ESTIMATING SOUND ABSORPTION COEFFICIENT UNDER VARIOUS SOUND PRESSURE FIELDS BY COMBINING AN AUTOMATED TEST BENCH TO SOUND FIELD REPRODUCTION AND ADVANCED POST-PROCESSING TECHNIQUES

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1 Introduction

Two normalized methods are currently used to characterize sound absorbing materials. The first one, namely the impedance tube method, allows the measurement of the sound absorption coefficient under plane waves and normal incidence only. The samples used are small and possibly not representative of the whole material. The second method is the reverberant room method and provides diffuse field sound absorption coefficient on large samples. A large surface of materials and specific mounting conditions are required as well as a room with minimum volume (over 150 m^3). The results are often overestimated (larger than unity) and show poor reproducibility.

Researchers seek to develop more reliable methods, that can also address *in situ* like conditions. In particular, a sound field reproduction approach was proposed by Robin et al., 2019 and estimates the absorption coefficient of materials under a synthetized acoustic field, using a virtual sound source array. Results show good agreement with Transfer Matrix Method simulations and need no specific mounting of the samples. Results are not overestimated and *in situ* measurements are possible. However, results are biased under 400 Hz, due to two reasons: the use of a simplified spherical wave propagation model, and measurements uncertainties, mainly concerning microphone or source positions [1].

This article suggests improvements of this method by using an automated test bench to reduce the measurement uncertainties, a more general propagation model, namely Allard's model and an advanced post-processing technique.

2 Measurements and post-processing method

2.1 Experimental measurements

An automated test bench allowing a point source to be moved along a plane above the surface material has been developed and measurement uncertainties minimized. Measurements were done on five different materials in a semi-anechoic room, with a virtual array of 49 sources separated by 15 cm in each (x-y) direction, a source height z_s of 30 cm above the material and two microphones placed at $z_{r1} = 5$ cm and $z_{r2} = 10$ cm above the sample, respectively. Transfer functions between the two microphones $H_{12} = p_2/p_1$ (H_1 estimator) are then calculated for each source position.

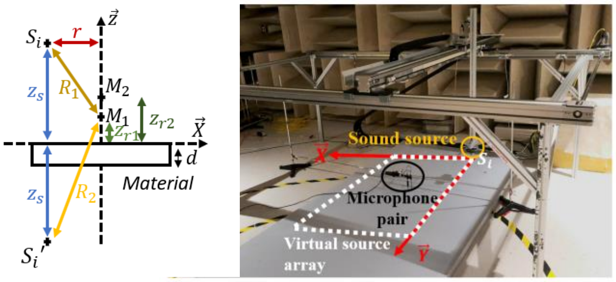

Figure 1: Automated test bench, virtual source array and geometrical parameters of the method.

2.2 Post-processing technique

2.2.1 Identification of materials parameters

An advanced post-processing technique is suggested using the automated test bench measurements and the Allard theoretical model of sound propagation above a material [2]. From this model, the total sound pressure at a given microphone and at angular frequency ω follows equation 1.

$$p_{tot}(r, z_r; \omega) = \mathrm{j}\omega\rho_0\Big[\frac{e^{-jk_0R_1}}{R_1} - \frac{e^{-jk_0R_2}}{R_2} + \int_{k=0}^{\infty} \frac{2\rho_m}{\rho_m\nu_0 + \rho_0\nu_m \tanh(\nu_m d)} e^{-\nu_0(z_s+z_r)} J_0(kr)kdk\Big] \tag{1}$$

with, ρ_0, the air density, R_1, the distance between the real source and microphone, R_2, the distance between the image source and microphone, $\nu_0 = \sqrt{k^2 - k_0^2}$, $\nu_m = \sqrt{k^2 - k_m^2}$, k_0, the acoustic medium wavenumber, d, the material's thickness, r, the distance between the real source and microphone along the material's surface and $J_0(kr)$, the zero order Bessel function.

The idea followed here is to recover the frequency-dependent, complex density ρ_m and complex wavenumber k_m of the material by inverting Allard's model. The `fmincon` Matlab function is used to minimize a cost function, which is the sum of squared differences between the measured transfer functions H_{12} on the test bench and those predicted by Allard's model over all point source positions of the virtual array, as in equation (2).

$$(\rho_m, k_m) = \min\left(\sum_i \left|H_{12TestBench,i} - H_{12Allard,i}\right|^2\right) \tag{2}$$

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2.2.2 Plane wave sound absorption coefficients

Using estimated ρ_m and k_m values and under a plane wave assumption, the sound absorption coefficient for a given incidence angle θ is calculated with the usual equation. The sound absorption coefficient under a diffuse acoustic field is obtained by averaging the oblique sound absorption coefficient over angles θ between 0 and $\pi/2$.

