Acoustical Performance of Rubber Crumb Material

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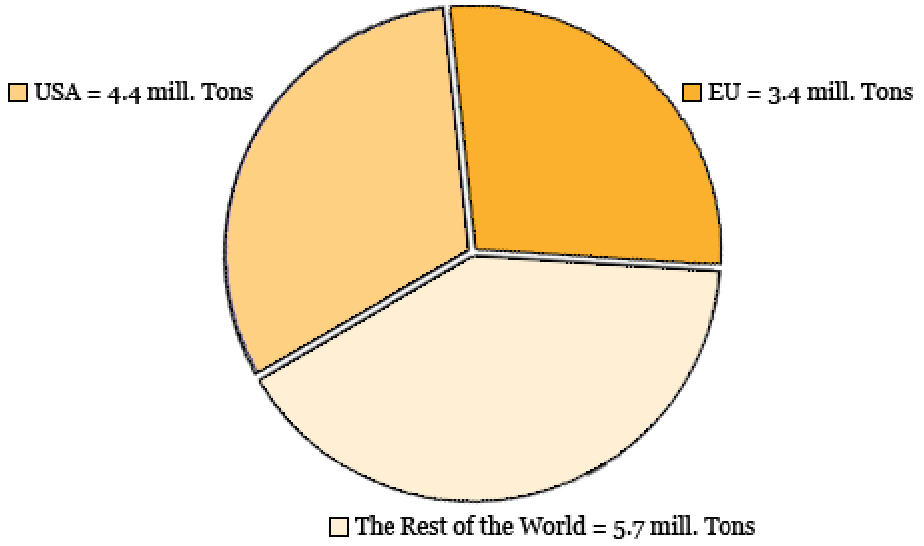
Alfa Acoustics
Discovering Silence through Sound

Outline

- Introduction
- Technical requirements of Acoustic materials
- Acoustic properties
- Nonacoustic properties
- Acoustic modeling-Rigid frame materials
- Sound Absorption and Transmission Loss-Impedance Tube
- Sound Absorption and Transmission Loss-Reverberation Room
- Simulation and Validation
- Conclusions

Introduction

- Scrap vehicle tyres make a significant contribution to the generation of environmental waste
- Approxmately 13.5 m tonnes of tyres are scrapped every year. These figures include all sorts of tyres from car tyres to truck tyres and the huge tractor and earth moving tyres.



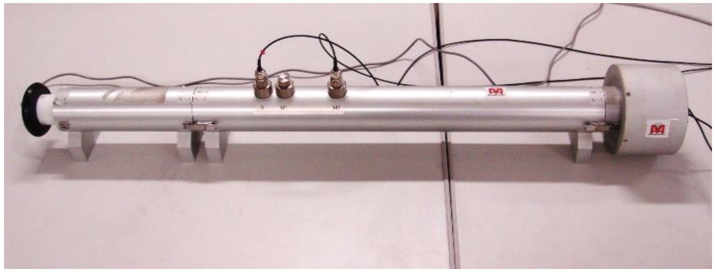
Technical Requirements of Acoustic Materials

- In General
  - ✓ Fire, Smoke and Toxicity
  - ✓ Weight, Flexibility and Handling
  - ✓ Color and Aesthetics (Visual appearance)
  - ✓ Thickness limitations
  - ✓ Longevity/Durability
  - ✓ Temperature range
  - ✓ Must be supplied in standard dimensions known by the industry
  - ✓ Financial implications (COST!!!)

Experimental Test setup

- Sound Absorption coefficient of Cellular rubber samples was evaluated as per
    - Normal Incidence- ASTM 1050 / ISO 10534-2
    - Random Incidence- ASTM 423 / ISO 354

- Sound Transmission loss of Cellular rubber samples was evaluated as per
    - Normal Incidence- ASTM E2611
    - Random Incidence- ASTM E90 / ISO 10140

