Recent developments free field PU impedance technique

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Introduction

Current standard techniques to measure the acoustic material impedance have limitations. The Kundt's method requires a sample to be cut out and put in a fully reflective tube. Many materials including some porous materials are not locally reacting, meaning the impedance depends on the angle of incidence. With the Kundt's tube it is only possible to measure at perpendicular sound incidence. The walls of the tube can influence the behavior especially if the material has a high flow resistivity [15] like some foams or multi-layer materials. Some samples cannot be cut and leakage effects are observed when the tube is put highly porous surfaces (eg. road asphalt or some aircraft engine liners).
With a reverberant room it is possible to measure the diffuse absorption but it requires large and expensive facilities and samples of several square meters.
There is a need to measure samples in the free field, or better in situ, without sample cut-out or large amounts of material. The free field PU impedance technique was tested successfully for the first time in 2004 [4]. A so-called PU probe makes use of a dedicated velocity sensor combined with a microphone. Directly the impedance can be measured close to the material. This paper gives an overview of recent developments of this method.

PU free field principle

The PU free field surface impedance technique makes use of a Microflown velocity sensor and a sound pressure microphone. Both sensors are mounted in one probe that is positioned close to the material and a sound source is positioned at a certain distance. The impedance can be derived from the ratio of pressure and velocity [4-12]. From this, material reflection and absorption can be calculated. The probe is able to measure in the whole audible range but the lower frequency limit of the method at this moment is 100~300Hz. This is due to the low sound pressure emission from the loudspeaker at low frequencies (and the limited dimensions of the sample).

Fixed distance probe-source

A PU probe can be calibrated with a spherical source in an anechoic room [13]. A model is used to calculate the plane wave sensitivity. The spherical surface impedance can be measured with the same source and has to be converted to the plane wave impedance with e.g. a F-term correction [5]. If the source-probe distance is kept constant the measurement results are similar on several materials when no corrections are applied at all. The calibration model and the measurement model seem to cancel each other. This has to be supported by theory and more measurements in the future.

Figure 1. Handheld PU free field impedance setup

A simple point source model can be used to allow for the measurement distance [9]. Due to this simple model measurement results can be produced in real time.
A fixed probe-source distance is now possible because the setup in Figure 1 is made in such a way that vibrations from the loudspeaker are isolated from the sensor support. This is especially important when the impedance of the sample is high.
A typical calibration takes 5 seconds and again 5 seconds for the material measurement. So it is common to calibrate before each measurement session.

Low influence of reflections

The distance between the probe and the source is only 26cm so reflections at some distance are less dominant than the signal of the direct source. The calibration and measurement can be done in a regular office, but even in a strong reverberant environment like a car interior, see Figure 2 [9].

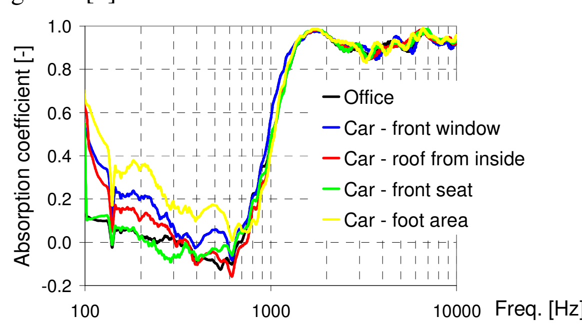

Figure 2. Absorption measurements in a car

A moving average in the frequency domain gives a result similar an anechoic measurement. A time windowing technique can also be used but the moving average is more robust [9]. The smoothed result should follow the actual impedance however when the actual impedance has a sharp change this averaging should not be applied, so some care is required.

Small spatial resolution

Because the method makes use of an ultra miniature PU probe the measurements can be done very close to the material. Much smaller samples are required than with other free field techniques. The measurement resolution is in the order of millimeters. Figure 3 shows the absorption calculated from the local impedance measured every 5mm above a sample with a quarter lambda tube [10]. To obtain the effective absorption of the whole sample the average impedance of the whole surface should be taken.

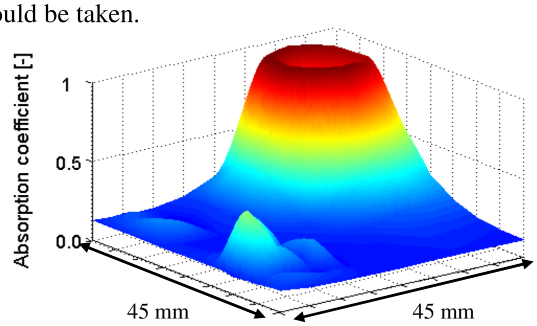

Figure 3. Absorption quarter lambda resonator at 1330Hz

Kundt's tube comparison

Results similar to the Kundt's tube are measured when the sample is measured in exactly the same conditions. Figure 4 shows certain samples can have totally different behavior when the sample size is increased, showing a limitation of the Kundt's method, [9]. In this figure also can be seen an absorption value lower than zero is measured. The reason for this is still unknown.

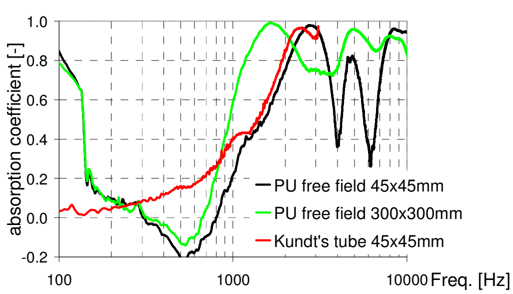

Figure 4. Influence of sample size

Moving samples and wind

Measurements are done on moving samples and it is possible to determine the absorption coefficient when the measurement time above an area of constant impedance is 0.05 seconds or larger [16]. This would for instance mean that the measurement area would be 1,1m if the speed would be 80km/h. These high speeds are necessary for impedance measurements on roads not to disturb traffic.

The acoustic behavior of materials may change after installation if the material is glued, mounted on a surface that is not fully reflective, etc. and needs to be checked. During production or time materials might vary. In line testing becomes feasible now.

Acoustic properties change when there is a flow over the material. Measurements are already successfully taken at relative low wind speeds of 7 m/s [16,17]. A goal is to measure aircraft engine liner material simultaneously at 0.5 mach, 500 deg Celsius and at high sound levels.

Measurements under an angle

It is possible to measure an acoustic sample under an angle [4,5,9]. The probe is rotated on the fixture and calibrated in this position. Measurements can now be taken with the probe in the normal direction. With this procedure the angle does not have to be modeled because the rotated calibration allows for this.

Conclusions

The handheld PU free field surface impedance technique has several benefits compared to established standard techniques that measure the acoustic material behavior. Due to a fixed probe-source distance corrections for the sound field during the calibration and the material measurement have become easier which reduced calculation power for the computer. Real time measurements on moving samples are possible. Measurements can be taken in situ, under an angle, even under difficult conditions like inside a car. The spatial resolution is in the order of millimeters, which could provide researchers extra insights in material behavior.

Further research will be focused on extending the method to lower frequencies to find the reason for absorption values lower than zero and measuring not only reflection, but also material transmission. The method shows the potential to measure with high flow speeds, high temperatures and at high sound levels. For utilization in a production environment the influence of very loud background noise needs to be investigated.

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