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The Acoustical Properties of Air Saturated Aerogel Powders

Yutong Xue
Midea Corporate Research Center, xyt@alumni.purdue.edu

J Stuart Bolton
Purdue University, bolton@purdue.edu

Hasina Begum
University of Sheffield, hbegum3@sheffield.ac.uk

Kirill Horoshenkov
University of Sheffield, k.horoshenkov@sheffield.ac.uk

The acoustical properties of air-saturated aerogel powders

Yutong Xue[1], J. Stuart Bolton[1], Hasina Begum[2], Kirill V. Horoshenkov[2]

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Presentation structure

- Aim of the study
- Materials characterization
- Experimental acoustical analysis
- Theoretical model
- Results & future work

Aim

- What physical processes control the acoustic absorption/ attenuation mechanisms of light, loose aerogel powders?
- How can we use a Biot-type viscoelastic model to predict the absorption coefficient of two aerogels powders (1-40 µm)?

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Aerogel powders

- Type 1 – Enova IC3100

Colour	White
Particle size range	1-40 µm
Pore diameter	~20 nm
Bulk density	120-150 kg/m^3
Thermal conductivity	0.012 W/m.K at 25 °C
Surface area	600-800 m^2/g
Porosity	> 90%

- Type 2 – JIOS AeroVa D20

Color	White
Particle Size Range	1 ~ 20 µm
Pore Diameter	20 nm
Bulk Density	0.04 ~ 0.1 g/cm^3
Surface Chemistry	Superhydrophobic
Thermal Conductivity	0.017 ~ 0.022 W/m·k
Surface Area	600 ~ 800 m /g^2
Porosity	> 90%
Temperature Range	-200°C ~ 1,600°C