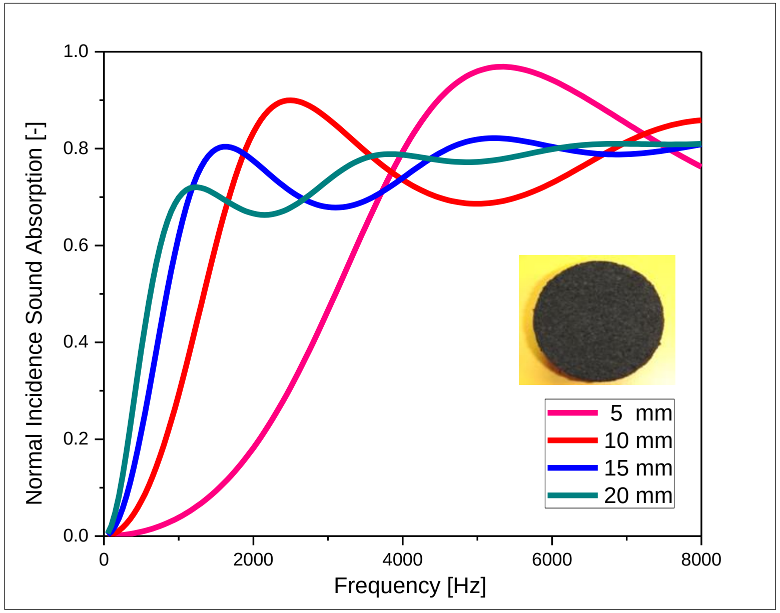


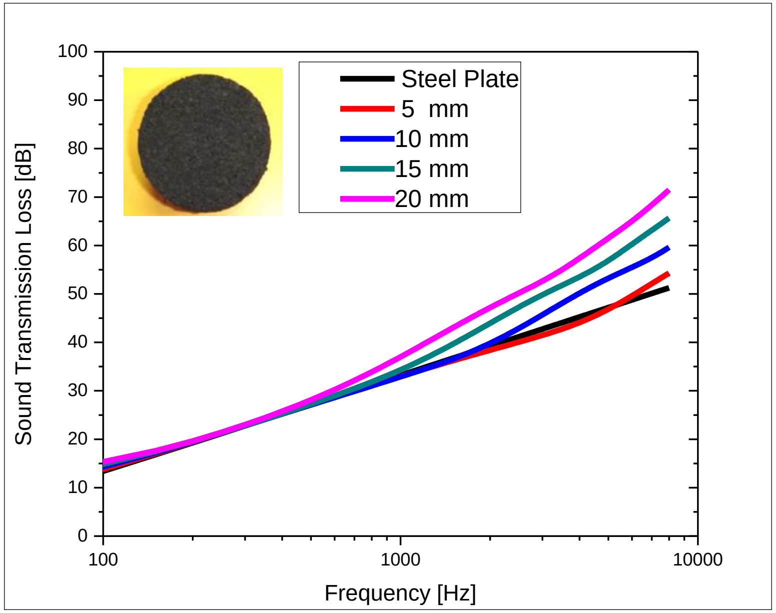
Normal Incidence Impedance Tube

Reverberation Suite

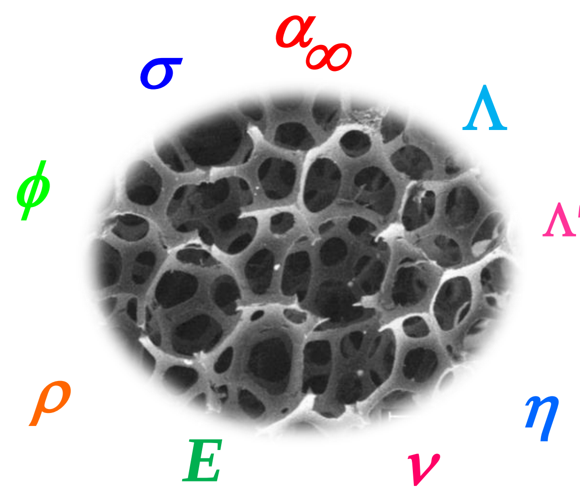
Experimental Test Results

- The sound absorption coefficient was measured in a reverberation chamber.
- For absorption measurement, sample size was 6.4 m^2
- For transmission loss measurement, sample size was 1.2 m^2



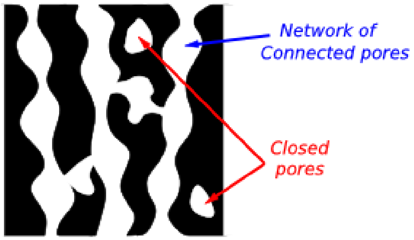


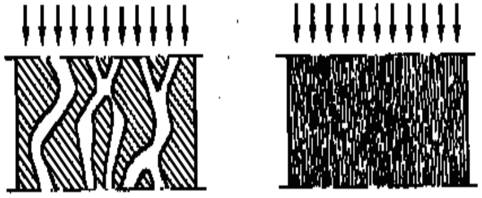
Macroscopic Characterization

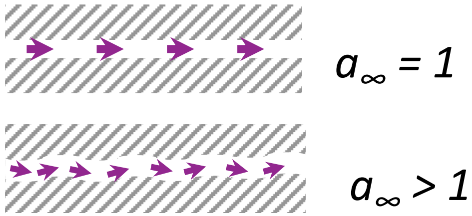


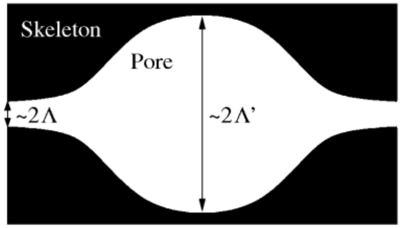
Intrinsic Parameters

- ✓ **Porosity**
- ✓ **Air-flow resistivity**
- ✓ **Tortuosity**
- ✓ **Viscous Characteristic Length**
- ✓ **Viscous Characteristic Length**



