SAPEM 2014

Characterization of Nonlinear Sound Absorption for Fibrous Metals

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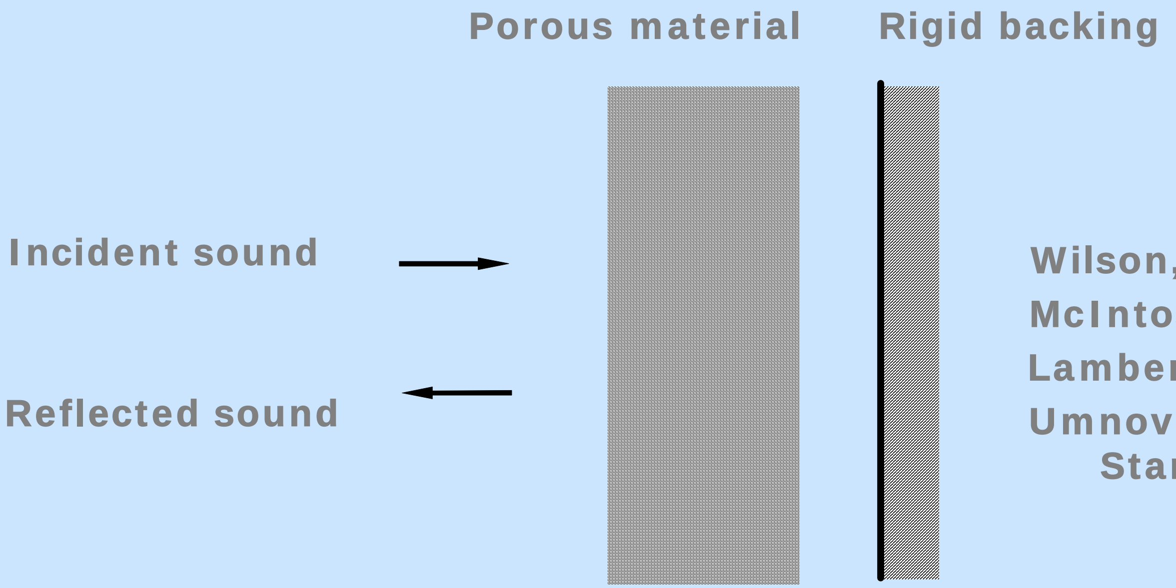
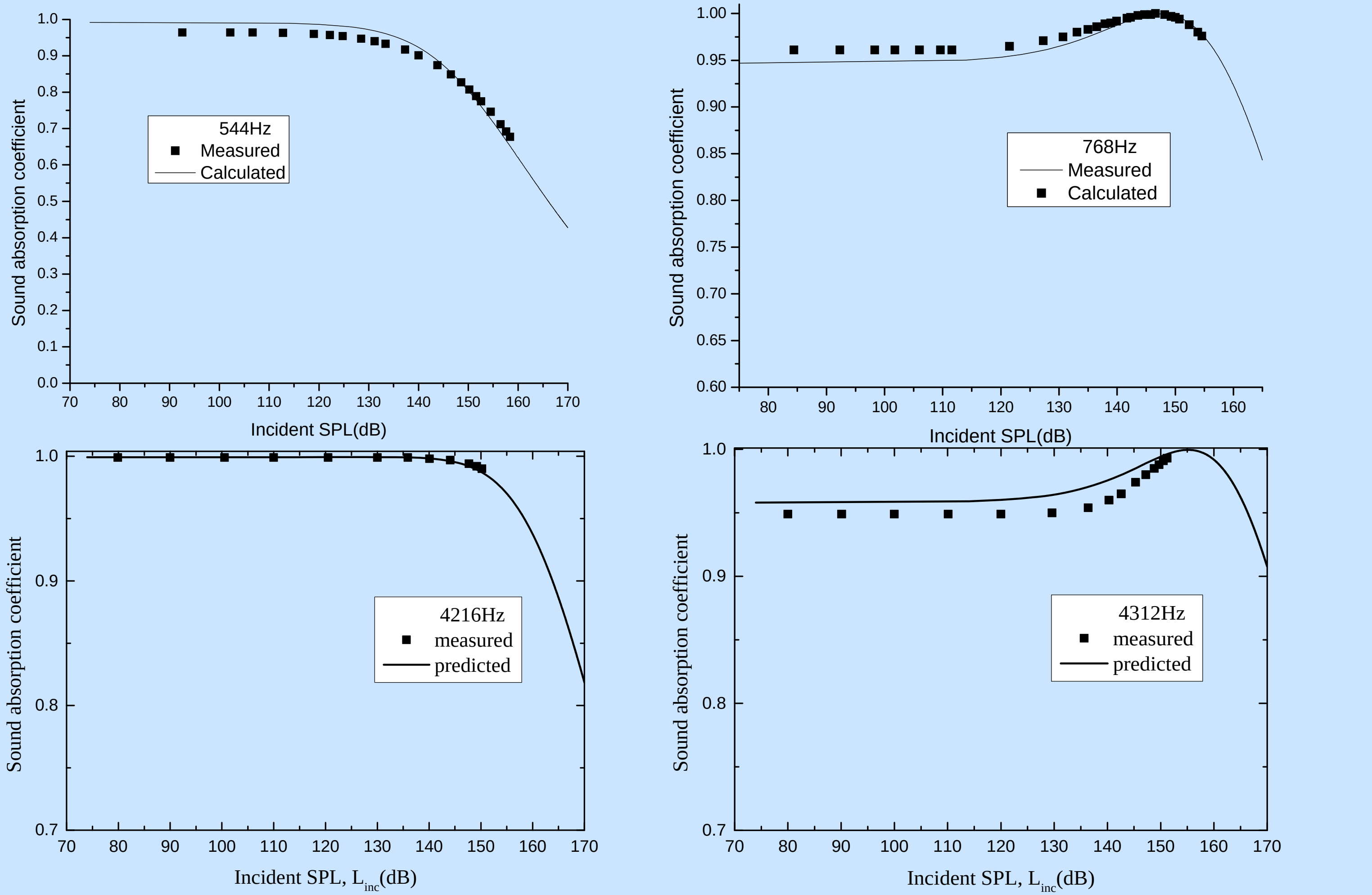
- Introduction
- Formulation of the problem
- Results and discussion
- Conclusion



