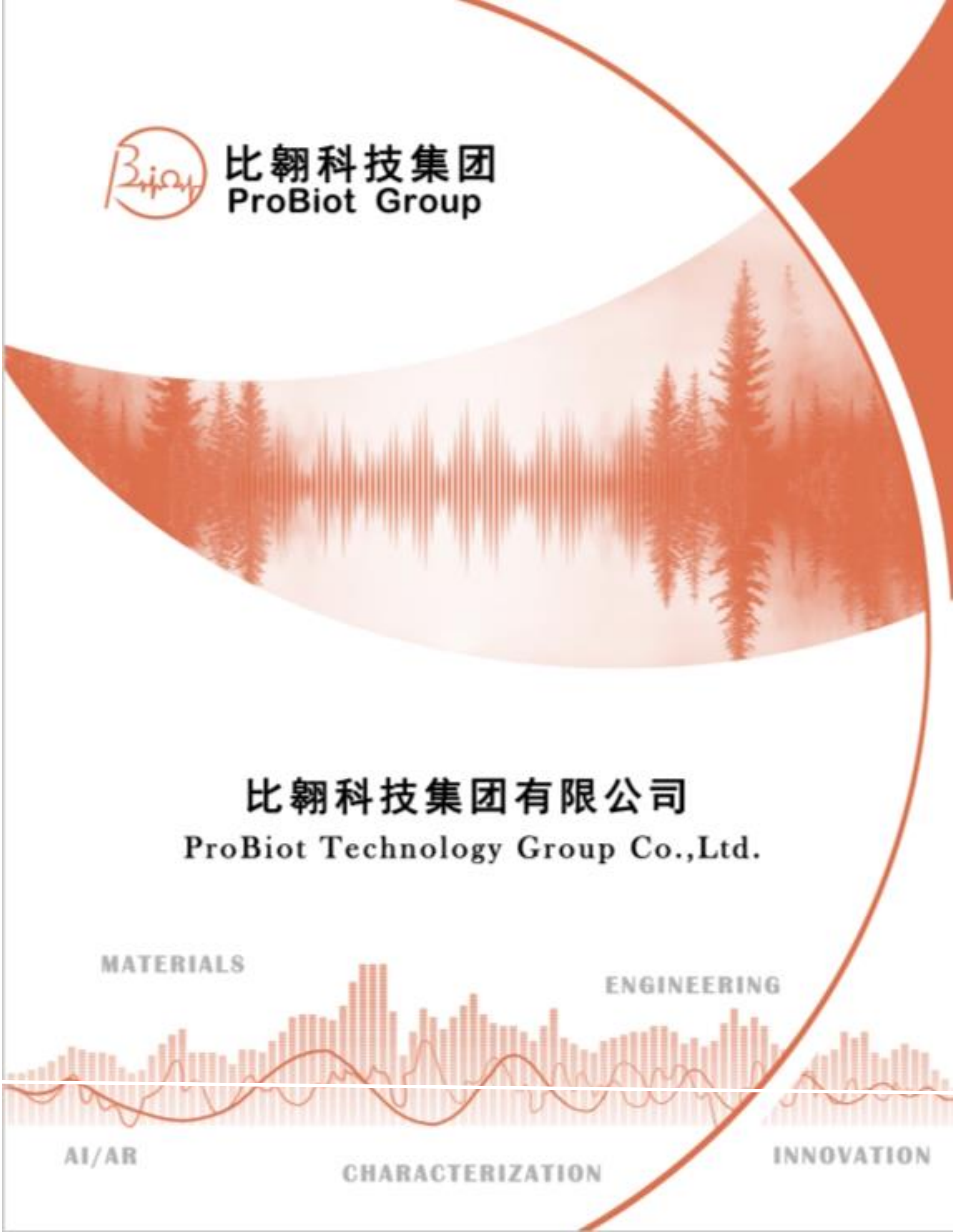

Enhancing the Acoustic Performance of Sound-Absorbing Materials through Surface Trim Modification

7th Nov. 2023

Topics

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1. ProBiot Lab Introduction
2. Current Material Property Study
3. Optimization
4. Micro-Perforate Panel + Absorber