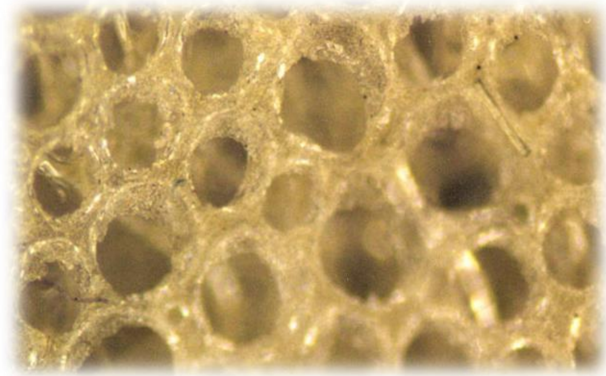


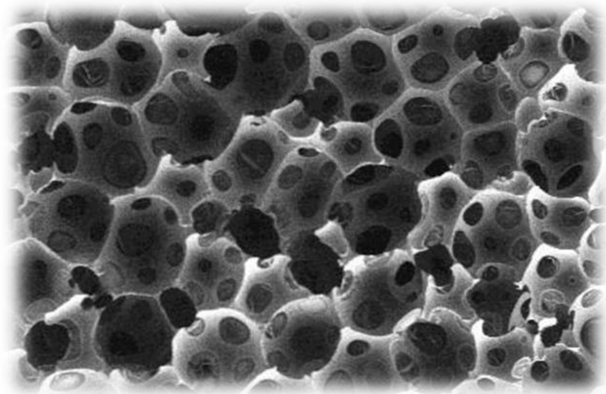




Biot’s Parameters for Characterization

Porosity	ϕ
Airflow resistivity	σ
Tortuosity	α_∞
Viscous Characteristic Length	Λ
Thermal Characteristic Length	Λ'
Density of the foam	ρ_m
Young's modulus	E
Poisson's ratio	ν
Loss Factor	η

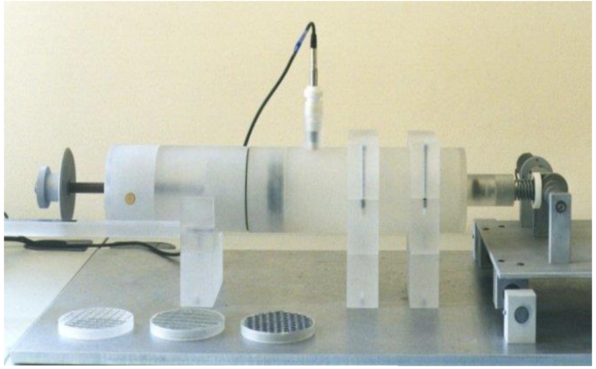




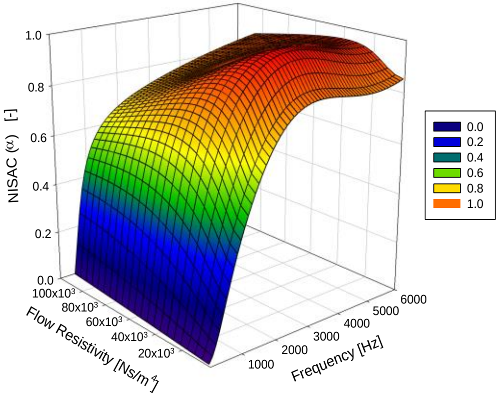
Airflow Resistivity Measurement

- It is the ratio of Air pressure difference to steady state velocity
- Standards- ISO 9053 / ASTM C 522

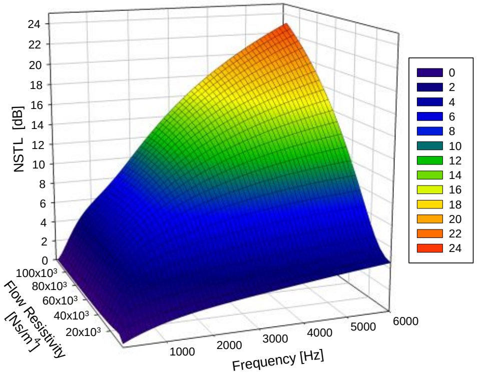
$$\sigma = \frac{\Delta P}{V.d} \qquad \mathrm{Ns/m^4}$$



