A study of influences of the in situ surface impedance measurement technique

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Abstract

The in situ surface impedance technique is proven in various papers. In this paper the method is tested in various conditions to study it performance.

First a comparison is made between the Kundt's tube and the in situ technique and it is shown that for a type of polyurethane foam the Kundt's tube results deviates from the real values. In a series of measurements it is shown why this deviation occurs and why the in situ surface impedance method performs well.

After this a series of measurements in 'difficult' acoustic environments are done to study the effect on the measurement results.

Introduction

The free-field acoustic impedance measurement is based on the measurement of sound pressure and particle velocity in certain position close to an acoustic material. The Microflown is an acoustic sensor which is used to obtain the particle velocity instead of the sound pressure. The construction and measurement principles of the Microflown were already explained in more details in many studies, see e.g. [1], [2]. If the microflown sensor is mounted together with a microphone, the PU probe is made which allows to measure directly particle velocity and sound pressure at certain location. The ratio of the sound pressure to particle velocity is called acoustic impedance and can be used for calculation of the reflection coefficient. The absorption coefficient can be simply calculated from the reflection coefficient. This is done with a simple 'image source model with plane wave reflection coefficient' that is explained in [3], [4], [5], [6], [7], [8], [9].

The free-field impedance measurement method is being used for estimation the acoustic properties of material due to simple measurement process in comparison with other methods. There is no need to cut the sample as in the case of Kundt's tube or, there is no need to prepare large sample as for reverberation room measurement [4]. Also, the time consumption is negligible in comparison with other methods; it takes less than one minute to obtain the reflection or absorption coefficient of the material (other methods take hours). This fast and broad banded method is relatively new. Therefore, there is still need to prove stability of the measurement device.

The aim of this work is to explain the stability of the measurement in relation with some ambient conditions to absorption coefficient.

Experiments

The free-field measurement device is shown in Figure 1. It consists of the noise source (loudspeaker) and detection device (PU probe). The loudspeaker and the PU probe are mounted a rod to secure the steady and constant position of the loudspeaker that is mechanically decoupled of the PU probe during measurement. The PU probe consist of the pressure sensor (microphone) and of particle velocity sensor called Microflown.

The noise is generated by the loudspeaker, the sound wave travels towards the material and the particle pressure and velocity are measured near the material surface by the PU probe.

Figure 1: The surface impedance setup

Before a measurement the probe is calibrated. This is done by taking a measurement in the free field (aiming away from a surface). The acoustic impedance is then calculated from calibration and measurement file using Matlab program and subsequently, the same program is used to calculate the complex reflection and absorption coefficient.

Kundt's tube comparison

The conventional Kundt's tube is used to measure the absorption coefficient. It allows us to compare the absorption coefficient with that obtained by the free-field method.

The absorption coefficient of the identical sample obtained via Kundt's tube and the free-field impedance method is in good agreement if a sample is measured under an identical situation; see black and red line in Figure 3. This was already observed before [9]. However, if the sample is removed from the container, so it has free edges, the absorption coefficient is moved to lower values (blue line in Figure 3).

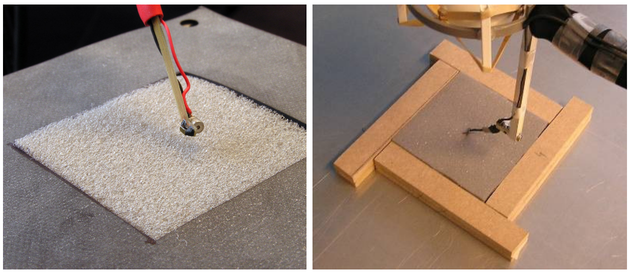

Figure 2 (left): surface impedance measurements in a kundt's tube, (right): a sample contained with a border.

It suggests that the material properties are influenced by sidewalls of the tube and therefore, the absorption coefficient is different. If a large sample is measured, the maximum peak of absorption coefficient is moved to lower frequencies; see yellow line in Figure 3. This result was obtained via free-field measurement method due to impossibility to measure such a large sample using the impedance tube.