1. ProBiot Lab Introduction

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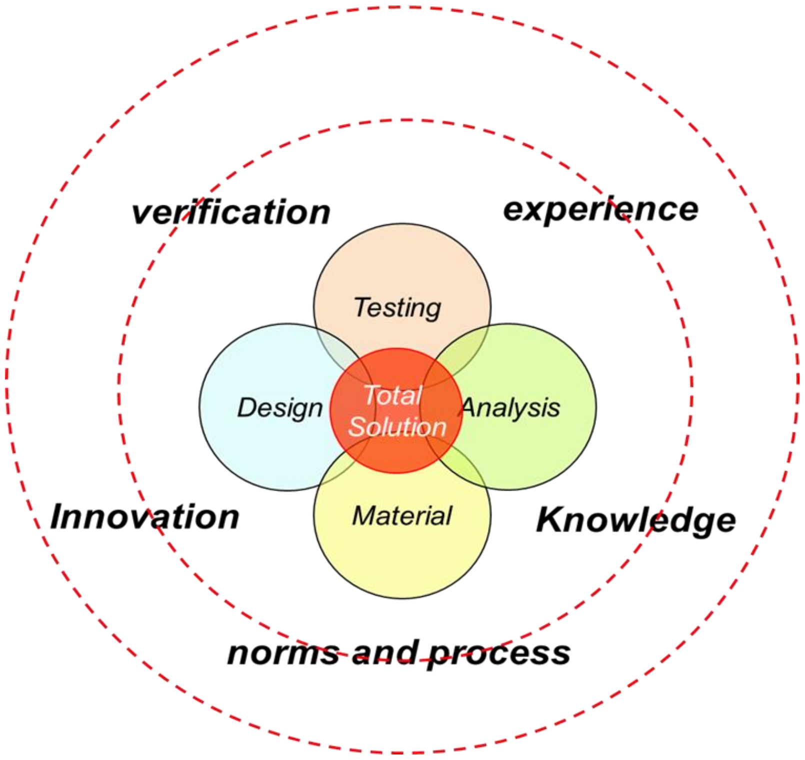
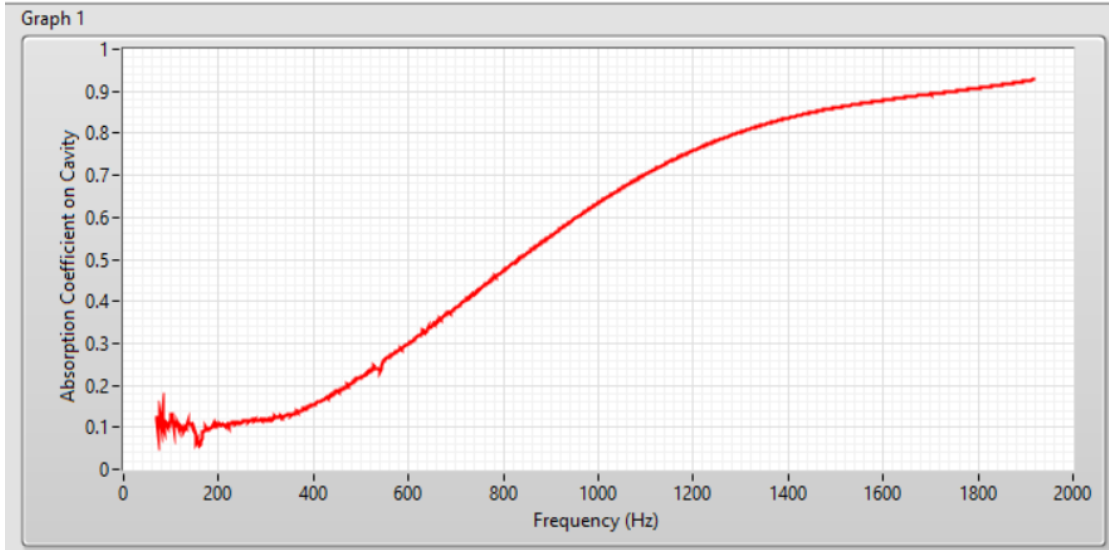