Range $$10^{3} < \sigma < 10^{6}$$



Effect of Airflow Resistivity on Absorption



Effect of Airflow Resistivity on Transmission loss

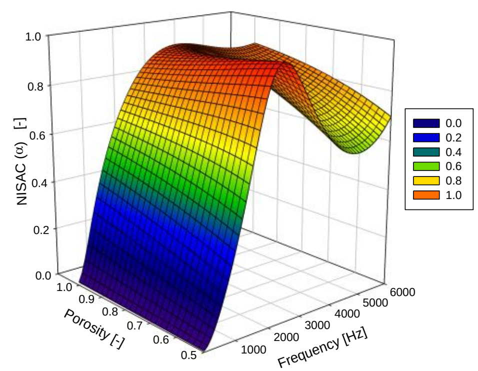
Porosity

- It is the ratio of the volume of air voids to total volume of material

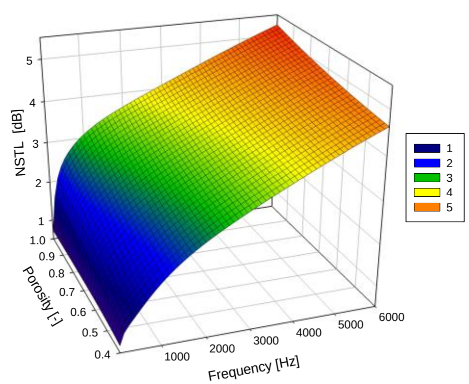
Open Porosity $$\phi = \frac{V_{air}}{V_{total}}$$

Range $0 < \phi < 1$

- No Standardized Test Method

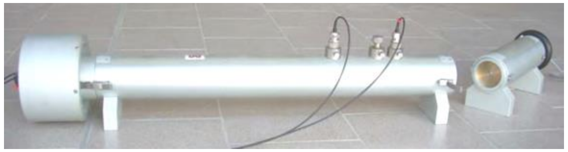


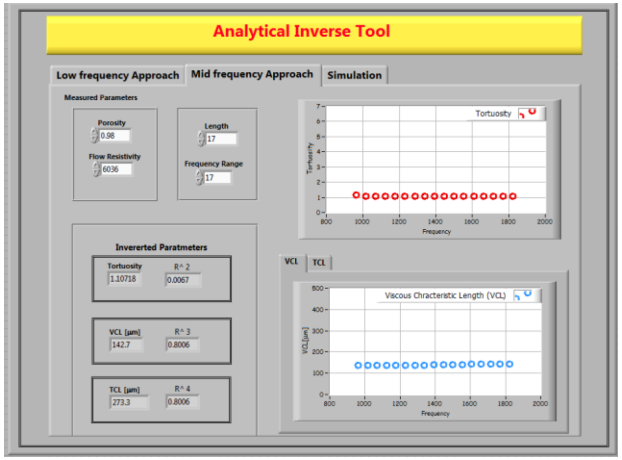
Effect of Airflow Resistivity on Absorption



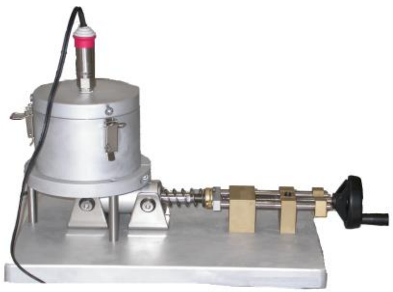
Effect of Airflow Resistivity on Transmission loss

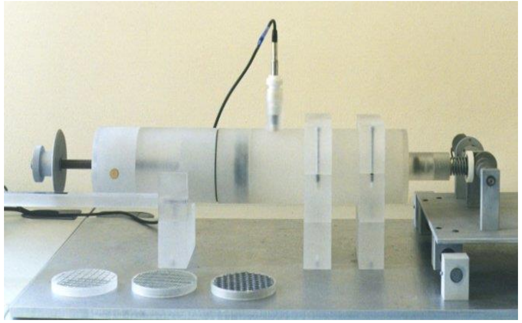
Intrinsic Parameters of Acoustic Materials





Inverse Software



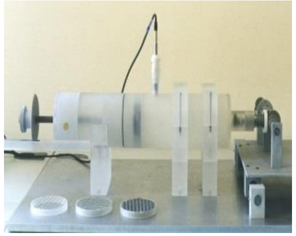


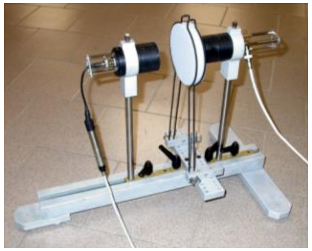
Porosity Rig

Airflow Resistivity Rig

Tortuosity
Viscous Characteristics Length
Thermal Characteristics Length

Intrinsic Physical Parameters-Cellular Rubber





Thickness 15 mm	Values
Porosity ϕ	0.86
Flow Resistivity σ	150388
Tortuosity α_∞	3.97
Viscous Length Λ	29
Thermal Length Λ'	29

Modeling of Acoustic Materials

$$\rho_c = \frac{\alpha_\infty \rho_0}{\phi} + \frac{\sigma}{i\omega}\sqrt{1 + \frac{4i\alpha_\infty^{\ 2}\eta\rho_0\omega}{\sigma^2 \Lambda^2 \phi^2}}$$