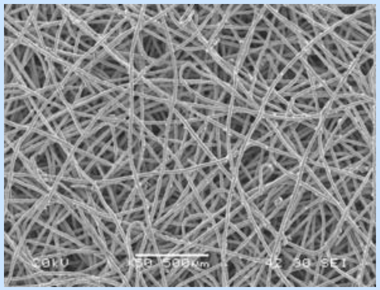
Wilson, McIntosh & Lambert
McIntosh & Lambert
Lambert & McIntosh
Umnova, Attenborough, Standley & Cummings

Solutions to porous metal layers at high sound intensities



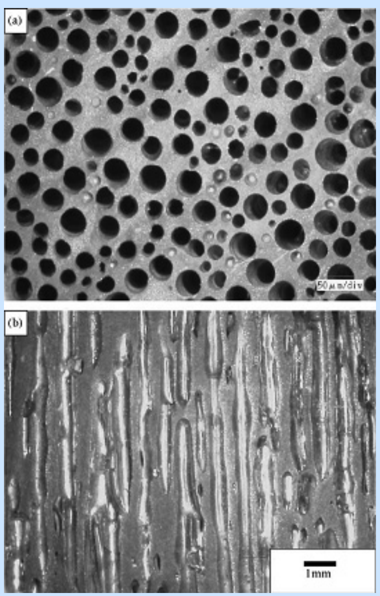
How can we verify these trends of chosen materials ?

Porous metal samples



Sample No	1	2	3	...	19	20	21
Radius r (μm)	12	100	200	...	12	100	200
Porosity	0.85	0.85	0.85	...	0.97	0.94	0.95

Fibrous porous metals

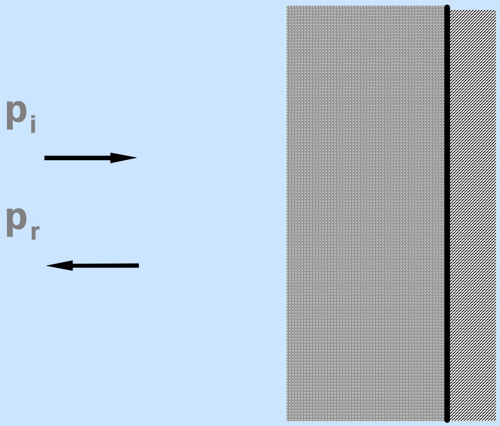


Maximum radius r (mm)	0.3	0.6
Porosity	0.236	0.430
Sample thickness (mm)	14.5	15.2

Lotus-type porous metals

Governing equations:

$$-\frac{dp}{dx} = \mathrm{i}\omega\rho u / \phi \qquad -\frac{du}{dx} = \frac{\mathrm{i}\omega\phi}{K} p$$



Resistivity $\sigma = \sigma_0(1+\xi\,|u|)$

Density $\rho = \frac{\phi Z_p k_p}{\omega} + \frac{8\xi\sigma_0\phi|u|}{3\pi\mathrm{i}\omega}$

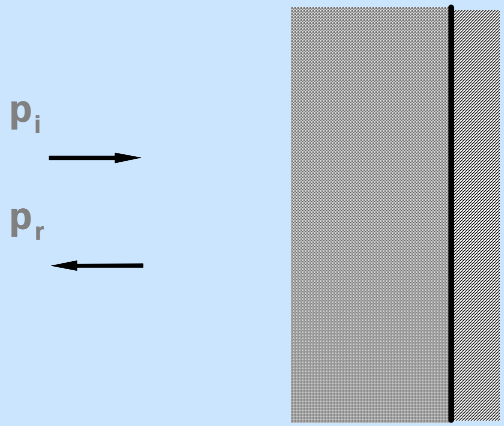
Bulk modulus $K = \frac{\phi\omega Z_p}{k_p}$

One-dimensional, rigid frame, nonlinear

$$\frac{d^2u}{dx^2} + k_p^2 u + \frac{8\xi\sigma_0 k_p}{3\pi\mathrm{i}Z_p}|u|u = 0$$