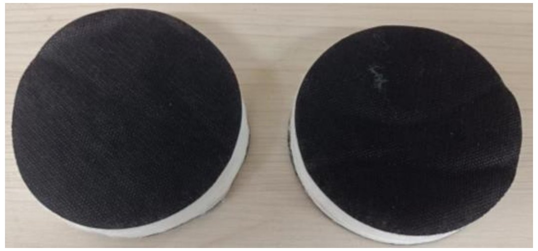
ProBiot Lab is a global leader in the construction, commercial transformation, engineering empowerment and industrialization of advanced theoretical systems for porous materials and artificial structures.

2. Current Material Property Study

Sample	Melt blown PP + black PET trim
Laboratory environment	Temperature: 25 ˚C, Relative humidity: 40 %, Atmospheric pressure: 1024 mbar
Sample dimension	Diameter: 100mm Thickness: 15mm
Porosity	0.999
Airflow Resistivity (Pa·s/m² or N·s/m⁴)	59161
Tortuosity	1
Viscous characteristic length (μm)	8.7
Thermal characteristic length (μm)	17.3



Weight: ~620g/m^2



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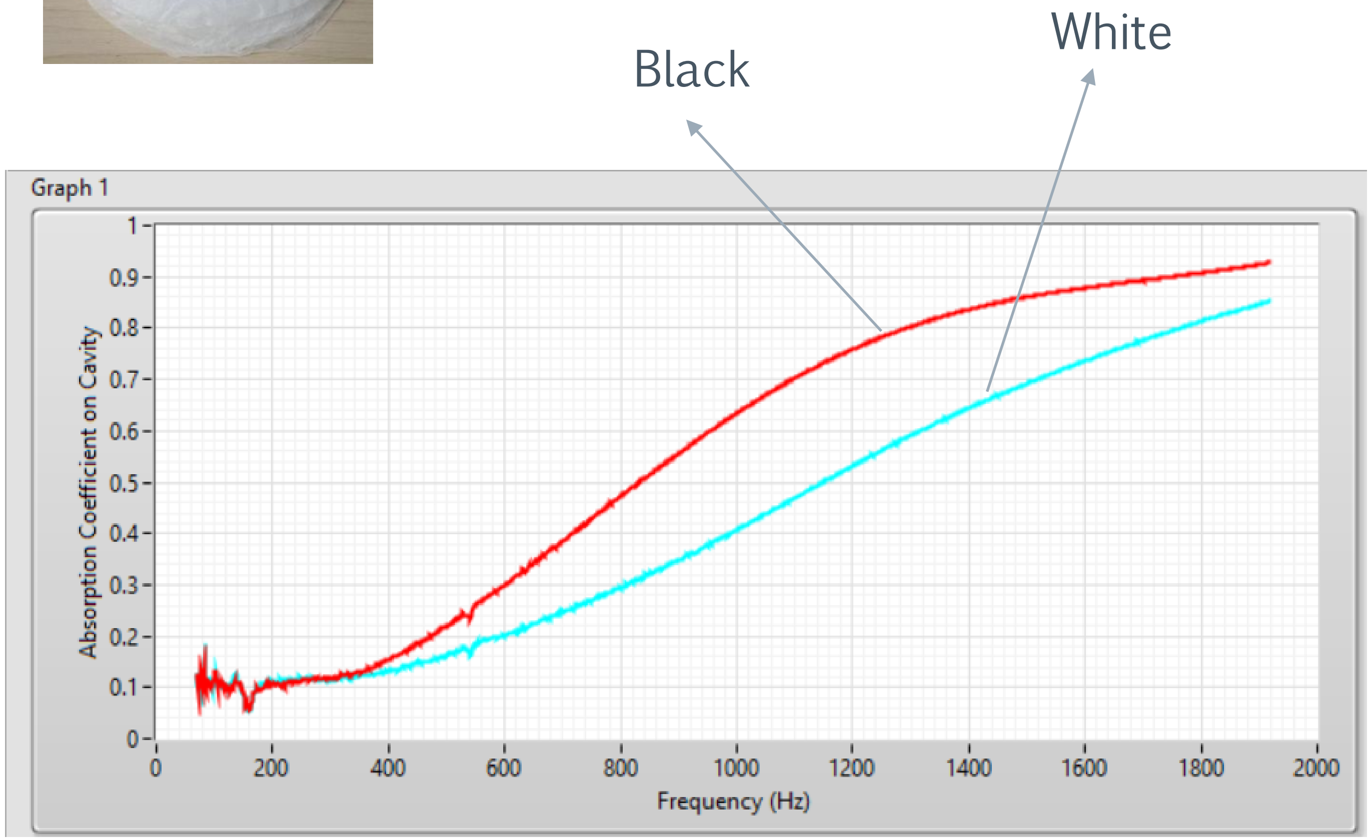
Sample to be improve

