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MEASURING ABSORPTION IN VEHICLES - THE POSSIBLE AND IMPOSSIBLE

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1. INTRODUCTION

The problem of quantifying the absorption in a vehicle is twofold. First, the absorption on the surfaces inside the vehicle is highly nonuniform and the field inside the vehicle is not diffuse. There is, therefore, no simple analytical expression defining the relationship between the reverberation time and the absorption. Second, the measurement of the sound decay is difficult because the decay is so short.

Though both concerns are important, this paper seeks to address the second issue. A number of techniques will be considered for the measurement of very short reverberation times and a number of these techniques will be used to asses the acoustic decay time in a full size passenger car.

2. METHODS AND PROCEDURES

Test Setup

Decay measurements were made inside a full size sedan with cloth seats. A loudspeaker system was located at the front passenger footwell. A microphone was placed at the center of the rear seat at approximately ear height. Several balloon bursts were also used to acquire impulse measurements. The balloon was positioned in approximately the same place as the loudspeaker.

Interrupted Noise With Real Time Digital Filters

A Bruel and Kjaer Type 2133 analyzer was set to generate random noise bursts. Many decays were measured to observe the effect of the type of averaging (linear or exponential), the length of the averaging time, and the number of decays. The analyzer was set to automatically calculate the reverberation time based on interrupted noise decay.

The first set of tests examined the influence of averaging a number of decays ranging from 1 to 50 decays. A 5 msec linear average was used for these measurements. These measurements suggest that increasing the number of decays does not improve results at high frequencies. At low frequencies, however, where the bandwidth is small the averaging greatly influences the results (see Figure-2(a)).

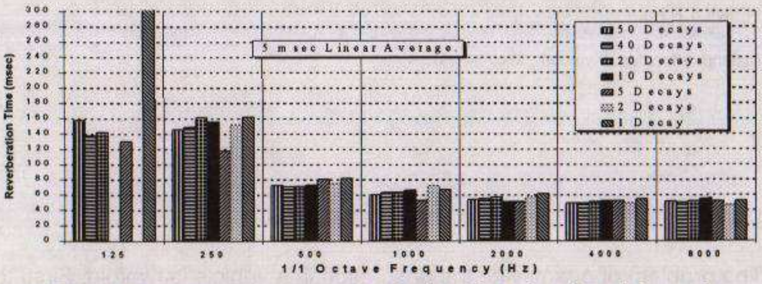

Figure-2(a): Interrupted noise results showing effect of number of decays for averaging

Though we expected to see larger differences between linear and exponential averaging, the difference was small (Figure-2(b)). Note, however, that as the exponential averaging time is increased to 1/64 sec, the measurement error increases greatly. This is because the averaging time must be much shorter than the decay time. If it is not, we are measuring the decay of the analyzer's averager rather than the decay of the sound in the vehicle

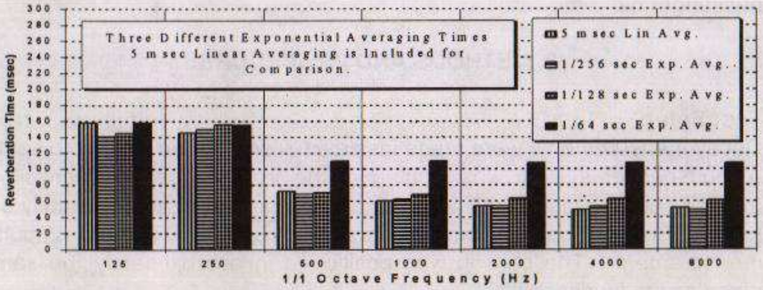

Figure-2(b): Interrupted noise results showing effect of linear and exponential averages

Interrupted Noise With An FFT Based Analyzer

It would be attractive to use an FFT analyzer to make these measurements since they are commonly available and are relatively inexpensive. There is, however, an inherent limitation when using these analyzers. It takes a finite period of time for these analyzers to acquire a block of time data. That acquisition time is too long for measuring these decays except in the highest frequency bands (2000 to 8000 Hz).

Schroeder's Reverse Integration Method

Measurements were also made with a Bruel and Kjaer Type 2133 analyzer set to automatically calculate the reverberation time based on a balloon burst using Schroeder's reverse integration method [1].

Figure-3 shows the influence of averaging time on this technique. From these results it appears that Schroeder's method requires that the averaging time be kept very small. It appears to be more critical here than for the interrupted noise measurements.