3 Results and discussion

In this paper, results are only provided for a single material (2-inches thick melamine sample with 1.8 m ×2.5 m surface).

3.1 Test bench uncertainties

The measurement uncertainties on the geometrical parameters, in particular on microphones and sources positions, are limited and show small impact on the results. The automation allows more reproducible and faster tests compared with previous works in which the source was manually translated [1].

3.2 Allard’s model inversion to obtain complex density and complex wavenumber

Figure 2 shows the optimized acoustic quantities ρ_m and k_m obtained with the Allard’s model inversion based on 10 measured transfer functions H_{12}, those obtained with the impedance tube method and those predicted by the Johnson-Champoux-Allard (JCA) model. The results derived from the test bench shows good agreement with the impedance tube data and JCA model, but below 700 Hz, a few peaks are observed certainly caused by the presence of the test bench.

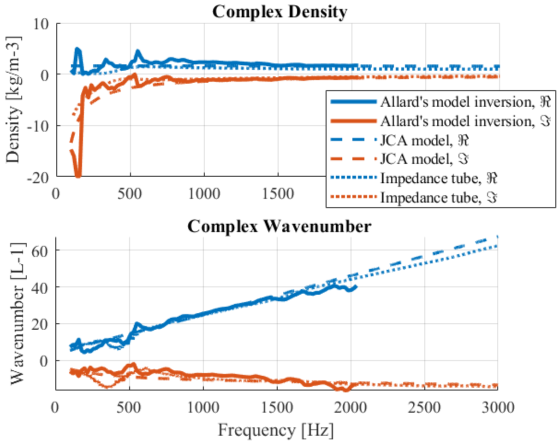

Figure 2: Complex density and complex wavenumber, methods comparison.

3.3 Absorption coefficient

Figure 3 shows the estimated absorption coefficients obtained under normal plane wave, oblique plane wave and diffuse field incidence. Impedance tube tests are used as a comparison for the normal incidence [1]. The results obtained from the Allard’s model inversion agree with the impedance tube results, as well as with the JCA model. Diffuse field absorption coefficients obtained with the proposed approach are in good agreement on the whole considered frequency range [1]. Abnormal absorption peaks are observed (same as for the complex density and wavenumber).

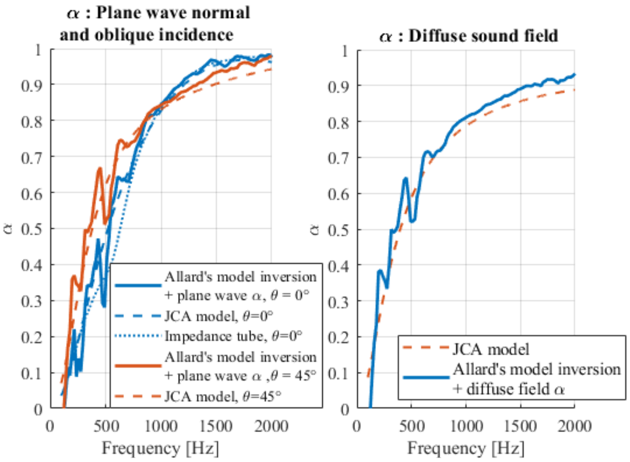

Figure 3: Absorption coefficient, methods comparison.

4 Conclusion

A method for estimating the absorption coefficient of absorbing materials for normal, oblique, or diffuse field incidence has been presented. The method is closer to real conditions, more reliable and provides improved results in the low frequency domain. This article proposed the automation of a test bench and reduced measurement uncertainties.

An improved post-processing technique using the Allard’s model inversion shows encouraging results for the melamine sample, especially in the low frequencies. Tests on other materials (glass wool, rock wool, recycled cotton and PU foam, not shown here) show consistent results too. However, spurious peaks were observed below 700 Hz, certainly caused by diffraction or reflection effects on the test bench’s sides or of the semi-anechoic room.

Another method using sound field reproduction and a power definition for the absorption coefficient is currently being tested.

Acknowledgments

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References

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