Weight:

~280g/m^2



Sample	Melt blown PP + white PET trim
Laboratory environment	Temperature: 25 ℃, Relative humidity: 40 %, Atmospheric pressure: 1024 mbar
Sample dimension	Diameter: 100mm Thickness: 15mm
Porosity	0.999
Airflow Resistivity (Pa·s/m^2 or N·s/m^4)	52421
Tortuosity	1
Viscous characteristic length (μm)	23
Thermal characteristic length (μm)	46

Rigid-Porous Acoustic Model：Johnson-Champoux-Allard(JCA)

$$\tilde{\rho}(\omega) = \frac{\alpha_\infty \rho_0}{\phi}\left[1 + \frac{\sigma\phi}{j\omega\rho_0\alpha_\infty}\sqrt{1 + j\frac{4\alpha_\infty^2 \eta\rho_0\omega}{\sigma^2\Lambda^2\phi^2}}\right]$$

$$\widetilde{K}(\omega) = \frac{\gamma P_0/\phi}{\gamma - (\gamma - 1)\left[1 - j\frac{8\kappa}{\Lambda'^2 C_p \rho_0 \omega}\sqrt{1 + j\frac{\Lambda'^2 C_p \rho_0 \omega}{16\kappa}}\right]^{-1}}$$

$$\tilde{c} = \sqrt{\frac{\tilde{K}_{EQ}}{\tilde{\rho}_{EQ}}} \qquad \tilde{Z}_{EQ} = \tilde{\rho}_{EQ}\tilde{c} = \sqrt{\tilde{\rho}_{EQ}\tilde{K}_{EQ}}$$

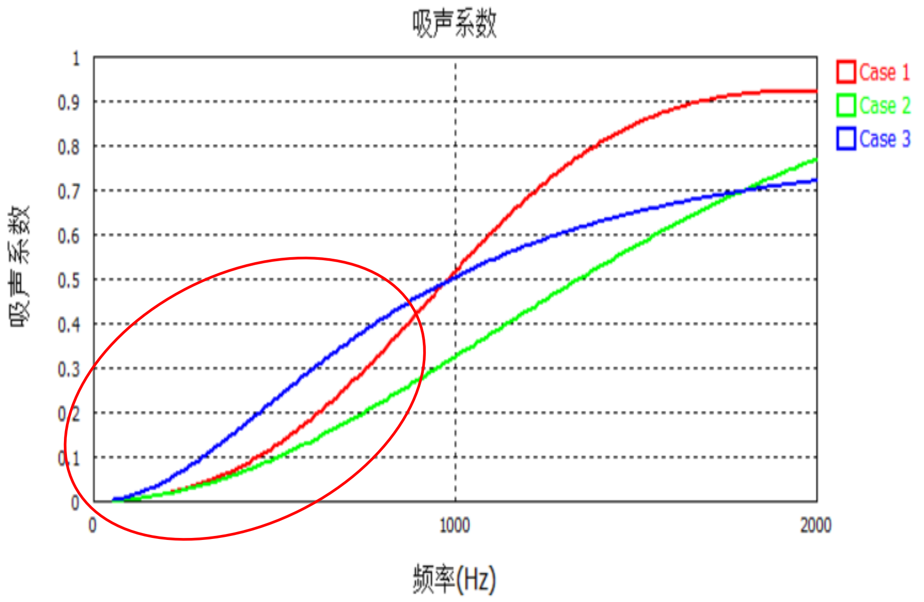
$$\tilde{k} = \frac{\omega}{\tilde{c}} = \omega\sqrt{\frac{\tilde{\rho}_{EQ}}{\tilde{K}_{EQ}}} \qquad \tilde{Z}_S = -j * \tilde{Z}_{EQ} * \cot(\tilde{k} * \mathrm{T})$$