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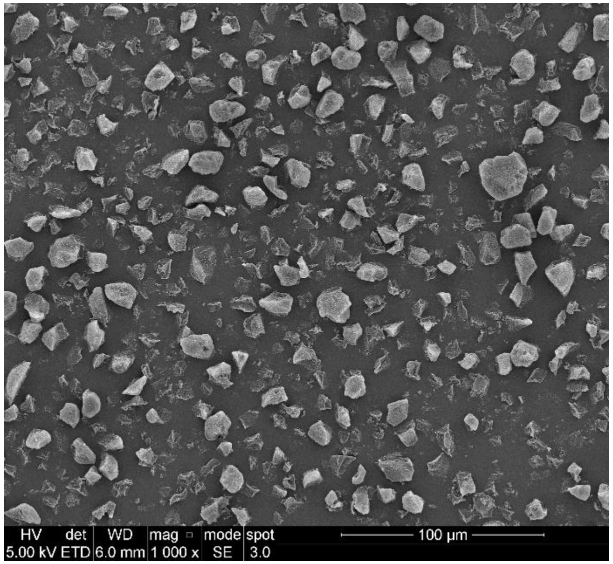
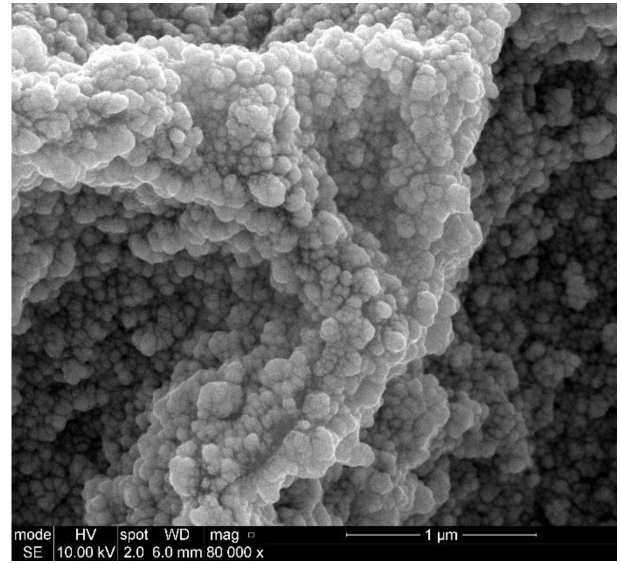
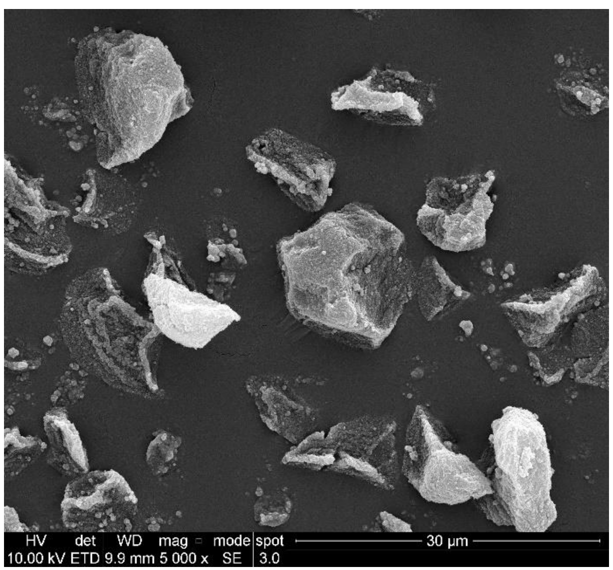
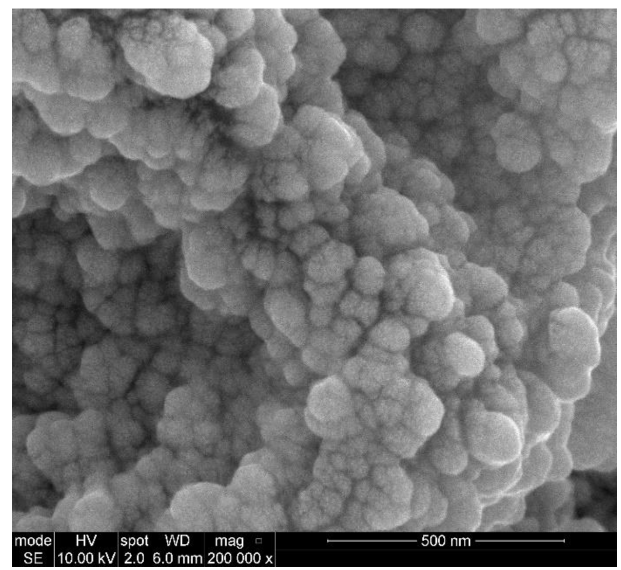
Type 1 Enova IC3100