Viscous effects

$$K_c = \frac{\kappa \cdot P_0 / \phi}{\kappa - (\kappa - 1)\left[1 + \frac{8\eta}{i\rho_0\omega N_p \Lambda'^2}\sqrt{1 + \frac{i\rho_0\omega N_p \Lambda'^2}{16\eta}}\right]^{-1}}$$

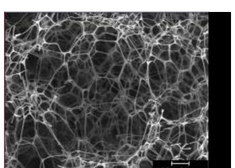
Thermal effects

$$Z_c = \sqrt{\rho_c \cdot K_c} \quad [\mathrm{Ns/m^3}]$$

$$k_c = \omega\sqrt{\rho_c / K_c} \quad [\mathrm{m^{-1}}]$$

Zc,kc

Z_s

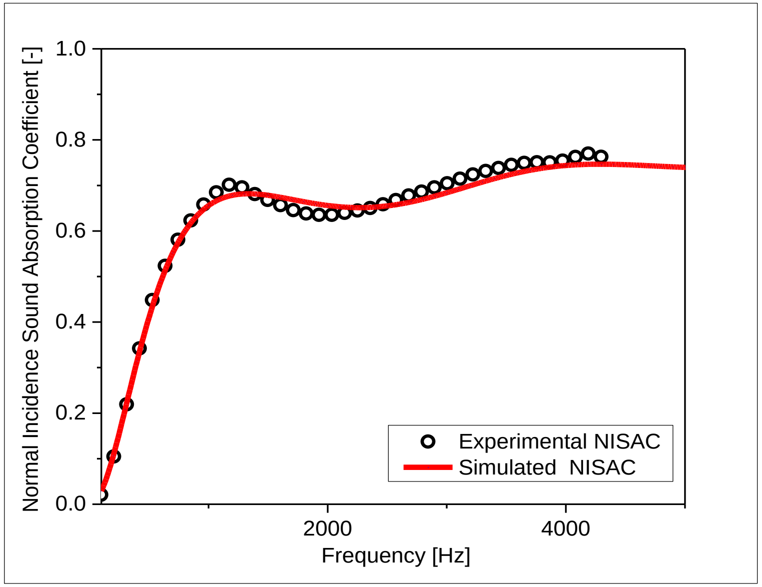


$$Z_S = Z_c \cot(k_c d)$$

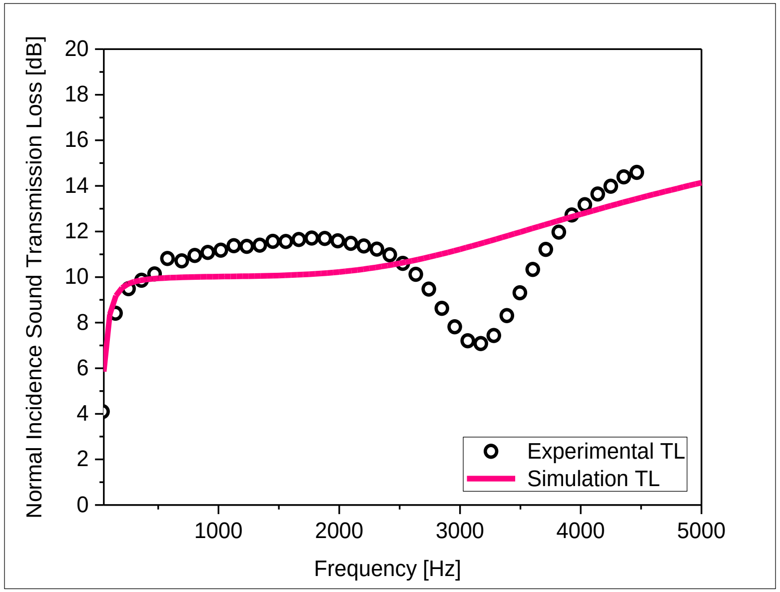
Johnson-Champoux-Allard Model-Rigid Frame

Measurement and Simulation-Normal Incidence

- Normal Incidence Sound Absorption Coefficient measured as per ISO 10534-2 / ASTM 31050
- Normal Incidence Sound Transmission Loss measured as per ASTM E2611

