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Laboratory measurement of the acoustic absorption coefficient based on the modal dispersion

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Abstract

The measurement of acoustic material characteristics using a standard impedance tube method is generally limited to the plane wave regime which implies that the size of the tube and, consequently the size of the material specimen must remain smaller than a half of the wavelength. This paper presents a novel method which enables us to extend the frequency range beyond the plane wave regime so that the size of the material sample can be much larger than the wavelength. The proposed method is based on measuring of the sound pressure at different axial locations and applying the spatial Fourier transform. A normal mode decomposition approach is used together with an optimization algorithm to minimize the discrepancy between the measured and predicted sound pressure spectra. This enables us to calculate the frequency and angle dependent reflection and absorption coefficients of the porous layer in an extended frequency range. The method has been tested successfully on samples of melamine foam and wood fibre in the frequency range which extends the maximum frequency of the tube by a factor of 3. The measured data are in close agreement with the predictions by the equivalent fluid model for the acoustical properties of porous media.

Rationale for this work

The upper frequency limit in **EN ISO 10534-2:2001**

is inversely proportional to the sample size

The condition for f_u is:

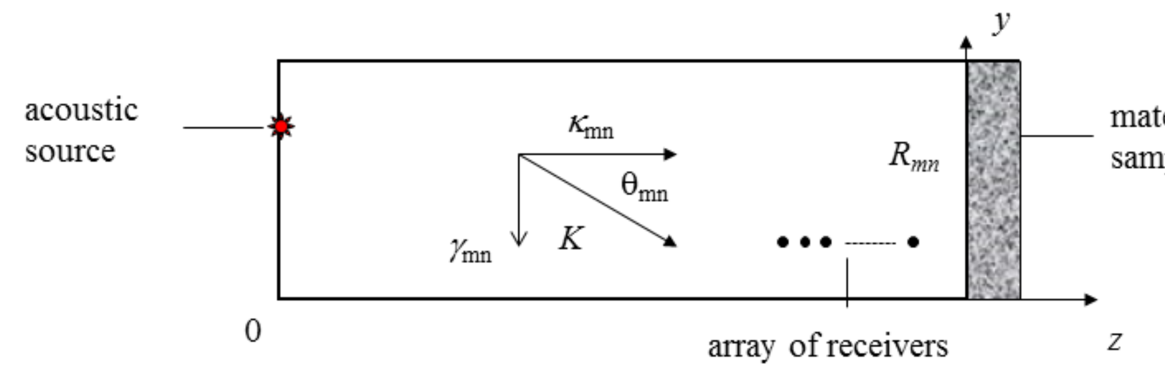
$$d < 0{,}58\,\lambda_u;\ f_u \cdot d < 0{,}58\,c_0 \qquad (2)$$

for circular tubes with the inside diameter d in metres and f_u in hertz.

$$d < 0{,}5\,\lambda_u;\ f_u \cdot d < 0{,}50\,c_0 \qquad (3)$$

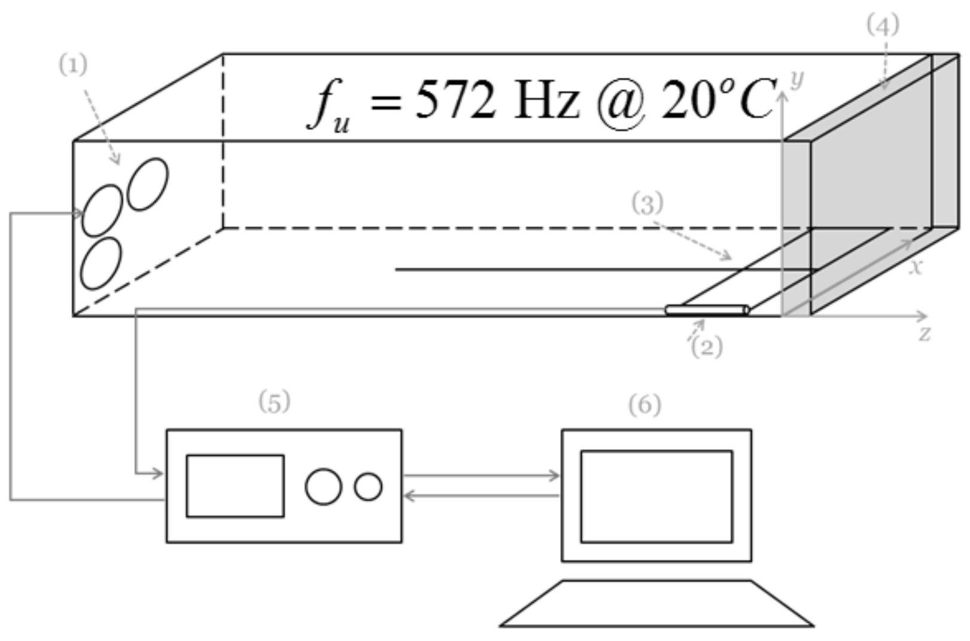
for rectangular tubes with the maximum side length d in metres; c_0 is the speed of sound in metres per second given by equation (5).