Governing equations:

$$-\frac{dp}{dx}=\mathrm{i}\omega\rho u/\phi \qquad -\frac{du}{dx}=\frac{\mathrm{i}\omega\phi}{K}p$$



Resistivity $\sigma=\sigma_0(1+\xi|u|)$

Density $\rho=\frac{\phi Z_p k_p}{\omega}+\frac{8\xi\sigma_0\phi|u|}{3\pi\mathrm{i}\omega}$

Bulk modulus $K=\frac{\phi\omega Z_p}{k_p}$

Dimensionless parameters

$$\beta=\frac{fL}{c_0},\chi=\frac{\sigma_0 L}{Z_0},\gamma=\frac{\xi|p_i|}{Z_0}$$

Mechel

$$\gamma = \frac{\xi |p_i|}{Z_0}$$

Introducing L_γ

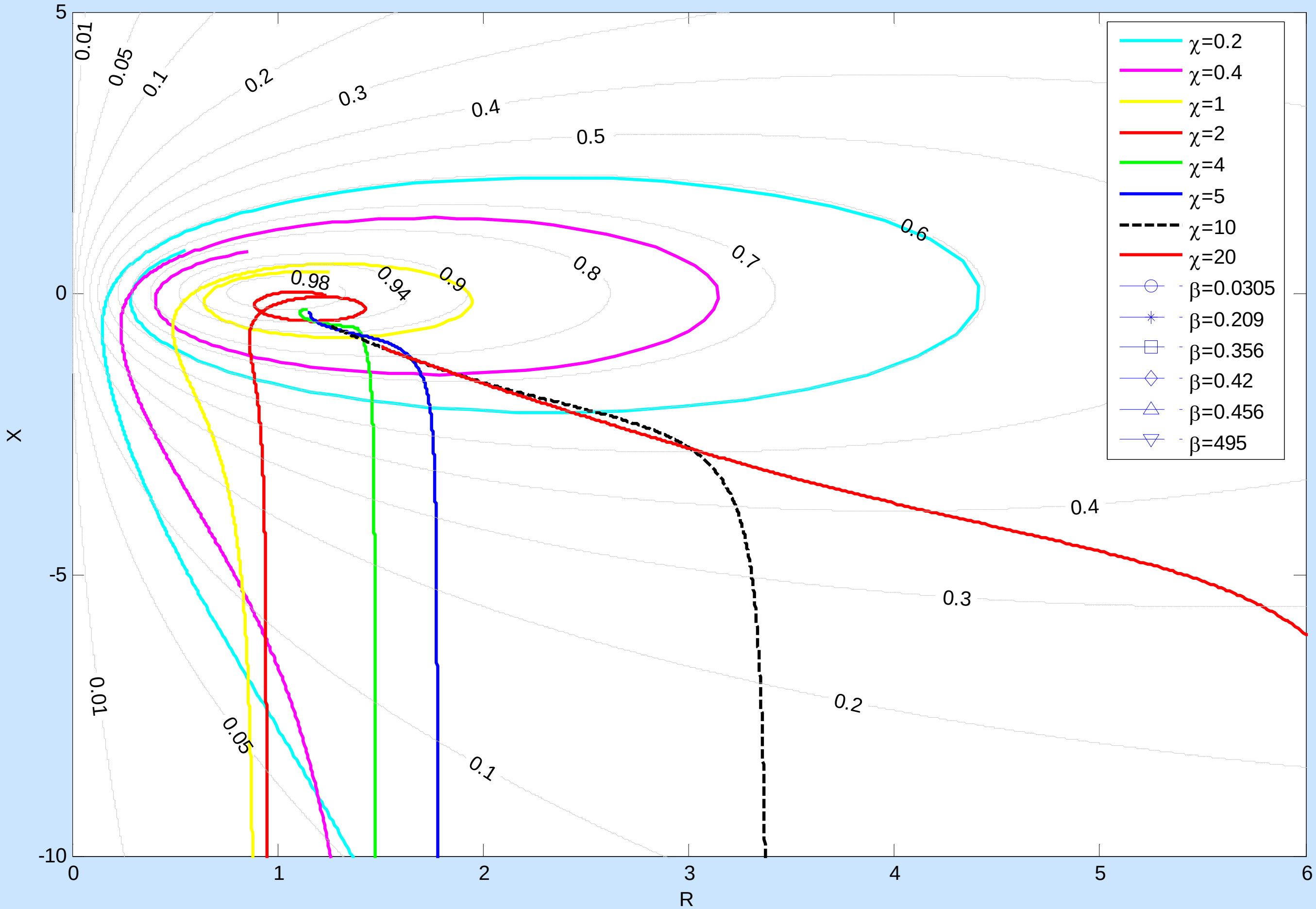
$$L_{p_i} = 20\lg\frac{|p_i|}{\sqrt{2}p_{ref}} = L_\gamma - 20\lg\frac{\sqrt{2}\xi p_{ref}}{Z_0}$$

Resistivity at the first absorption resonance frequency

$$\frac{\sigma_0 L_p}{Z_0}\left(1+\frac{\xi|p_i|}{\sqrt{2}Z_0}\right) = \chi\left(1+\gamma/\sqrt{2}\right) = \chi_m$$