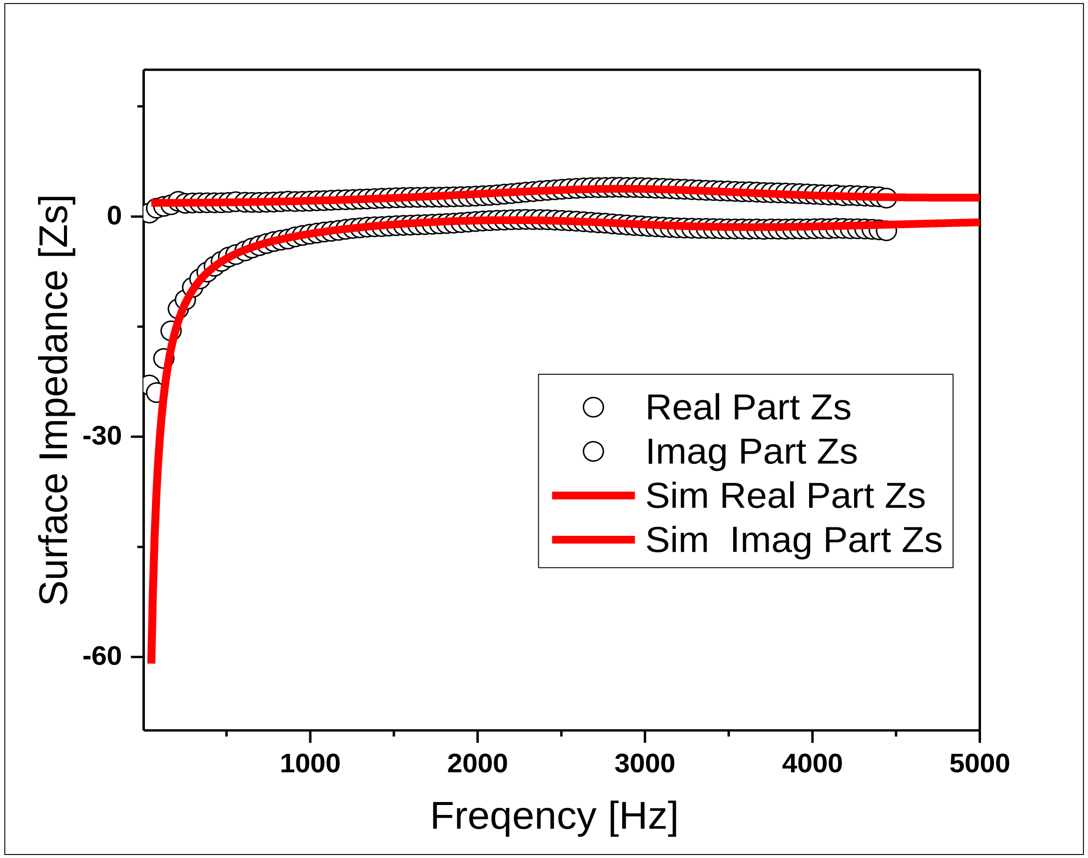


Comparison of Absorption Coefficient-Measurement and SImulation



Comparison of Transmission Loss-Measurement and SImulation

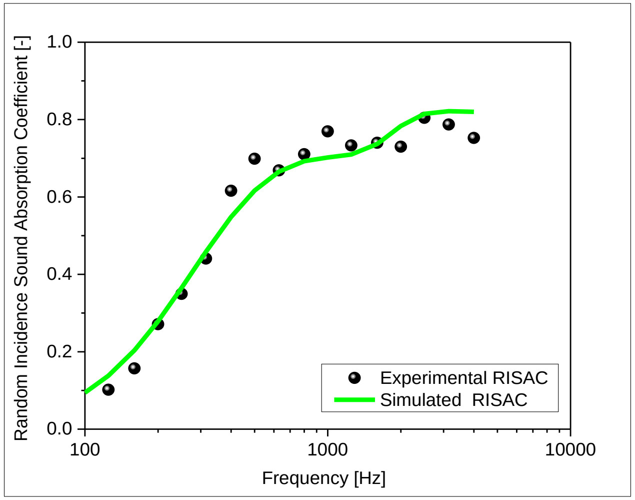
Surface Properties-Cellualr Rubber



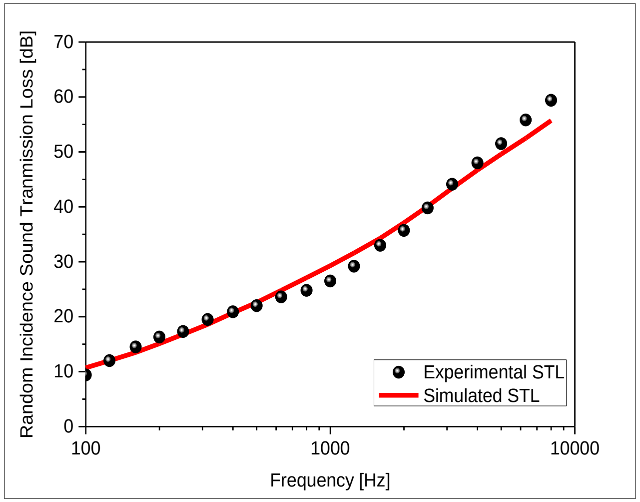
Comparison of Measured and Predicted Surface Impedance

Measurement and Simulation-Random Incidence

- Random Incidence Sound Absorption Coefficient measured as per ISO 354 / ASTM C423
- Random Incidence Sound Transmission Loss measured as per ASTM E90 / ISO 10140