$$\tilde{R} = (Z_0 - \tilde{Z}_S)/(Z_0 + \tilde{Z}_S)$$

Alpha=1-abs($\tilde{R}$)^2

Frequency band(20-1000Hz)
Object=max_Alpha(φ, σ, α∞, Λ′, Λ)

Case 1——Meltblown_black_620g/m^2
Case 2——Meltblown_white_280g/m^2
Case 3——Perfect_absorber_0-1000Hz

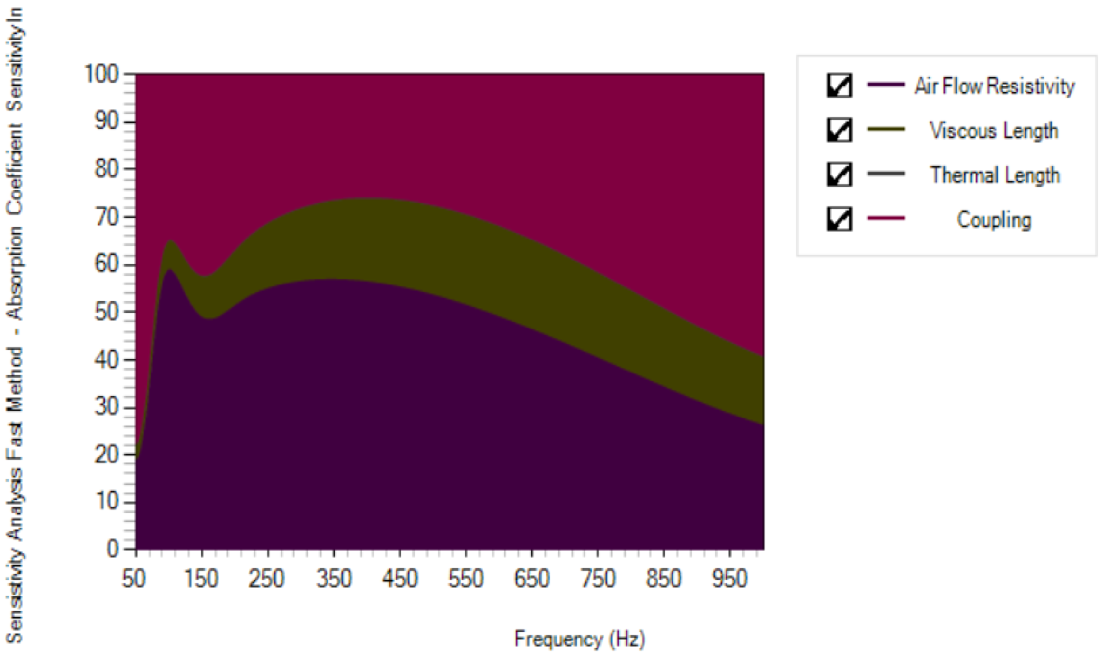


3. Optimization

Sample	Melt blown PP + black PET trim	Melt blown PP + white PET trim	Perfect Absorber (0-1000Hz)
Laboratory environment	Temperature: 25 ℃, Relative humidity: 40 %, Atmospheric pressure: 1024 mbar		
Sample dimension	Diameter: 100mm Thickness: 20mm		
Porosity	0.999	0.999	0.992
Airflow Resistivity (Pa·s/m^2 or N·s/m^4)	59161	52421	162462
Tortuosity	1	1	1
Viscous characteristic length (μm)	8.7	23	10.28
Thermal characteristic length (μm)	17.3	46	80.59