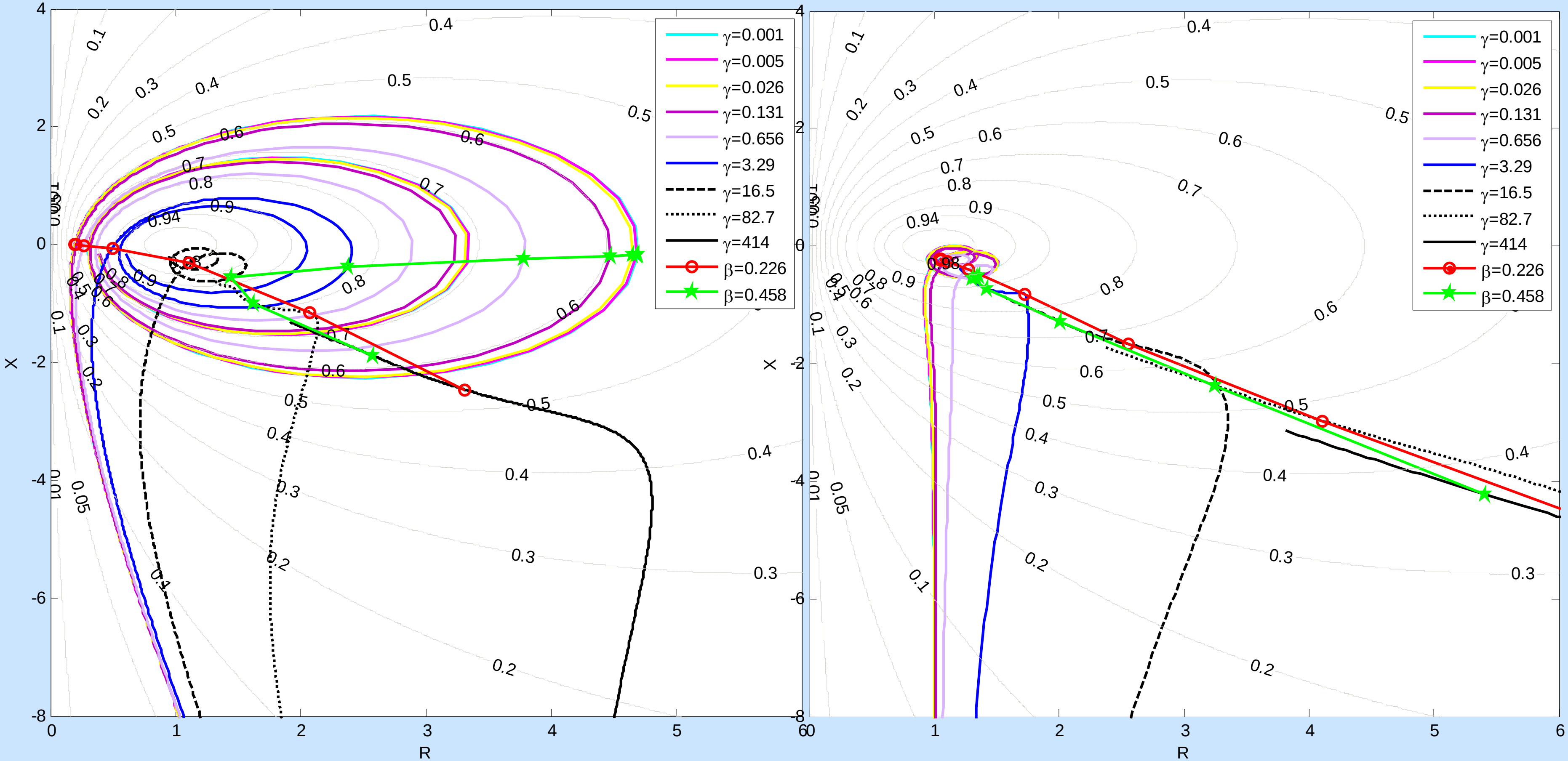
Characteristic flow resistance level

$$L_{\gamma cr} = 20\lg\left(\sqrt{2}\left(\frac{\chi