Note that there are very long reverberation times measured for the low frequencies. These are due to measurement errors caused by putting very little energy into the vehicle in the lowest frequency bands. This is an inherent problem for impulse measurements.

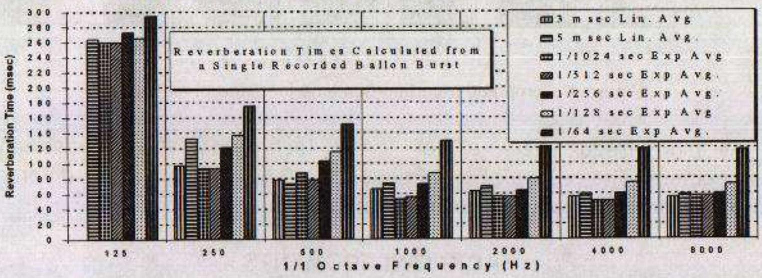

Figure-3: Results of Schroeder's reverse integration method showing measurement to measurement repeatability.

Time-Frequency Analysis

The fundamental use of time-frequency analysis is to describe the spectral content of a signal as a function of time. To study the history of sound decays from a balloon burst, binomial distribution was chosen. The cross terms associated with the Wigner distribution are suppressed using the Binomial distribution with analytic signals [2]. Decay times based on this analysis are compared to the other measurements in Section 3.

Maximum-Length Sequence System Analyzer

MLS's are periodic binary sequences conveniently generated recursively using digital shift registers. These sequences yield an impulse under circular correlation. The basic idea is to apply an analog version of MLS to a linear system and sample the resulting response with the original sequence. Essentially, the result of the cross correlation is the system's impulse response. Information on MLSSA can be found in [3]. Measurements were made using from 1 to 50 averages. There was very little difference in the results even for a single average with this technique. The MLS results are compared to the other techniques in Section 3.

3. DISCUSSION

The various analysis methods are compared in Figure-4.

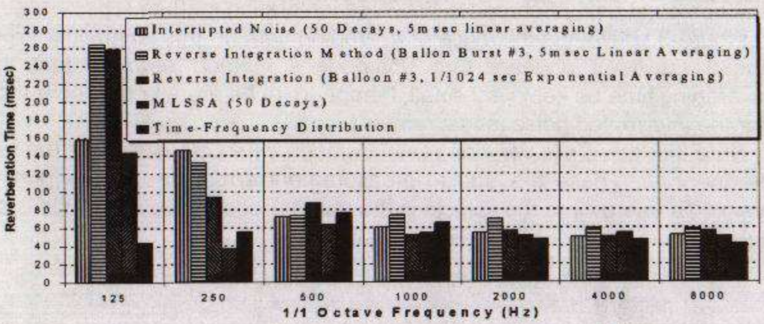

Figure-4: Computed reverberation time for different methods

At high frequencies, all of these techniques show reasonable agreement. The results at low frequencies, however, are quite different. These differences will be explored in a future paper.

ACKNOWLEDGMENTS

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NON-DESTRUCTIVE QUALITY CONTROL OF PLASTIC FOAMS USING AIR-COUPLED ULTRASONIC TRANSDUCERS

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1. INTRODUCTION

Porous materials are extensively used for sound absorbing purposes. In order to predict the acoustic behaviour of a material a certain number of material parameters are needed [1]. Ultrasonic transmission experiments can be used to determine the tortuosity [2][3] and the viscous characteristic length [4][5][6] of the sample.

In addition these experiments are useful to detect inhomogeneities and defects in sheets of plastic foam.

2. EXPERIMENTAL SETUP

The experimental setup is shown in fig. 1.

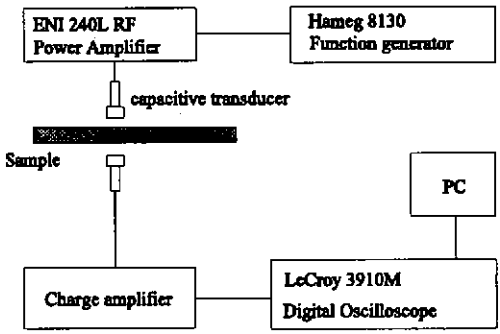

Fig. 1. The experimental setup.

Two air-coupled ultrasonic transducers are scanned across the surface of a sheet of plastic foam. Capacitive transducers made of a thin (6 µm) vibrating Mylar film with aluminium coating have been used. These transducers are very efficient in air and emit ultrasonic pulses containing frequency components up to 700 kHz.
The sample is attached to a computer controlled XY positioning system in order to detect the transmitted signal at different positions on the sample.