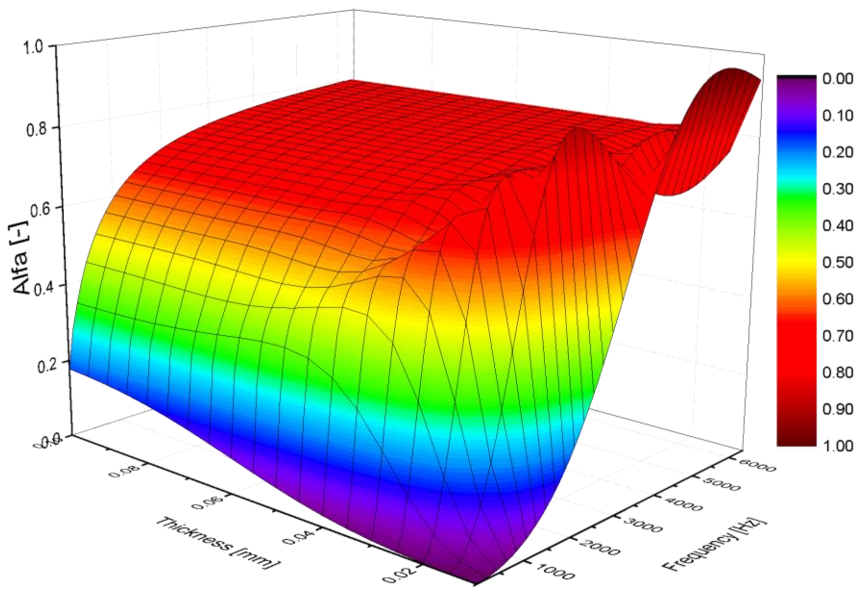
Comparison of Absorption Coefficient-Measurement and SImulation



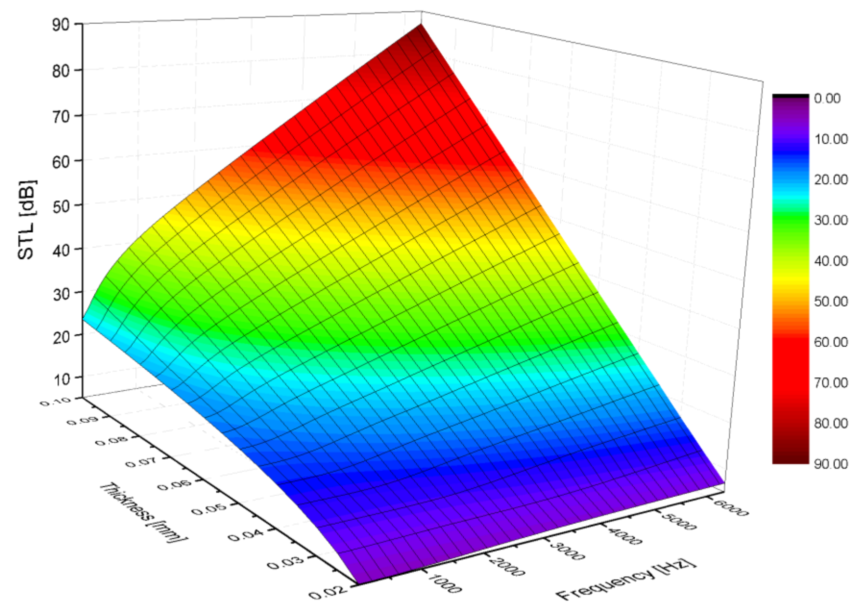
Comparison of Transmission Loss-Measurement and SImulation