_m}{\chi}-1\right)\right)$$



$\gamma = 0$

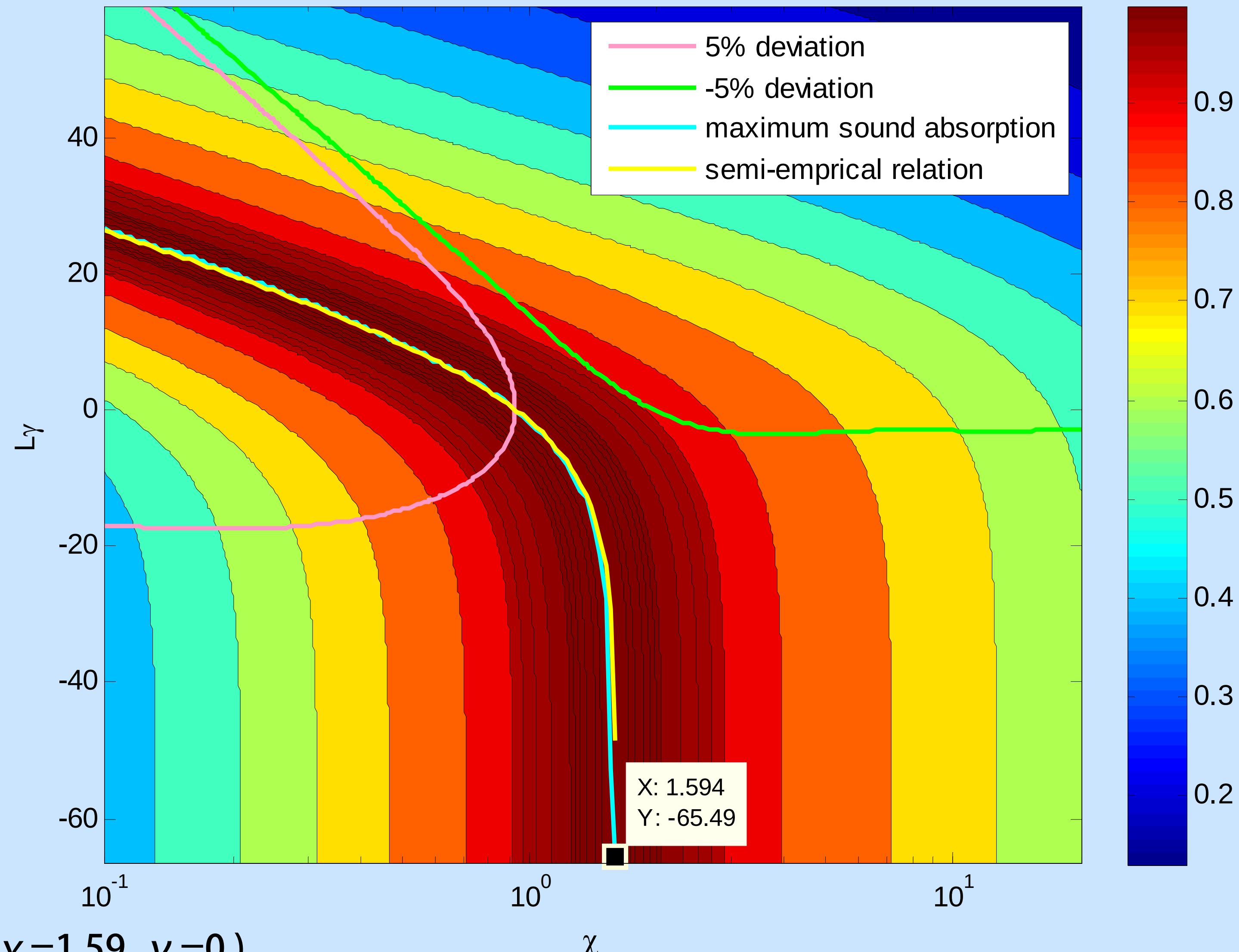
Surface impedance absorption contour, χ , β