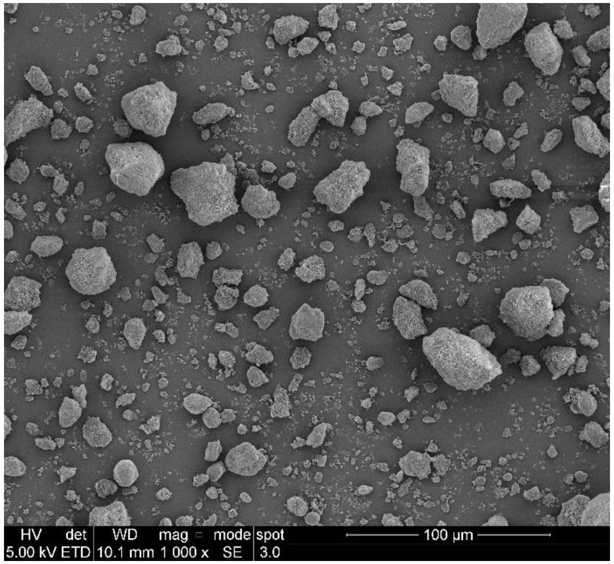


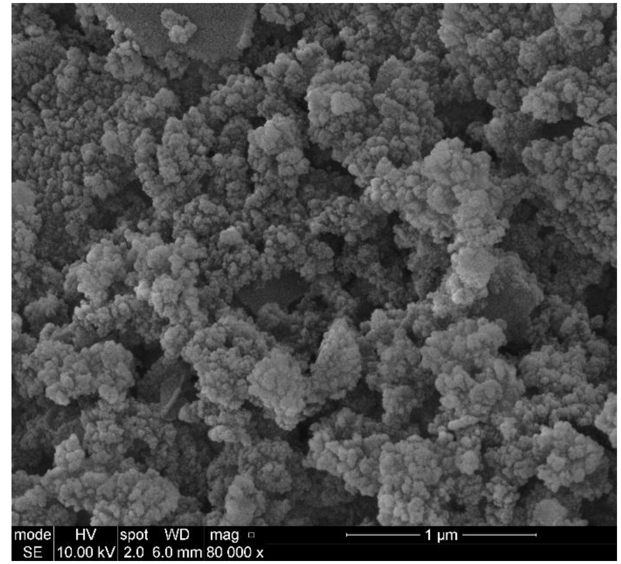


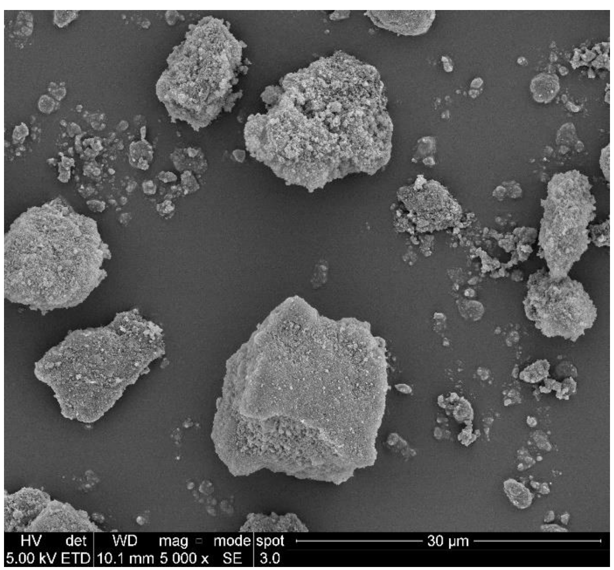


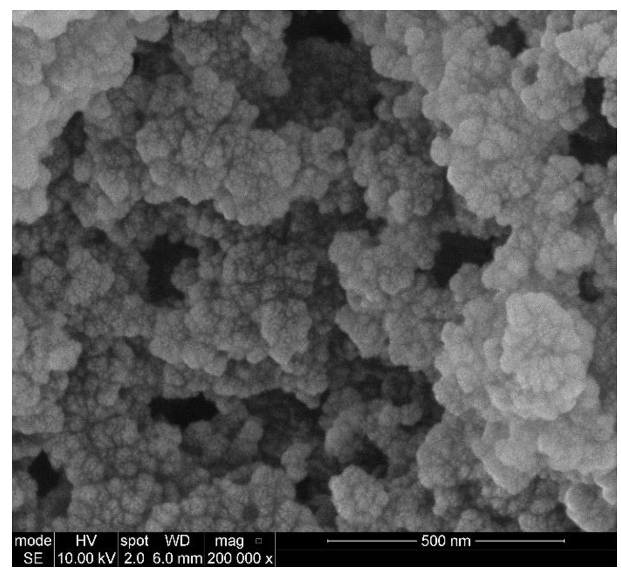


Type 2 JIOS AeroVa D20

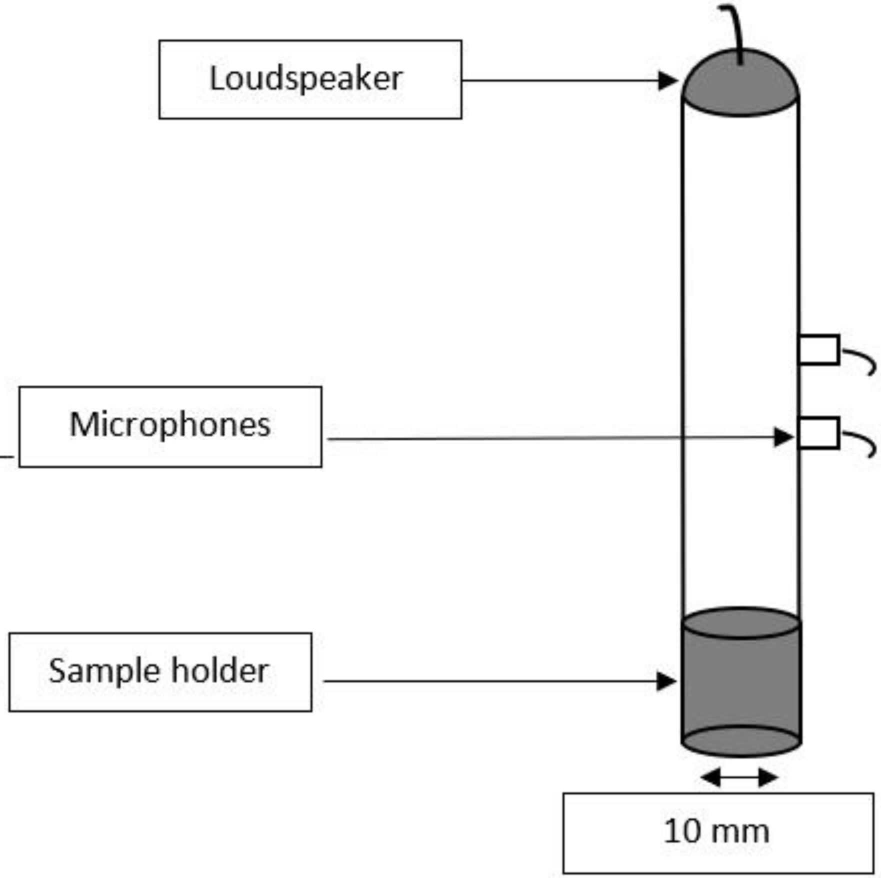




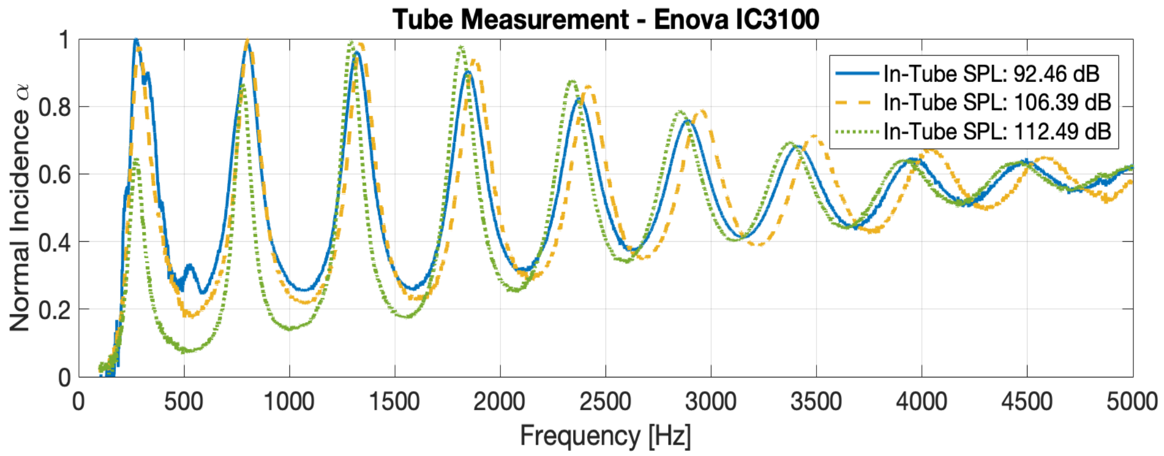


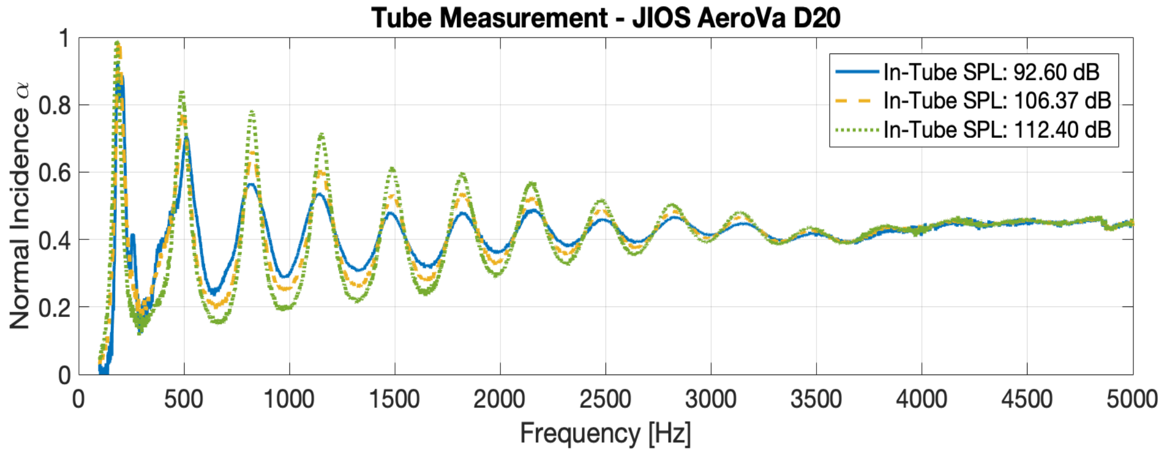


Acoustic measurements



Impedance tube measurements





- Lightly damped, depth resonances
- Large peak values of absorption occur at unusually low frequencies
- Heights of the peaks, decreased with increasing sound pressure level (SPL)
- Aerogel sample stacks behave non-linearly