Theoretical foundation



$$\tilde{p}(K,\omega) = \sum_{m=0}^{\infty}\sum_{n=0}^{\infty} \cos\frac{m\pi}{a}x \cos\frac{n\pi}{a}y \left(A_{mn}\int^{\infty} e^{i(K-k_{mn})z}dz + A_{mn}R_{mn}\int^{\infty} e^{i(K+k_{mn})z}dz \right)$$

Basic measurement method



300mm x 300mm
4.5m long

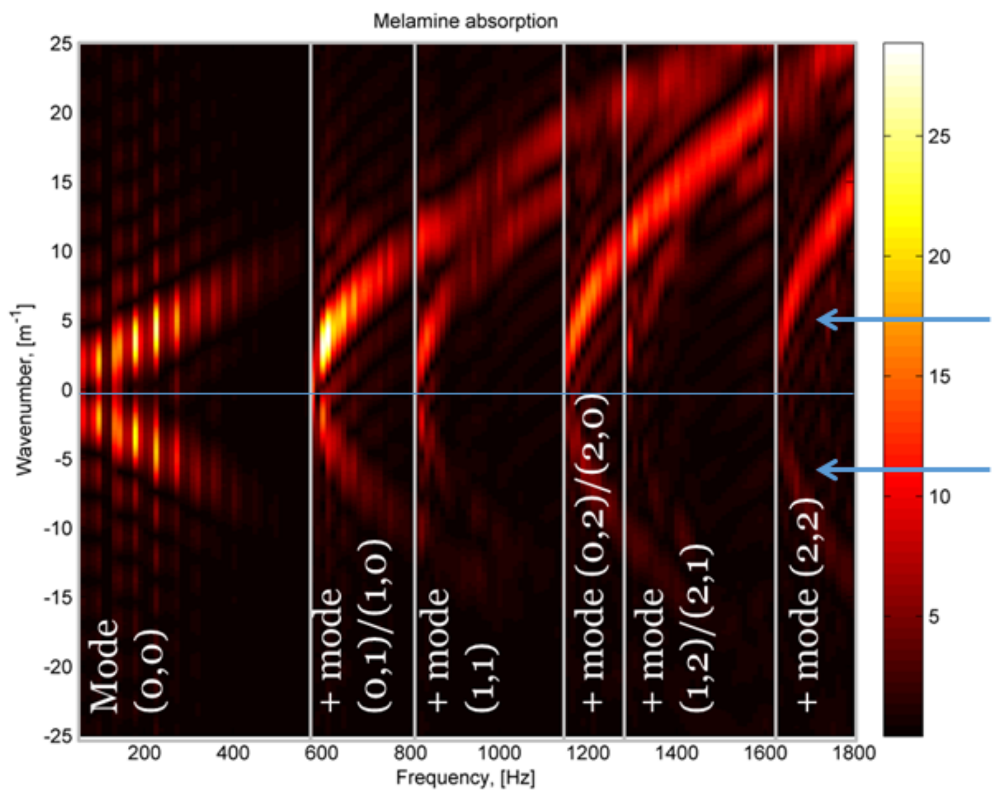
Sound pressure spectrum

$$\tilde{p}_m(K,\omega) = \int_{-\infty}^{\infty} p_m(z,\omega)e^{iKz}dz \simeq \frac{\Delta}{2}\sum_{j=1}^{N}\left[p_m\left(z_{j+1},\omega\right)e^{iKz_{j+1}} + p_m\left(z_j,\omega\right)e^{iKz_j}\right]$$

N = 52 measurement positions along the tube

$$p(z_j,\omega) = \frac{1}{2}(p(z_j,\omega) + p(z_{j-1},\omega)),$$
$$u(z_j,\omega) = -\frac{1}{i\omega\rho\Delta}(p(z_j,\omega) - p(z_{j-1},\omega))$$