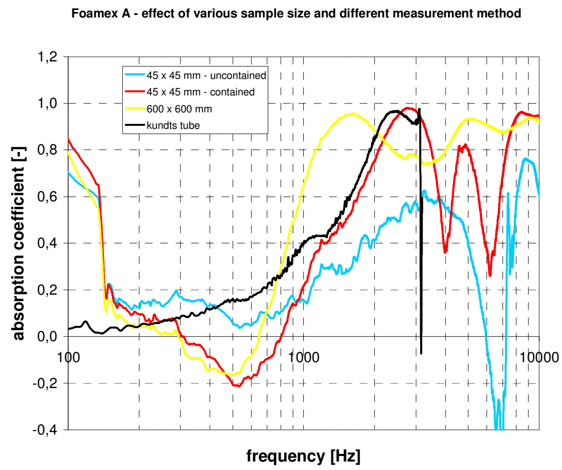

Figure 3: Absorption measurements

The continuous shift of the frequency peak to the lower frequencies as sample size increases is presented in more detail in Figure 4. The samples were contained by the borders (see Figure 2 right) during the measurement.

As can be seen in Figure 4 the maximal absorption seems to shift to lower frequencies if the sample is taken larger.

This suggests that the properties of the acoustic material change if it is cut to a smaller sample. If the sample is larger than 15cmx15cm the deviation becomes negligible compare to a very large sample however when the sample is chosen smaller than 15x15cm, the measured values deviate from the true value.

This illustrates that a measurement in a standing wave tube produces results that not reflect the free field values.

Other materials are also tested and show a different amount of deviation. This means that the standing wave tube can also not be used for a A/B comparison.

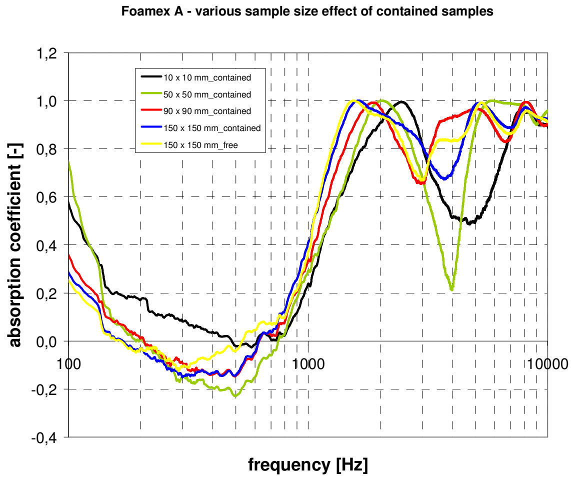

Figure 4: acoustic absorption measurements with various sample sizes.

Conclusion

A fast and free field method is demonstrated that is able to measure the acoustic absorption of acoustic damping materials. With the method it is show that the results produced by the Kundt's tube method deviate from the true free field values.

References

[1] H-E. de Bree et al, The Microflown; a novel device measuring acoustical flows, Sensors and Actuators: A, Physical, volume SNA054/1-3, pp 552-557, 1996

[2] H.-E. de Bree: The Microflown: An acoustic particle velocity sensor, Acoustics Australia 31, 91-94 (2003)

[3] M. A. Nobile and S. I. Hayek, Acoustic, propagation over an impedance plane, J.Acoust. Soc. Am. 78(4), 1325–1336, 1985.

[4] R. Lanoye et al, a practical device to determine the reflection coefficient of acoustic materials in-situ based on a Microflown and microphone sensor, ISMA, 2004.

[5] R. Lanoye, G. Vermeir, W. Lauriks, R. Kruse, V. Mellert: Measuring the free field acoustic impedance and absorption coefficient of sound absorbing materials with a combined particle velocity-pressure sensor, JASA, May 2006

[6] Roland Kruse, Volker Mellert, In-situ Impedanzmessung mit einem kombinierten Schnelle- und Drucksensor, Daga 2006, Germany

[7] HE de Bree et al., Two complementary Microflown based methods to determine the reflection coefficient in situ, ISMA 2006

[8] J.D. Alvarez, F. Jacobsen, In-situ measurements of the complex acoustic impedance of porous materials, INTER-NOISE 2007

[9] HE de Bree, M. Nosko, E. Tijs, A handheld device to measure the acoustic absorption in situ, SNVH, GRAZ, 2008

[10] Tijs et al, Non destructive and in situ acoustic testing of inhomogeneous materials, ERF33, Kazan, Russia, 2007

[11] JD Alvarez and F Jacobsen, In-situ measurements of the complex acoustic impedance of porous materials, INTER-NOISE 2007

[12] Finn Jacobsen et al, A note on the calibration of pressure-velocity sound intensity probes, Jasa, 2006

[13] H-E de Bree et al, Broad band method to determine the normal and oblique reflection coefficient of acoustic materials, SAE 2005

[14] Yang Liu and Finn Jacobsen, Measurement of absorption with a p-u sound intensity probe in an impedance tube, ASA, 2005

[15] T.E. Vigran et al., Prediction and measurements of the influence of boundary conditions in a standing wave tube, Acta Acustica, 83, 419-423 (1997).