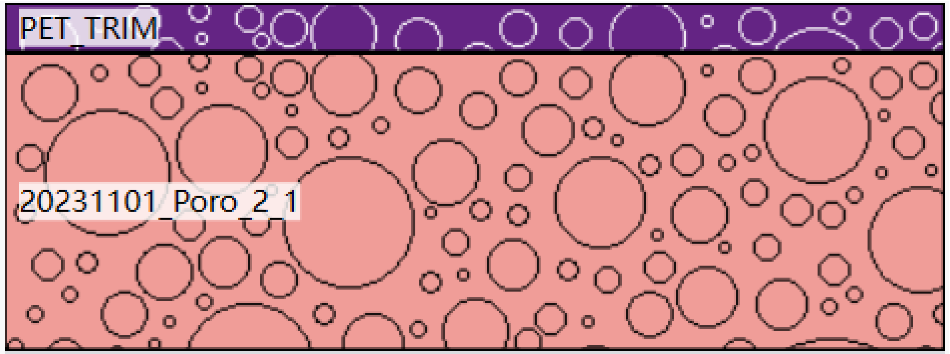
Sensistivity Analysis

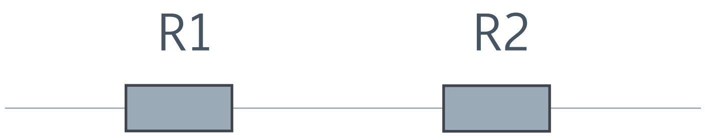
(σ, Λ′, Λ)



Low frequency absorption will benefit from high air flow resistivity.

3. Optimization





Example:

$\sigma 1$ = 216040 Pa.s/m²

h_1 = 0.0025 m

$\sigma 2$ = 52421 Pa.s/m²

h_2 = 0.0125 m

σ = 79691 Pa.s/m²

airflow resistance R=R1+R2

specific airflow resistance $R_S = R_{1S} + R_{2S} = \sigma_1 * h_1 + \sigma_2 * h_2$

airflow resistivity $\sigma = \frac{R_S}{h_1 + h_2} = \frac{\sigma_1 * h_1 + \sigma_2 * h_2}{h_1 + h_2}$

By using high flow resistance thin layer trim, we can increase the total airflow resistivity!