Acoustical theory

- 2 models used to predict the frequency-dependent equivalent density ρ_e and bulk modulus k_f
- 5-parameter JCA model: airflow resistivity, σ; (ii) porosity, ϕ; (iii) tortuosity, α_∞; (iv) viscous characteristic length, Λ; and (v) thermal characteristic length, Λ'
- 3-parameter Páde approximation model: median pore size, s_b, porosity, ϕ, and standard deviation of the pore size, σ_s
- Biot theory used to account for the frame elasticity
- Other ambient parameters used: η=1.82×10^{-5} Pa s, c_0=343 m/s, ρ_0=1.21 kg/m^3, B^2=0.71, γ=1.402

Results

- MATLAB built-in numerical optimization function “particleswarm”
- Manual and empirical adjustment was used η_m=0.2, E_1=775 Pa and ν=0.396

JCA-Biot

Material	σ [Rayls/m MKS]	φ	α_∞	Λ [μm]	Λ' [μm]	ρ_b [kg/m³]	E_1 [Pa]	ν
Type 1	10.5×10^6	0.999	3.0	36.1	36.1	35.5	775	0.396
Type 2	10.5×10^6	0.999	3.0	36.1	36.1	94.0	775	0.396

3P-Biot

Material	φ	s_b [μm]	σ_s	ρ_b [kg/m³]	E_1 [Pa]	ν
Type 1	0.999	14.7	0.756	35.5	775	0.396
Type 2	0.999	14.7	0.756	94.0	775	0.396

Results

$$\log_{10} \eta_m = af + b$$

This congruence allowed the introduction of a 4900-step loss factor that decreased logarithmically with increasing frequency