3. NON-DESTRUCTIVE TESTING

An example of a signal obtained with the described setup on a rather highly attenuating plastic foam is shown in fig. 2. If the sample is perfectly homogeneous, this signal will not change as a function of the position of the transducers. However, if there is an inhomogeneity in the material, amplitude and time of flight will both change.

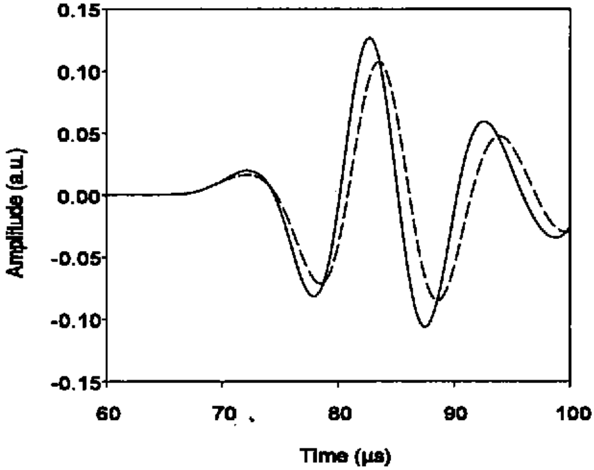

Fig. 2. Example of the change in amplitude and time of flight (dashed curve) of the signal when passing an inhomogeneity.

Figure 3 shows an example of an XY scan over the surface of the porous material. The difference in grayscale is related to the change of the amplitude of the transmitted signal. The scans are performed on an area of 7 by 7 cm. The black line in the picture indicates a place where the material has been damaged by folding the slab.

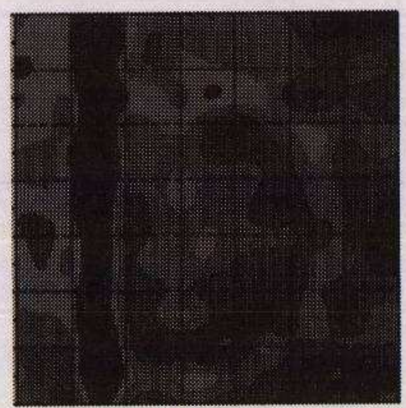

Fig. 3.

4. MATERIAL PARAMETERS

Out of a reference measurement (no sample between the source and the receiver) and a transmission measurement on the sample (see figure 4) one can calculate the wave velocity and the attenuation in the sample as a function of frequency. Both the tortuosity and the viscous characteristic length can be deduced from the high frequency behaviour of these curves.
The variations of these parameters, which influence the sound absorption of the material considerably, can be investigated by measuring on different locations.

5. CONCLUSIONS

Using the proposed setup it is possible to perform a non-destructive quality control of plastic foams. The detected signal seems to be rather sensitive to inhomogeneities in the sample caused by the production process or by damaging the foam.
The same transmission experiment is also a useful tool to obtain some parameters that are needed to predict the acoustic behaviour of porous materials which find a wide application in noise control.

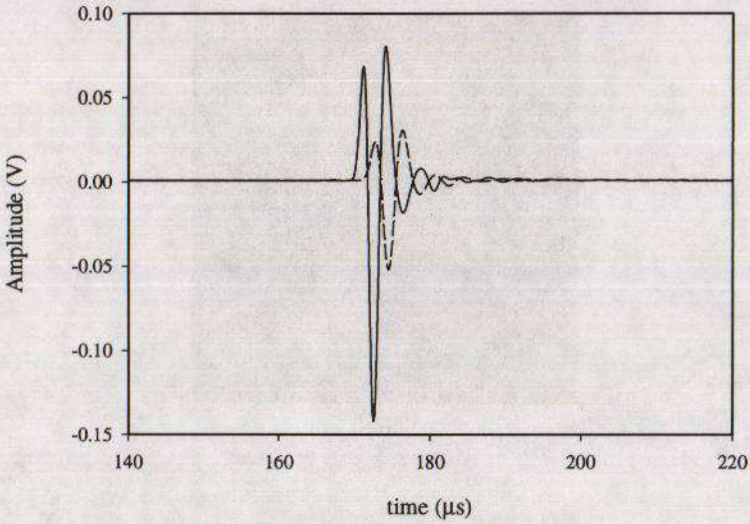

Fig. 4. Detected signal with (dashed curve) and without (plain line) the sample between the transducers

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