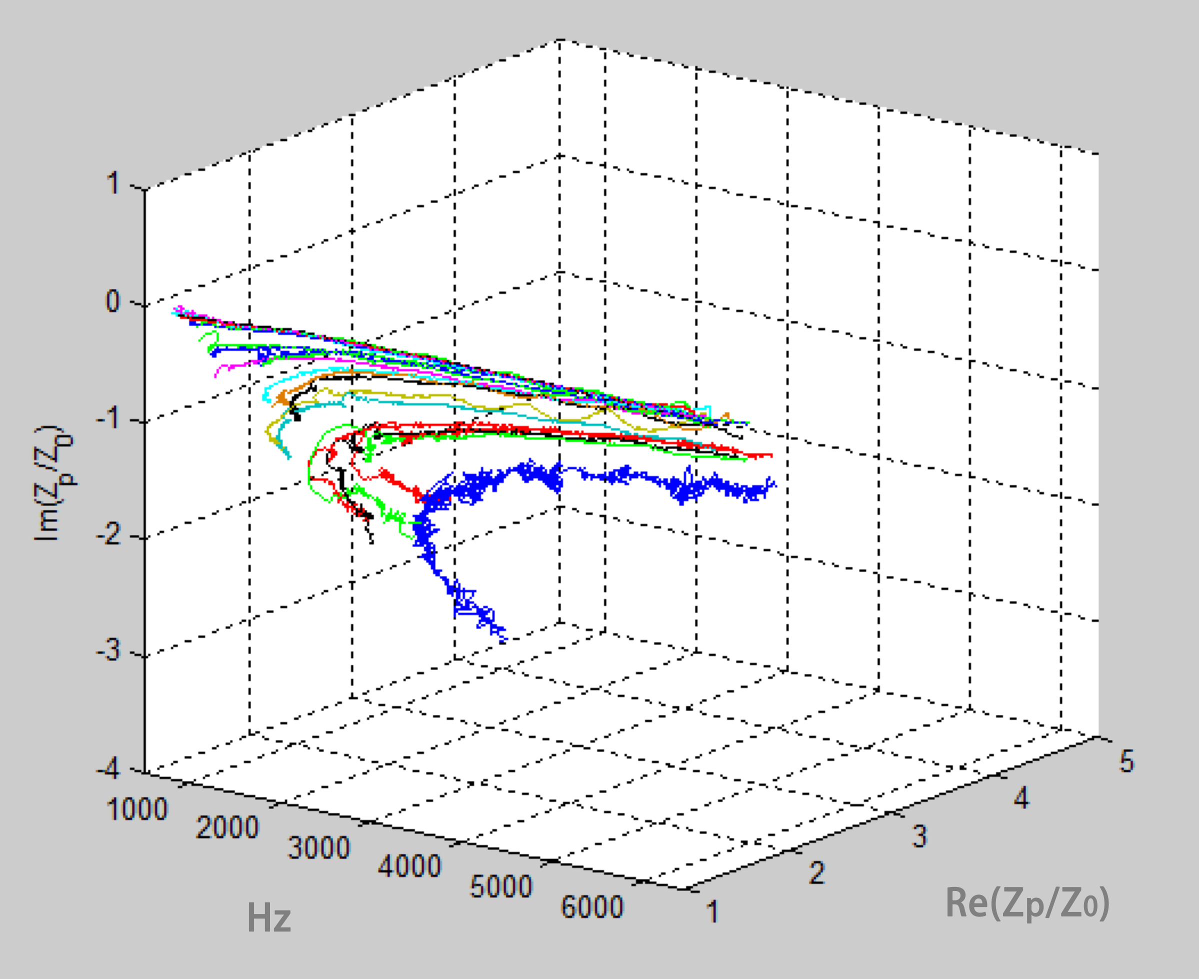
χ =0.2

χ =2

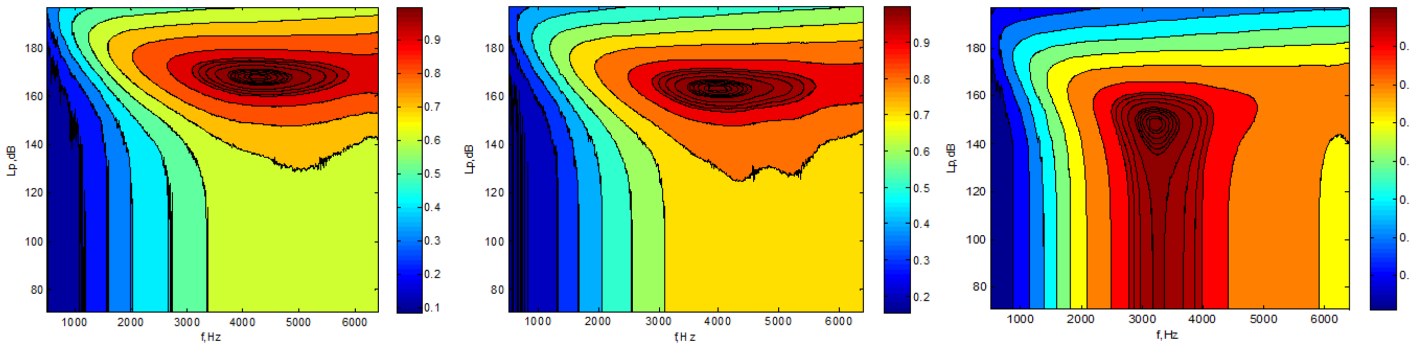
Surface impedance absorption contour, γ , β



$\beta = 0.26, (\chi = 1.59,\ \gamma = 0)$



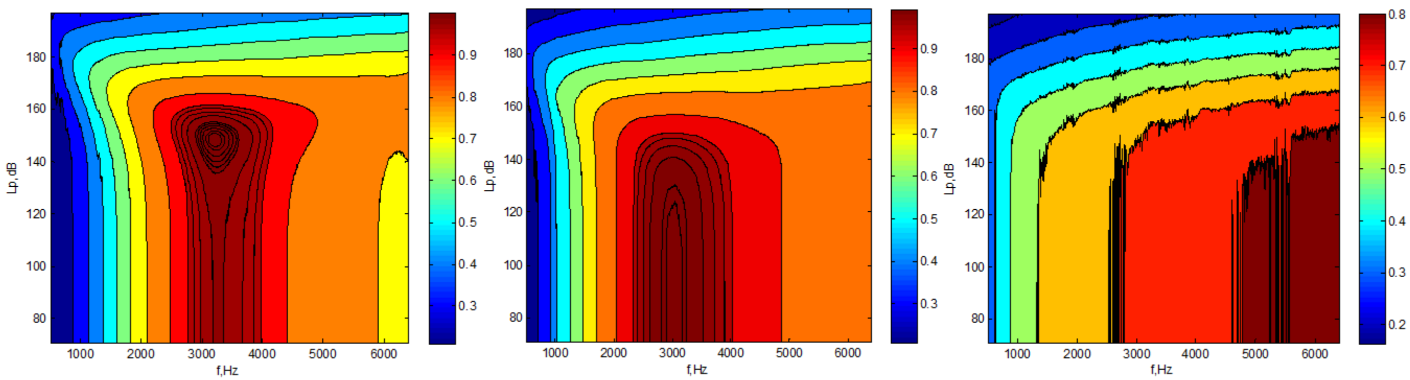
Characteristic impedance of fibrous metal samples