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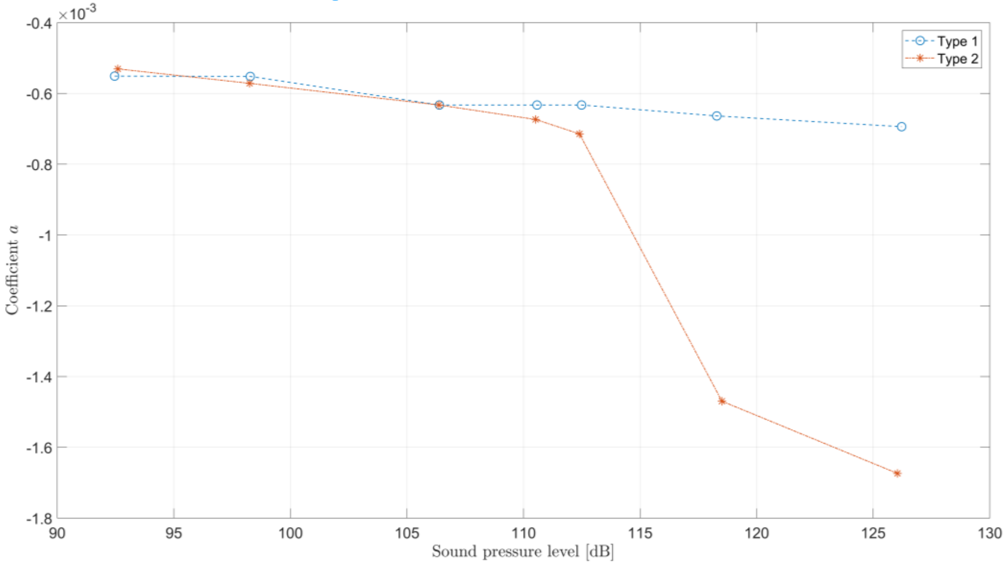
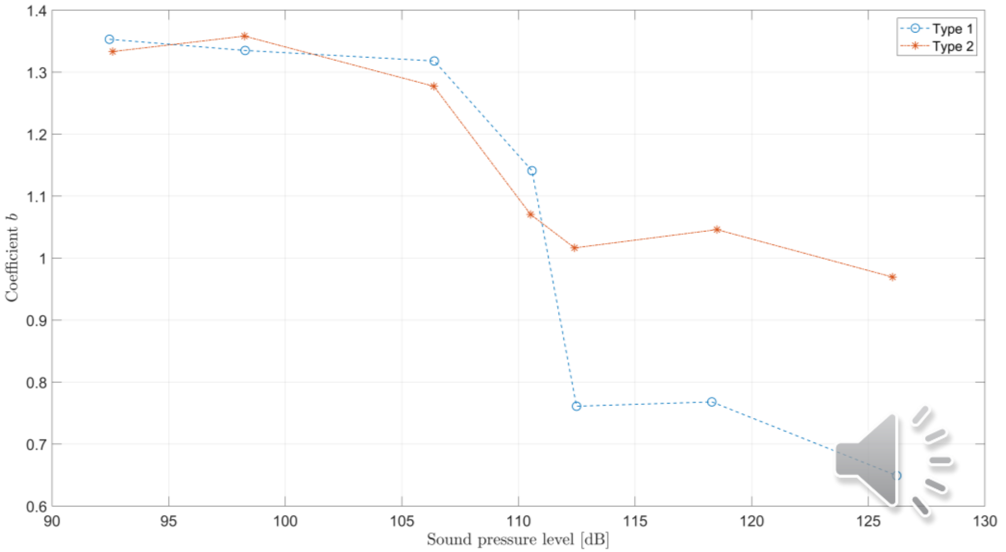
Results