Modal dispersion and absorption

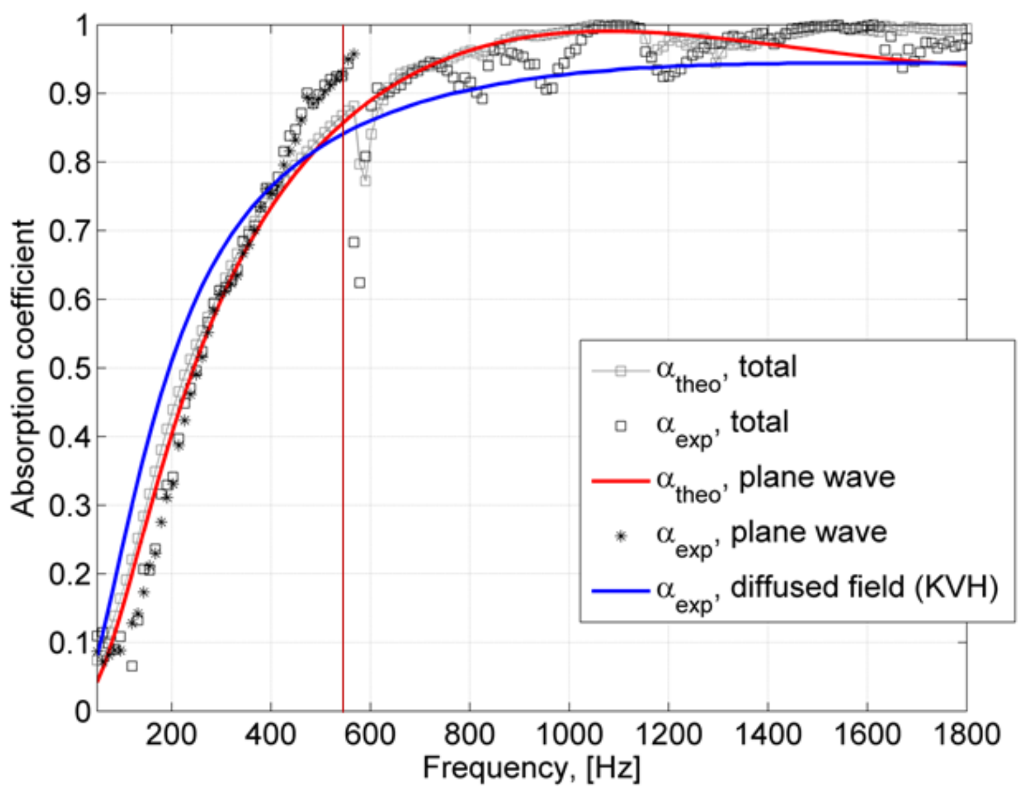


incident

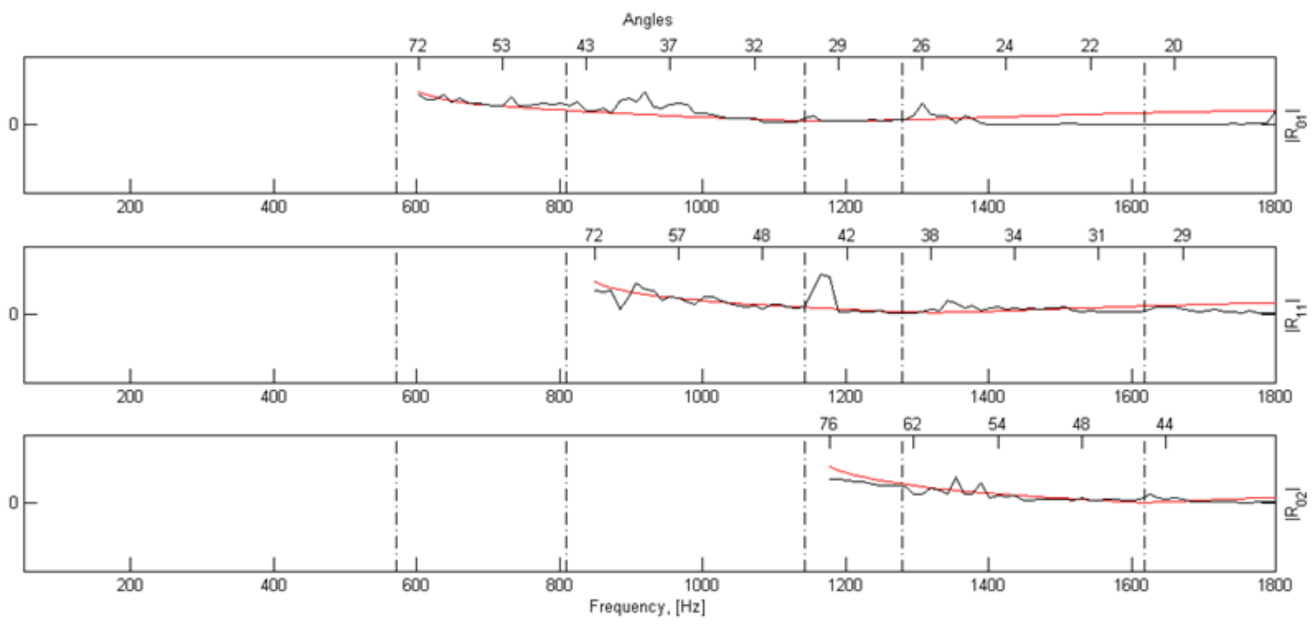
reflected

$$\alpha(\omega) = 1 - \frac{\int I_r(K,\omega)dK}{\int I_i(K,\omega)dK}$$

Results: Total absorption coefficient



Results: Angular-, frequency-dependent absorption coefficient



Conclusions

- In this work we have studied a novel acoustic method for measuring the complex reflection and absorption coefficients over an extended frequency range.
- The proposed measurement method enables us to measure the acoustic absorption coefficient of relative large material samples which cannot be currently achieved with ISO 10534 method.
- It enables us to characterize accurately the acoustical properties of representative material samples using a suitable equivalent flow model.
- It enables us to measure these properties at a range of angles of incidence which is achieved through mode separation.

The full work is published in J. Prisutova, K. V. Horoshenkov, J.-P. Groby and B. Brouard, “A method to determine the acoustic reflection and absorption coefficients of porous media by using modal dispersion,” J. Acoust. Soc. Am. 136, 2947-2958 (2014). http://dx.doi.org/10.1121/1.4900598.