$\phi = 0.95$ $\quad$ $\phi = 0.93$ $\quad$ $\phi = 0.85$

$\sigma_0 = 2102\,\mathrm{Pa\cdot s/m^2}$ $\xi = 1.047\,\mathrm{s/m}$ $\quad$ $\sigma_0 = 3860\,\mathrm{Pa\cdot s/m^2}$ $\xi = 0.937\,\mathrm{s/m}$ $\quad$ $\sigma_0 = 14137\,\mathrm{Pa\cdot s/m^2}$ $\xi = 0.581\,\mathrm{s/m}$

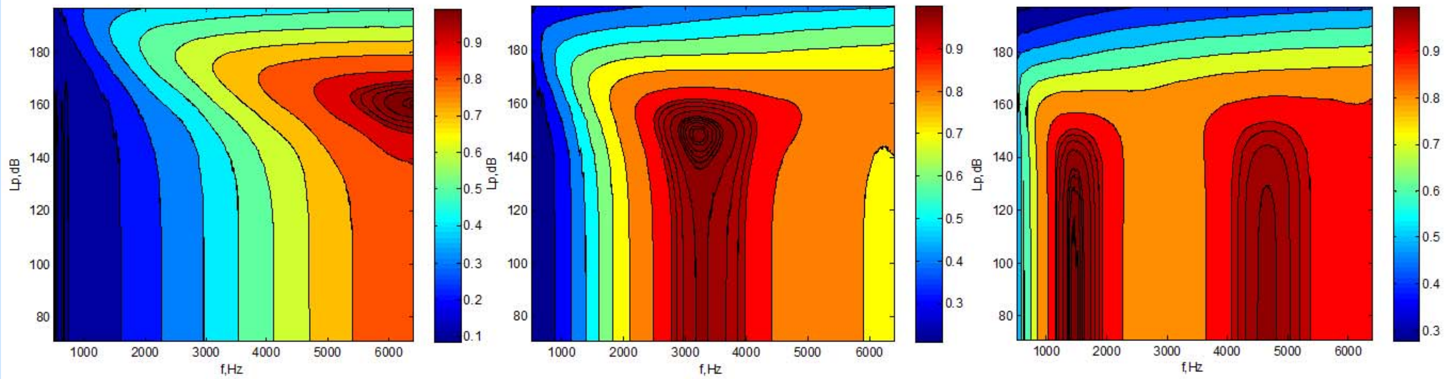
Effects of porosity on absorption at high SPLs（$d = 200\mu\mathrm{m}$）



$d = 200\mu\mathrm{m}$ $\quad$ $d = 100\mu\mathrm{m}$ $\quad$ $d = 12\mu\mathrm{m}$

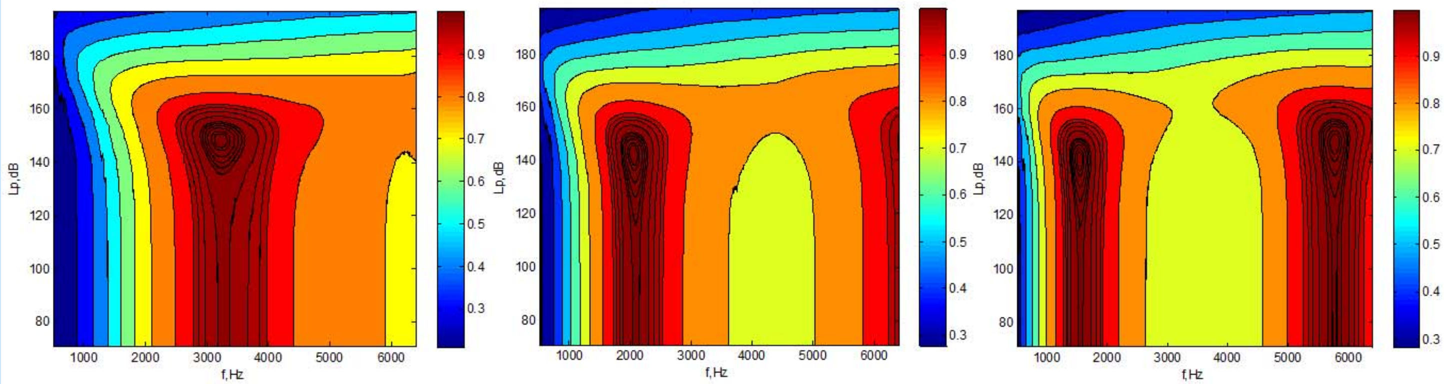
$\sigma_0 = 14137\,\mathrm{Pa\cdot s/m^2}$ $\xi = 0.581\,\mathrm{s/m}$ $\quad$ $\sigma_0 = 41377\,\mathrm{Pa\cdot s/m^2}$ $\xi = 0.383\,\mathrm{s/m}$ $\quad$ $\sigma_0 = 124279\,\mathrm{Pa\cdot s/m^2}$ $\xi = 0.330\,\mathrm{s/m}$