3. Optimization

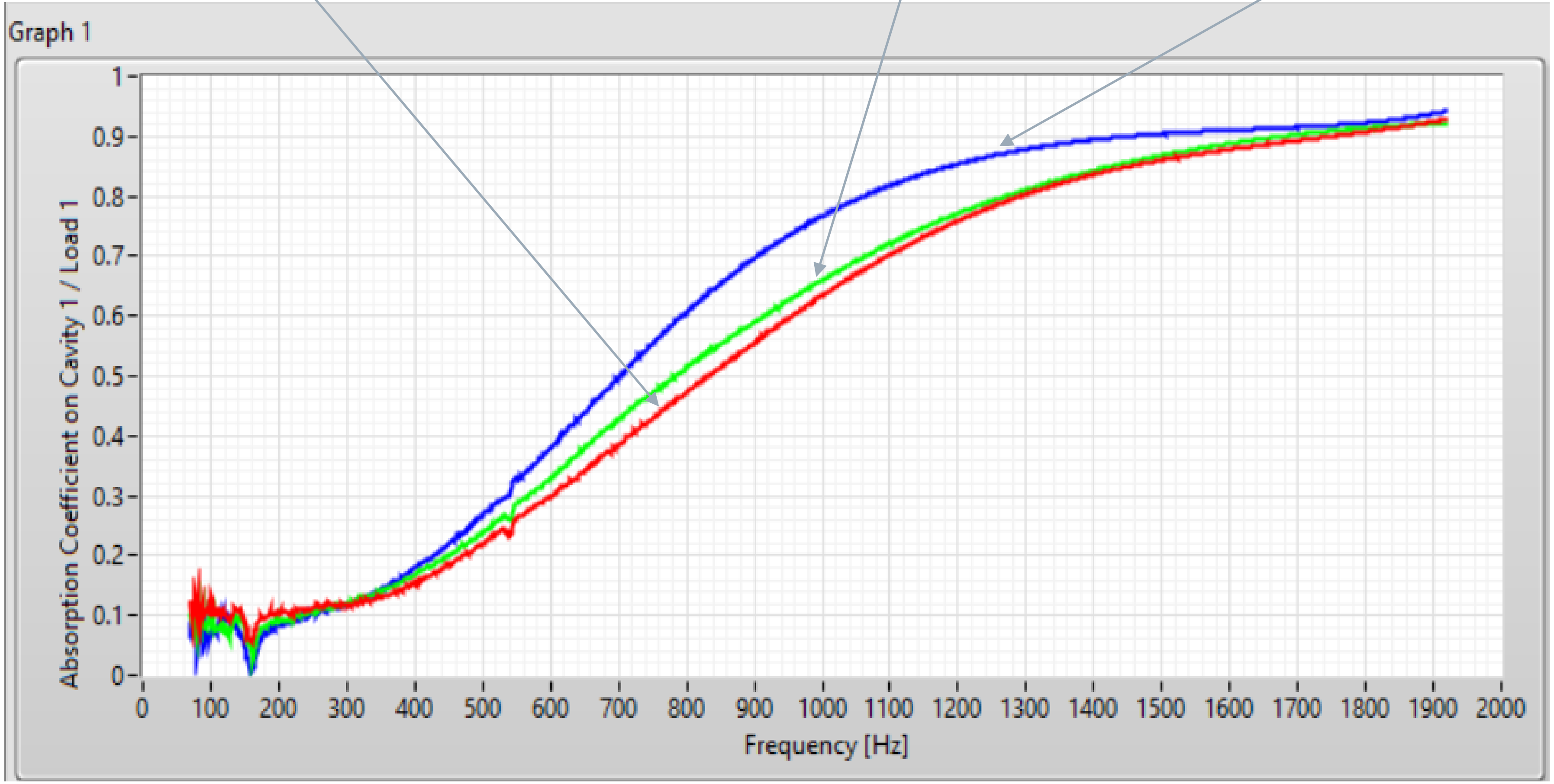
Red-Original black sample 620g/m^2

Green-white sample improved 380g/m^2

Cost down

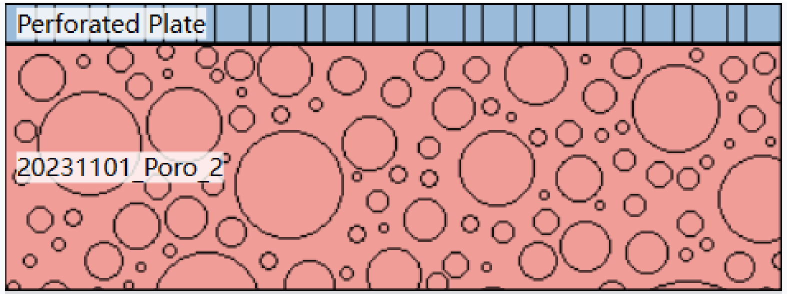
Blue- another white sample 517g/m^2

Cost down + performance improved



all samples:
15mm

4. MPP + Absorber



σ=8η/(φ*r^2)

Λ=r

Λ′=r

α∞=1+2* ε /h

ε=(1−1.13ξ−0.09ξ^2+0.27ξ^3)*8r/3π

$$\xi = 2\sqrt{\frac{\phi}{\pi}}$$

MPP -Equivalent fluid

Multilayer – TMM in series

$$\begin{pmatrix} p \\ v \end{pmatrix}_{front} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} p \\ v \end{pmatrix}_{back}$$

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix} = \begin{pmatrix} a & b \\ c & a \end{pmatrix}_1 \begin{pmatrix} a & b \\ c & a \end{pmatrix}_2 \begin{pmatrix} a & b \\ c & a \end{pmatrix}_3 \begin{pmatrix} a & b \\ c & a \end{pmatrix}_4 \begin{pmatrix} a & b \\ c & a \end{pmatrix}_5$$

Reference: Acoustical characterization of perforated facings (matelys.com)

