In situ impedance and absorption coefficient measurements compared to poro-elastic simulation in free, diffuse or semi-statistical fields using microflown p-u probes

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Introduction

Obtaining reliable diffuse field absorption coefficients is a key issue for the development of noise control treatments using simulation tools like S.E.A or Ray-Tracing Methods. We have called ”Vehicle Acoustic Synthesis Method”, an energy based method calculating the Sound Pressure Level at ear points from the combination of sound power measurements and acoustic transfer functions panel/ear measured or simulated -with Ray-Tracing Methods- for the middle and high frequency range.

We have developed the 2nd generation of the ”Vehicle Acoustic Synthesis Method” (VASM 2) using microflown\textsuperscript{®} p-u pressure-particle velocity probes \[1\], for both sound intensity and transfer functions measurements (without moving the probes), in order to speed-up the time to build a validated model of a fully trimmed vehicle in the middle and high frequency range, while increasing accuracy both in terms of source localization and source quantification and while addressing unsteady operating conditions like run-ups \[2\].

When the transfer functions are measured with a monopole source positioned at ear point applying the reciprocity principle, only the pressure channel of the p-u probe is used. The question is if it would be possible to get the reflection coefficient of the materials constituting the panels using both pressure and particle velocity channels (from the direct impedance or from the ”absorbed” intensity). Unfortunately, one needs an acoustic field hypothesis to answer that question: free-field, standing waves or diffuse field \[3\].

The reality of a car interior cavity is a semi-statistical field in the middle and high frequency range (315Hz - 10000Hz). Nevertheless, upper than a given frequency (typically 1000Hz in a car), one can do the hypothesis of local diffuse fields like S.E.A users are doing. In order to validate this procedure, we have measured and simulated the absorption coefficients (respectively reflection coefficient: $\alpha = 1 - |R|^2$) of poro-elastic materials in reverberant rooms of different sizes.

Diffuse field absorption coefficients: classical techniques

It is well known that using large reverberant rooms (about 200$m^3$) and large surfaces of materials (12$m^2$) to determine the diffuse field absorption coefficient of flat materials or parts, using the reverberation time technique (following the Norm ISO 354), gives much better results than using small reverberant rooms, the most famous one being the Alpha Cabin, which lead to overestimation particularly in the low and middle frequency range due to a lack of diffusivity and due to diffraction effects linked to the finite sizes of the samples.

Three materials: a 4 mm thick PES carpet, a 13 mm thick PES felt and a 20 mm Cotton felt have been successively measured in Alpha Cabin with a 1.2$m^2$ flat sample and in the large reverberant emitting room 2 of the Faurecia’s Center of Acoustic Technology with a 12$m^2$ flat sample (cf. figure 1).

In order to simulate successively the absorption coefficients of these materials for normal and random incidence with Maine 3A V1.3, their Biot parameters have been determined using an inverse technique based on impedance tube measurements and direct airflow resistivity measurements \[4\].

Figure 1: Large reverberant rooms of the C.A.T

Figures 2, 3 and 4 show a discrepancy between the Alpha Cabin and the large reverberant room growing towards the low frequency with the performance of the materials, whereas the diffuse field simulation shows an excellent correlation with the large reverberant room measurements in all cases. In fact, when the absorption (or better said the equivalent absorption area) is growing, the field becomes less and less diffuse and therefore more and more sensitive to the boundary conditions (explaining why Alpha Cabins have to be compared with one another). The Ray-Tracing method gives a good representation of those phenomena. If the beams meet high absorbing surfaces,
they will vanish after only a few reflections: there is then no diffusivity anymore.

Figure 2: Random Incidence Absorption Coefficient: measurement versus simulation

Figure 3: Random Incidence Absorption Coefficient: measurement versus simulation

Figure 4: Random Incidence Absorption Coefficient: measurement versus simulation

Diffuse field absorption coefficients: p-u probe technique

The principle of the measurement is to put the p-u probes very close to the surface (10 in our case decoupled with a 2 mm thick closed cell foam) of the flat samples positioned on the floor of the large reverberant emitting room 1 of the Faurecia’s Center of Acoustic Technology and to measure the inwards "absorbed" intensity due to the diffuse excitation field.

The absorption coefficient is defined by:

\[
\alpha = \frac{I_A}{I_I} = \frac{I_A}{\frac{\langle \delta p^2 \rangle}{4pc}}
\]  

(1)

\(I_A\) is the absorbed intensity directly measured normal to the surface with the p-u probes (neglecting the lateral contributions) and \(I_I\) is the incident intensity obtained in a diffuse field from the averaged mean squared pressure measured with 5 microphones in the room. This method has already been used with p-p probes, with the limitation of a \(\delta p - I\) index that should be classically lower than 12 dB [5]. The advantage of the p-u probes is that they are not sensitive to the \(\delta p - I\) index allowing to measure in real diffuse fields.

Figures 5 and 6 show that the p-u probes give good results compared to simulation and to measurements done in the largest emitting room 2 in the high frequency range upper than 1000 Hz.

Figure 5: Random Incidence Absorption Coefficient: p-u probes measurement

Figure 6: Random Incidence Absorption Coefficient: p-u probes measurement

Conclusion

This study has been the first direct characterization of in-situ diffuse field absorption coefficients using microflown® p-u probes, showing encouraging results compared to measurements using the reverberation time technique or to poro-elastic simulation.

References