Effects of fibre diameter on absorption at high SPLs（$\phi = 0.85$）



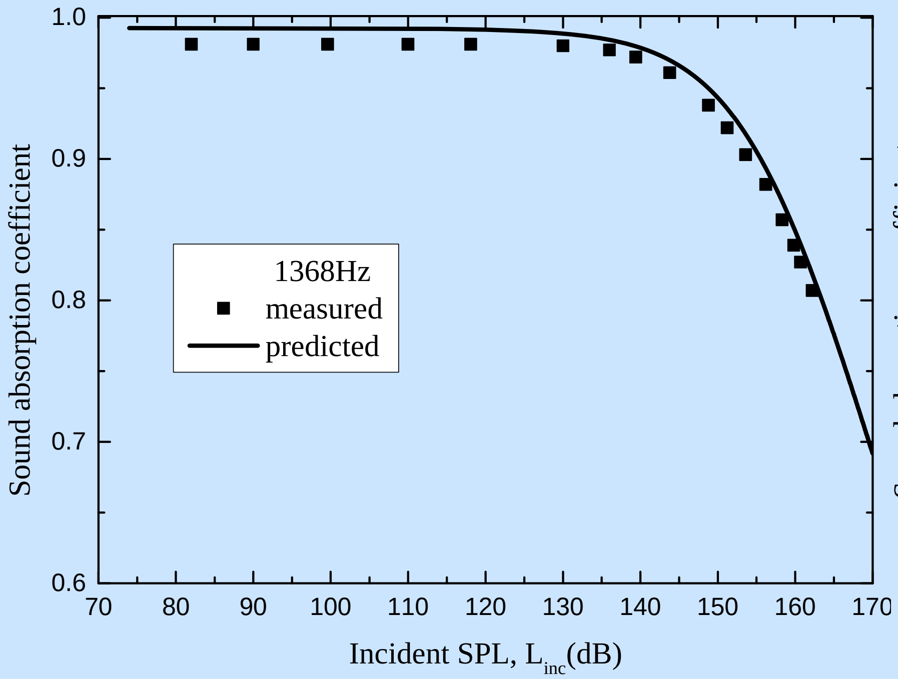
$L_p = 10\text{mm}$　　$L_p = 20\text{mm}$　　$L_p = 40\text{mm}$

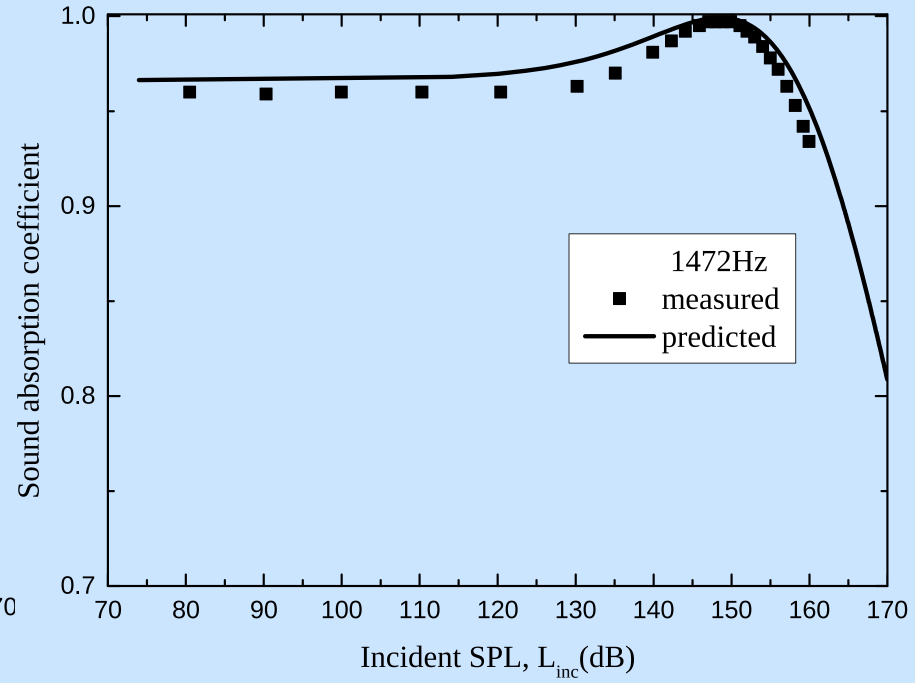
Effects of thickness on absorption at high SPLs（$d = 200\mu\text{m}$， $\phi = 0.85$）



$L_c = 0$　　$L_p = 10\text{mm}$　　$L_c = 20\text{mm}$

Effects of back cavity on absorption at hight SPLs（$d = 200\mu\text{m}$， $\phi = 0.85$， $L_p = 20\text{mm}$）





Trend characteristics being verified by two samples

Conclusions

- **Constant SPL curves on a surface impedance map indicate that the first absorption resonance maxima tend to shift toward the acoustic higher resistance and lower reactance ends.**
- **With SPL increasing at a constant frequency, absorption of samples with larger fibre diameters are more likely to first increase to a maximum then followed by decreasing, while absorption of small fibre diameter samples or samples having low porosities tends to monotonically decrease.**
- **The trend of sound absorption coefficient at a resonance frequency at high SPLs can be reflected by a characteristic flow resistance at the first absorption resonance at linear SPLs.**

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