4. MPP + Absorber

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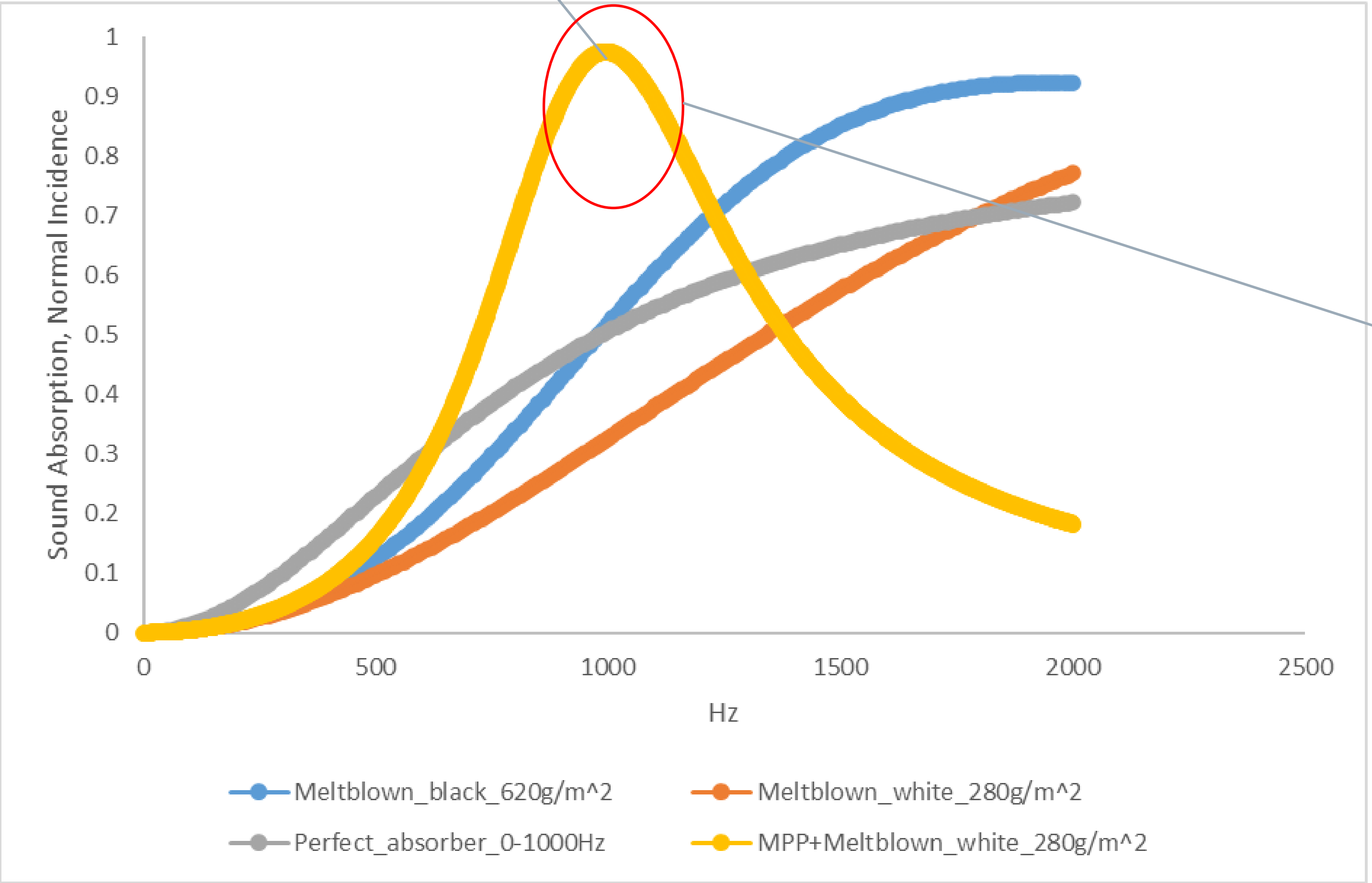
Perforated panel thickness: 2mm
Absorber thickness: 15mm



The peak can be tuned for specific frequency band

Q&A