Higher Thickness Simulation- Cellular Rubber

Thickness is varied from 5 mm to 100 mm



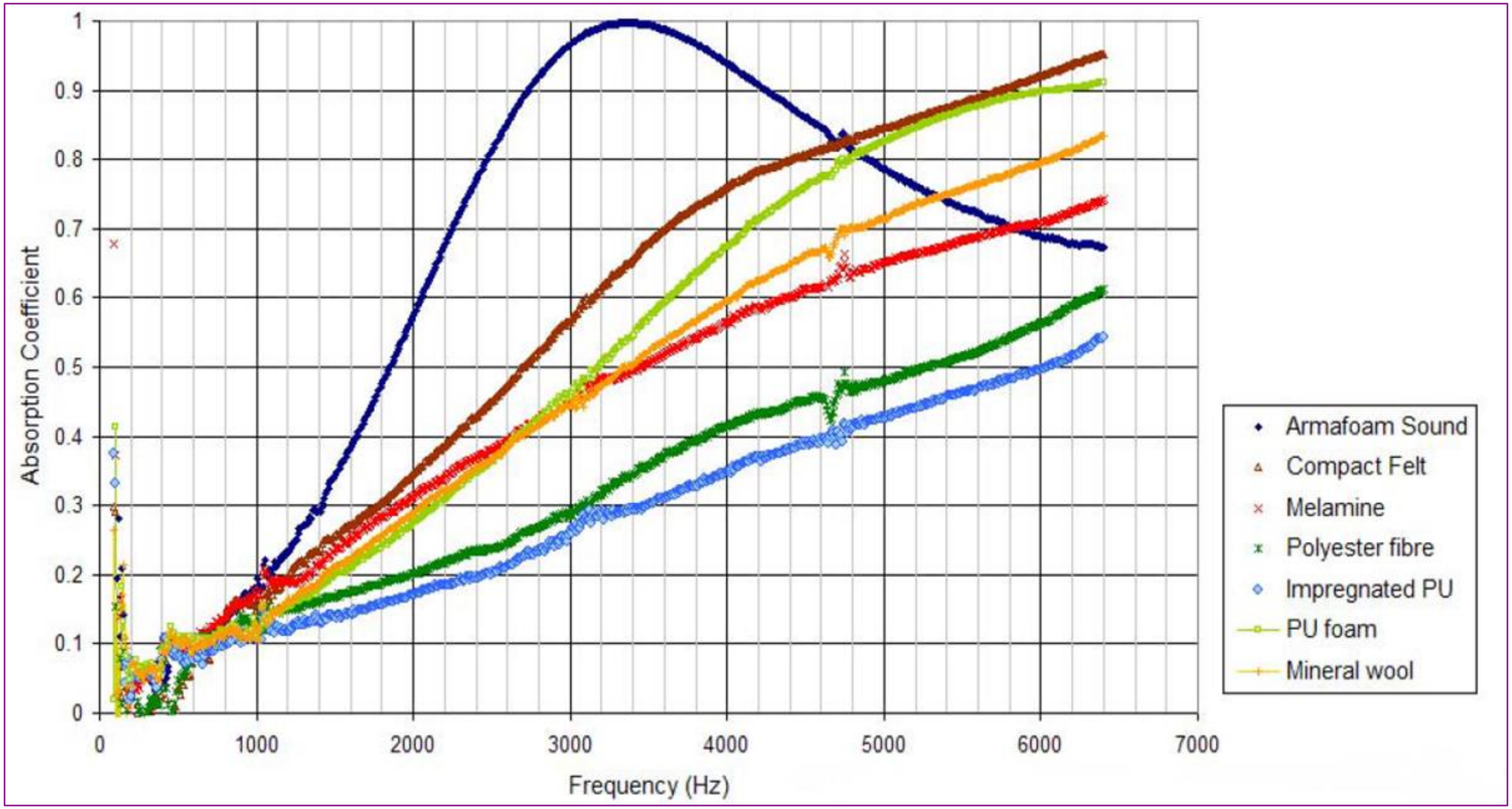
Simulation of Absorption Coefficient



Simulation of Sound Transmission Loss

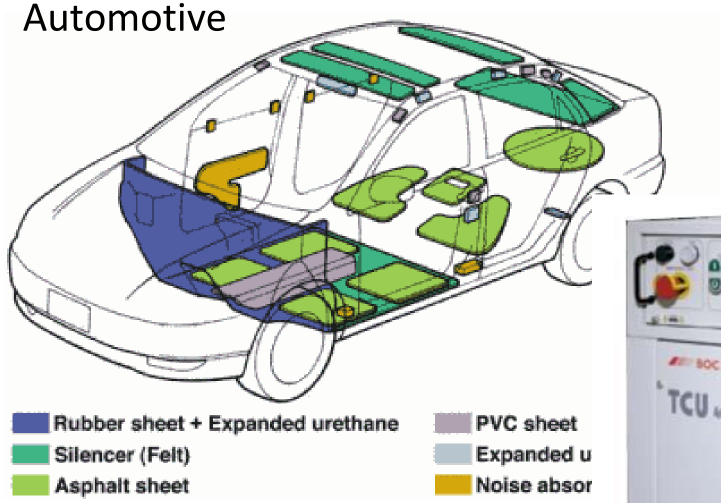
Sound Absorption Comparison with Other Materials

All samples have thickness 10 mm- Tested as per ISO 10534-2



Application Areas

Automotive



Heavy Vehicles

HVAC

Noise Barriers

Genset

Conclusions

- Acoustic performance is better than other conventional acoustic materials
- Cellular rubber is sustainalble and recyclable
- As the base materials is rubber, it can also be used vibration applications

References:

- ASTM-C522, Materials for acoustical applications- Determination of airflow resistance, 1991
- ISO 354, Measurement of sound absorption in a reverberation room, 2003
- ISO 10140-2 / ASTM E 90- Air borne sound transmission loss Measurement, 2010
- J. F. Allard, Y. Champoux, 1992, New empirical equations for sound propagation in rigid frame fibrous materials, J. of Acoust. Soc. of Am., 91(6), 3346-3353

Thank You

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