Applications of a free-field transfer function method to measure the acoustic impedance

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Several in-situ methods have been suggested to investigate the acoustic performance of absorbing or reflecting materials. After a short review of historical methods one of these modern methods, the transfer function method [1], will be briefly described and some results will be presented. These results compare well with other methods for many materials.

GENERAL INTRODUCTION

Apart from standardised methods like standing wave tube and reverberation chamber measurements there have been several approaches to deduce the absorption coefficient or impedance under approximated free-field conditions. Many of the existing procedures assume plane wave propagation and can thus be referred to as geometrical procedures.

BRIEF HISTORICAL REVIEW

One of the earliest set-ups to measure the absorption of a material in-situ has been proposed by CREMER [2] in 1933 by investigating standing waves in front of a reflecting surface. In 1934 SPANDÖCK [3] presented a method using short tones with 800 Hz and 4000 Hz of only 1/200 s duration. By this he was able to separate the reflected signal from the incident signal in front of a reflecting surface. Similar to CREMER'S approach INGARD/BOLT [4] investigated the sound field in front of a surface and compared it with the sound field in front of a perfectly reflecting surface. This comparison allowed to deduce the absorption coefficient and the impedance respectively. For small angles of incidence these authors give a clear hint that the influence of sphericity of the sound waves might influence the result especially at low frequencies. Further methods have been described by DAVIES/MULHOLLAND [5] and KINTSL [6] also using a comparison of two measurements, one without reflection and the other with reflections at the surface investigated. KINTSL [6] deduces a formula later quoted by GARAI [8] and in [10] to calculate the area influencing the reflection. HEINZ/WILMS [7] and GARAI [8] show the first applications of modern MLS-based measurement equipment to deduce absorption coefficients in-situ. A MLS-based procedure similar to SPANDÖCKS [3] method is introduced by MOMMERTZ [9] as subtraction technique. This method has been modified to be used as a standard procedure described in draft ENV 1793 [10], part 5. All these methods assume plane waves, e.g. k r should be sufficiently high. So an alternative method (transfer function method) has been proposed relying on spherical wave propagation above an absorbing plane [1, 11, 12]. In the following the method will be described very briefly and results are shown.

TRANSFER FUNCTION METHOD

Fig. 1 shows the two steps needed for the measurement of the excess attenuation function, e.g. transfer function between source and receiver normalised to free-field propagation. First a pseudo-free-field measurement between source and receiver is carried out as reference. Parasitic reflections are removed by applying time windows. The same time window is used when investigating the reflection close to the surface. The spectra of both time windowed signals are calculated.

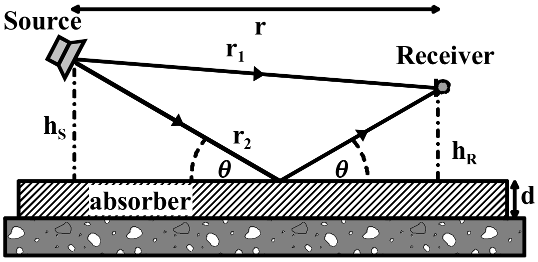

FIGURE 1. Set-up for reflection measurement close to the surface under investigation.

Dividing the reflection measurement spectrum by the reference spectrum yields the wanted complex excess attenuation function or normalised transfer function [11, 12]. Magnitude and phase of this transfer function are used as input to a numerical inversion procedure as described in [11, 12] to deduce the acoustic impedance of the surface. The impedance Z allows to calculate the absorption coefficient for normal ($\alpha_{90°}$) or diffuse incidence (α_{diff})[1, 9, 11, 12].

EXPERIMENTAL RESULTS

Several measurements have been carried out above different surfaces. A typical experimental set-up for determining the absorption properties of a wall surface in a room is shown in Fig. 2.

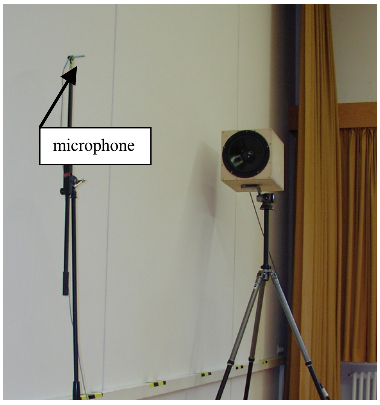

FIGURE 2. Set-up of microphone and loudspeaker for reflection measurement close to wall surface, distance r = 1.8 m.

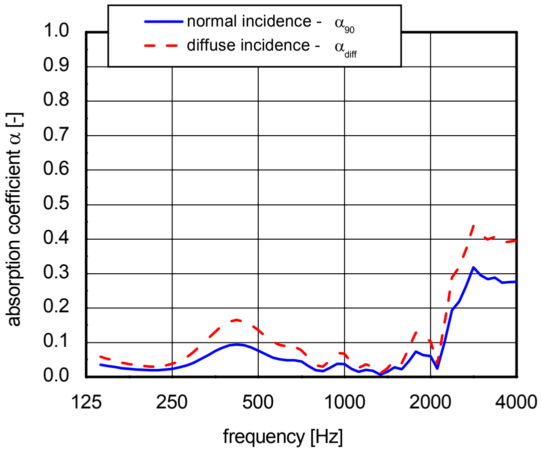

FIGURE 3. Result for the measurement of the wall in Fig. 2.

Fig. 3 shows the result for the absorption coefficient for a gypsum board wall (Fig. 2) as calculated from the measured impedance values for normal and diffuse incidence [12]. The lower frequency limit of this measurement was 133 Hz according to the time window length of 7.5 ms applied in the measurement. Up to 2000 Hz the absorption coefficient is below 0.15 as could be expected for such a material of this kind.

Fig. 4 shows the result for the impedance of a 5 cm thick layer of a mineral fibre. The corresponding absorption coefficient agrees well with measurements in a standing wave tube. The influence of different measurement geometries is given by the error bars drawn.

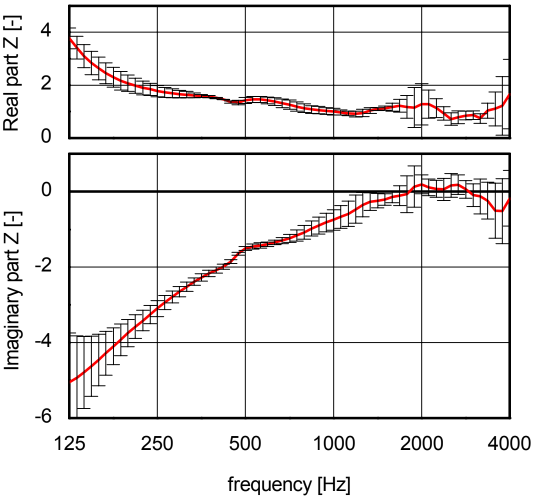

FIGURE 4. Result for the complex impedance measurement above an absorbing material. Error bars result from different measurement geometries.

FUTURE WORK

Other materials and linings of walls have been investigated. The results agree well with literature values and other measurements. For some absorbing structures like plate-like resonators further investigations are needed. Results from strongly diffusing surfaces should be interpreted with care, further investigations will concentrate on this aspect that might be explained with the concept of an effective impedance as suggested in [13].

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