Dependence of a

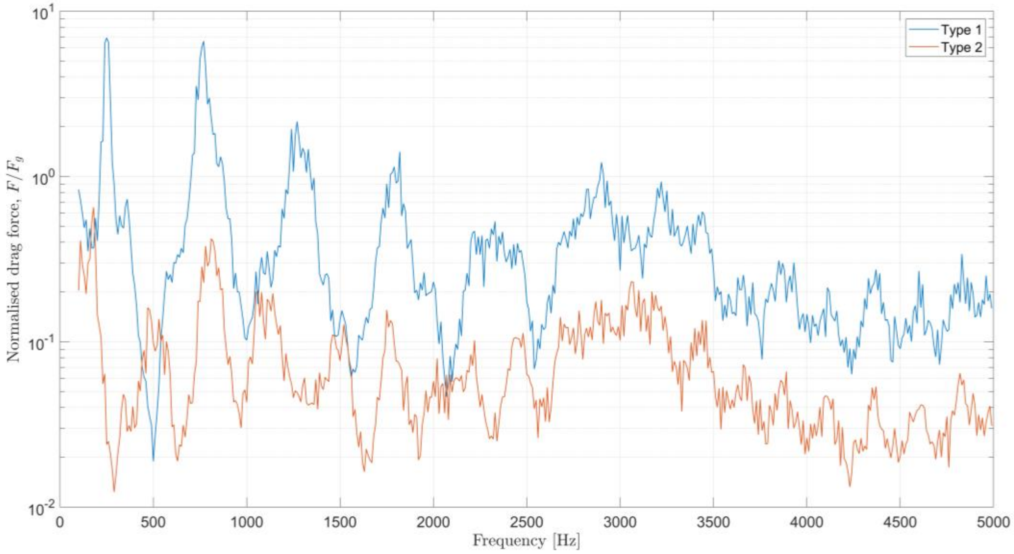


Dependence of b

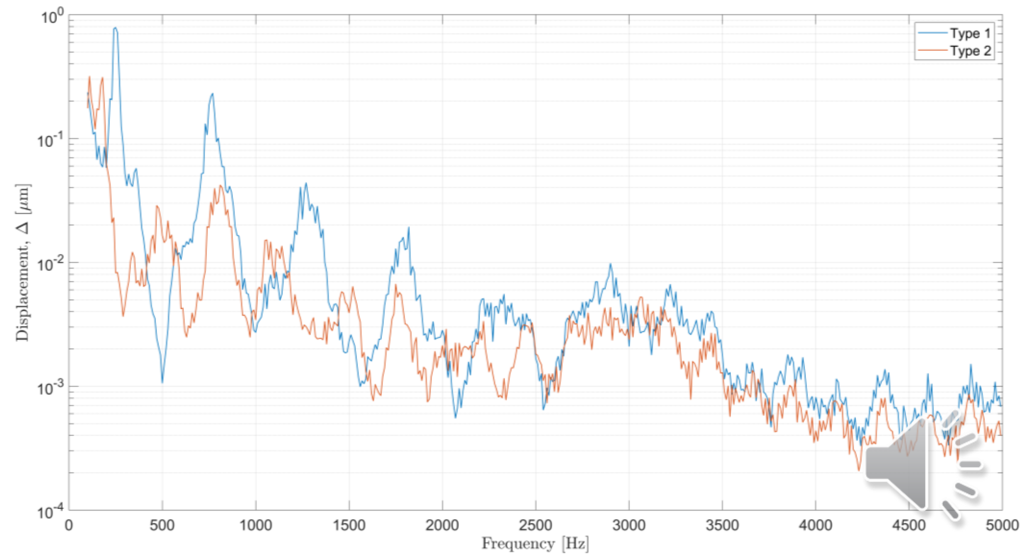


Results

Normalized drag force



Displacement of air molecules



Conclusions & Future work

(1) Bulk density for Type 2 (94 kg/m^3) was twice that of Type 1 (35.5 kg/m^3), but when characterized using the models, the values were smaller (Type 1: 38.7 kg/m^3, Type 2: 104.9 kg/m^3). The aerogel's mass density might vary under different standing wave tube input voltages due to non-linearity.

(2) A small but finite elasticity expressed in terms of the Young's modulus of both materials' solid frame structure needs to be introduced in the modeling process to ensure a good fit of the sound absorption over a broad range of frequencies.

(3) An additional sound absorption mechanism could not be captured by the Biot-type poro-elastic model and needs to be considered to provide better fits in the high frequency region (i.e., above 2000 Hz)

(4) The loss factor required to fit the measured data at low frequencies (i.e., below 2000 Hz) is higher than is physically reasonable for an elastic porous medium. An additional loss mechanism may be working at low frequencies to contribute to the non-linearity of the sound absorption.

Acknowledgements

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