Applications of in-situ measurement techniques of absorption

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Abstract

Two in-situ measurement techniques for sound absorption are compared, a subtraction technique and an excess attenuation measurement. Non-local reaction of the specimen investigated gives rise to differences in the frequency-dependent sound absorption coefficient.

1. Introduction

A short introduction on two different techniques to measure sound absorption or the acoustic surface impedance in-situ is given and an application in room acoustics illustrated. Early in-situ test methods date back to the 1930s[1]. Modern mls-based measurement equipment has been used to determine the absorption coefficient in-situ since the early 1990s [2-3]. A mls-based procedure similar to an early method[1] has been introduced as a subtraction technique[3] and is the basis of ENV 1793 (part 5)[4]. An application of this subtraction method in comparison with a transfer function method[5-8] is presented in this contribution.

2. Methods applied

The subtraction method and a transfer function method are both used on the same sample in an investigation in room-acoustic in situ, i.e. the specimen is not available for a laboratory measurement. The basic concept behind the two methods is totally different. While the subtraction technique relies on plane wave propagation at normal incidence to the surface under consideration, the transfer function method is based on spherical wave propagation near grazing incidence.

2.1. Subtraction technique

The subtraction technique as described by Mommertz[3] deduces the reflection factor R_p for plane waves at normal and oblique incidence. R_p is used to calculate the absorption coefficient $\alpha_{90°}$ for normal incidence. To obtain the reflection from the surface a mls-measuring equipment is used. This avoids any special requirements for the measurement environment. Time windowing removes parasitic reflections from the recorded impulse responses. Two measurements need to be carried out: One with only the direct sound and possible parasitic reflections. This measurement serves as reference and is subtracted from the second, the reflection measurement.

The latter uses the microphone positioned close to the surface. By time windowing and subtraction, the time signal of the reflected sound is extracted and used to calculate the complex reflection factor R_p and the absorption coefficient α_θ for the angle θ of incidence.

A frequency range between 250 Hz and 8000 Hz is employed[3] for normal incidence. For oblique incidence no range of validity is proposed[3]. The method is basis of some standards, one known as ADRIENNE method[4] (EN 1793-5).

Meanwhile commercial software is available that allows to use the subtraction method[9] as well as the ADRIENNE method[10] on standard measuring equipment. The software uses automatic time windowing and carries out the calculation of the absorption coefficient α and other quantities.

2.2. Transfer function method

Figure 1 :Sketch of set-up for transfer function measurement in front of an absorbing surface.

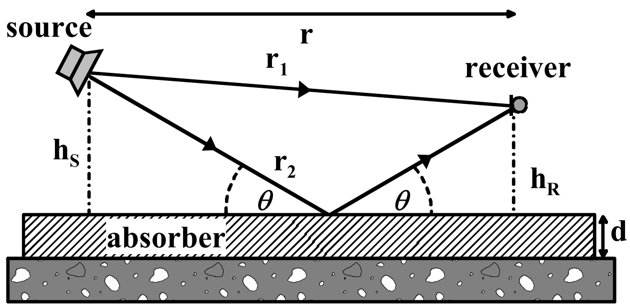


Fig. 1 shows a sketch of the set-up for measuring the excess attenuation function, ("transfer function") between source and receiver, normalised to free-field propagation[5]. As for the subtraction technique, a pseudo-free-field measurement between source and receiver is carried out as reference. Parasitic reflections are also removed by time windowing. The same time window is used when analysing the reflection close to the surface near grazing incidence. The spectra of both time windowed signals are calculated. Dividing the reflection measurement spectrum by the reference spectrum yields the wanted complex excess attenuation function or normalised transfer function [7]. Magnitude and phase of this transfer function are used as input to a numerical inversion procedure (described in [7]) to deduce the acoustic impedance of the surface. The impedance Z allows to calculate the absorption coefficient for normal ($\alpha_{90°}$) or diffuse incidence.

3. Application of both methods

Both methods have been tested extensively in the laboratory. Results from these validating measurements have been published elsewhere[5-8]. For locally reacting materials very similar results in comparison to standing wave tube measurements have been obtained with both methods[8]. The transfer function methods also yields values for the complex surface impedance of a material. For non-locally (or extended) reacting surfaces, such as backed light weight foam with low flow resistivity, the transfer function methods shows deviations to results from other methods. These correct deviations (due to non-local reaction) can be taken into account with the concept of an effective surface impedance [9].

For the application in-situ it might not be clear if the material under investigation is locally or extended reacting. Thus the interpretation of measurements must carefully be carried out, and both methods may not deliver the same result.

Fig. 2 and 3 show results obtained from both methods. The limiting lower frequency of 200 Hz for the subtraction technique takes the size of the wall of about 3 m × 3 m into account. The lower frequency limit depends on the size of the sample[2]. For the given geometry and sample size the transfer function method could be applied down to 125 Hz. The subtraction method measurement was carried out in 1/3 octave bands, the transfer function method measurements in 1/12 octave bands. For the transfer function measurement a PC-based audio measuring system has been applied. The impedance values deduced with the transfer function method have been used to calculate the sound absorption coefficient $\alpha_{90°}$ for normal incidence.

Figure 2 : Ssubtraction technique result.

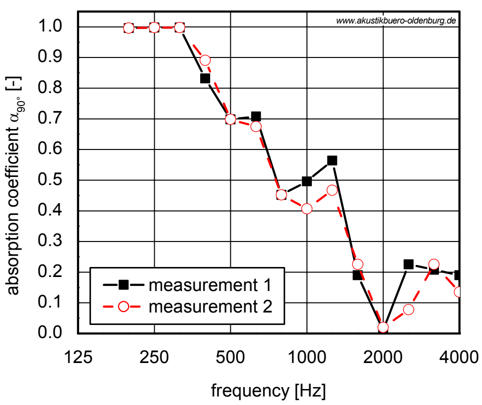
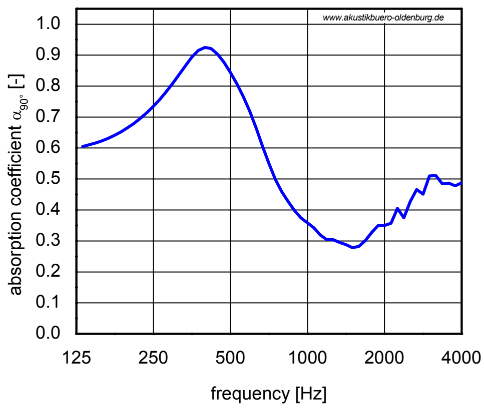


Figure 3 : Ttransfer function technique result.



4. Conclusions

The results obtained from both methods differ, only the general dependency of α_{90} is similar. Both methods show a decrease of absorption between 400 Hz and 1000 Hz. The reason for the deviations below 400 Hz and above 1000 Hz between both methods might be caused by the non-local reaction of the resonant-type, layered sound absorber. Values from standing wave tube or reverberation chamber measurements have not been available. At least, the lack of absorption in the room yielding long reverberation at high frequencies is in agreement with the in-situ measurements of absorption.

Further systematic investigations of a wide range of materials and sound absorbing constructions should be initiated. To conclude, more comparisons between modern in-situ and classical methods (standing wave tube and reverberation chamber) are required.

5. References

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