston

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Cutting with Rotating Blade

Impedance Tube Measurements

Inexpensive and accurate if kept sharpened

Stanley, Internoise 2012
Water Jet Cutting
Impedance Tube Measurements

Expensive but accurate

Stanley, Internoise 2012
Stamping Press System

Impedance Tube Measurements

Used for low-density fibrous materials

Stanley, Internoise 2012
“Bad” and “Good” Specimens

Impedance Tube Measurements

Stanley, Internoise 2012
Stanley, 2012 Specimen Preparation

Impedance Tube Measurements

- Very important step for good results
- Gravity aided insertion and self centering
- Face uniformly flush with cell lip
- Front surface even across lip of test cell
- No facing protrusions or wrinkles interacting with cell wall
- Extremely small (at most) and consistent gap between specimen and cell wall
- No specimen compression in cell

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Comparison of 5 Samples (Water Jet)

Impedance Tube Measurements

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Noise and Vibration
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Comparison of 4 Samples

Impedance Tube Measurements

Absorption Response of One Die Cut, and Three 99 mm Water Jet Cut Foam Samples of Slightly Different Diameter.

Stanley, Internoise 2012
Effect of Impedance Tube Size

Impedance Tube Measurements

8 Samples of 2 inch fiber

Absorption Coefficient vs. Frequency (Hz)

- 1.375 inch tube
- 3.875 inch tube

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Effect of Cutter Size
Impedance Tube Measurements

8 Samples of 0.75 inch thick 0.6 lbs/ft³ Melamine

Frequency (Hz)
Absorption Coefficient

- 1.375 inch Diameter Cutter
- 1.360 inch Diameter Cutter
Summary

“While the use of an impedance tube system to measure acoustic absorption is not an extremely precise and repeatable process due to unavoidable variations of specimen cutting and cell fit, the disciplined use of the guidelines stated in this paper will help to insure that test results maintain a consistent level of accuracy and validity. The experience gained with repeated preparation and testing will also contribute to a better feel for more subtle aspects of preparation and specimen fitting for testing.”

Stanley, Internoise 2012