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ADVANCED TECHNIQUES USED FOR ACOUSTICAL PARAMETERS DETERMINATION OF SOUND ABSORBERS

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ABSTRACT: This paper deals with the comparison of methods that enables determination of sound absorbers' parameters. The first part deals with the description of sound absorbing materials' acoustical parameters. The following part introduces three methods for determination of these parameters. Two of them are traditional methods (impedance tube methods, reverberant field method), the third is an advanced technique created by Microflown Technologies. The advantages and disadvantages of above mentioned methods are highlighted in conclusion.
KEYWORDS: sound absorbers, impedance tube, reverberant field, Microflown technique

❖ INTRODUCTION

All materials have some sound absorbing properties. Incident sound energy which is not absorbed must be reflected, transmitted or dissipated. Incident sound striking a surface yields sound energy comprising reflected sound, absorbed sound and transmitted sound. Most good sound reflectors prevent sound transmission by forming a solid, impervious barrier. Conversely, most good sound absorbers readily transmit sound. Sound reflectors tend to be impervious and massive, while sound absorbers are generally porous, lightweight material. It is for this reason that sound transmitted between rooms is little affected by adding sound absorption to the wall surface. A material's sound absorbing properties can be described acoustical parameters which are presented below.

❖ ACOUSTICAL PARAMETERS

All materials have some sound absorbing properties. Incident sound energy which is not absorbed must be reflected, transmitted or dissipated. A material's sound absorbing properties can be described as a sound absorption coefficient in a particular frequency range. The sound absorption coefficient α is defined as the ratio of the sound power, W_{nr}, that is not reflected and the sound power incident on the face of the absorber, W_{inc}:

$$\alpha = \frac{W_{nr}}{W_{inc}} \tag{1}$$

The coefficient can be viewed as a percentage of sound being absorbed, where 1.00 is complete absorption (100%) and 0.01 is minimal (1%). For convenience in analyses, the absorption coefficient is defined in terms of sound pressure reflection factor R of the absorber interface, namely

$$\alpha = 1 - |R|^2 \tag{2}$$

The reflection factor R is a function of the angle of sound incidence, the frequency, the material and the geometry of the absorber. The absorber is characterized by its wall impedance Z_w, defined as

$$Z_w = \frac{p}{\upsilon_n} \ [\mathrm{N.m/s^3}] \tag{3}$$

where p is the sound pressure and υ_n is the normal component of the particle velocity, both evaluated at the interface. [4]

THE CRITICAL FEATURES TO THE OPTIMIZATION OF ABSORPTION PERFORMANCE

A number of features will significantly impact the absorption performance. These features can also be categorized as being part of the intrinsic material properties or being defined as part or consequence of the conditions under which the system is processed [7]:

Material properties:

- density,
- porosity,
- tortuosity.

System properties:

- total thickness and surface,
- presence of membrane,
- presence of layers, including skin.

The impact of these features on the performance of a system to absorb sound can be described in a simple schematic manner noting that in reality it is actually impossible to separate the impact of effects as they are linked. If it were possible to change key variables whilst holding other variables constant the following relationships could be established (see figure 1).

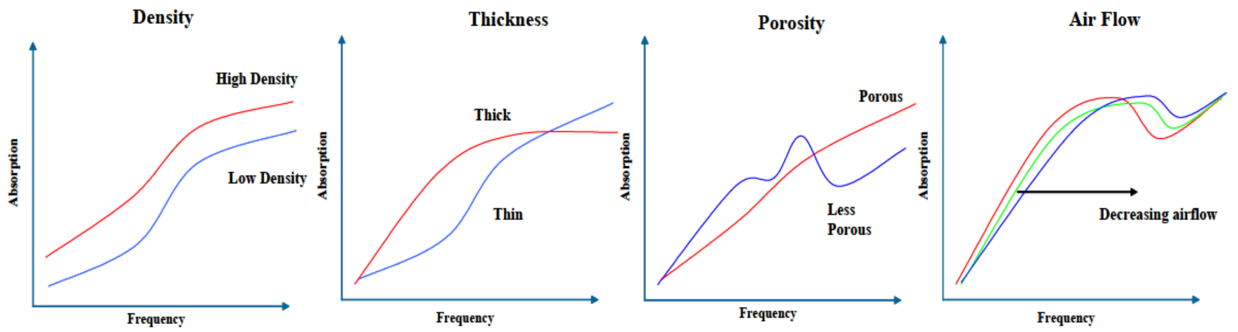

Figure 1 Schematics of the key features driving absorption performance [7]

Summarizing the effects highlighted in the graphs increasing density /thickness/ porosity and airflow will result in increased levels of absorption performance and with that the potential to improve the acoustic comfort of any space that these materials are used within. [7]

IMPEDANCE TUBE METHODS

Although a number of measurement techniques can be used to quantify the sound absorbing behavior, most often the determination of the properties takes place in a standing wave tube. This is because in a tube the mathematic problem becomes one-dimensional (in a certain bandwidth): sound waves can only propagate in one direction. This makes the experimental set-up relatively simple and small. In figure 2 a sketch of two basic techniques is shown. [1]

At the left-hand side a loudspeaker is placed and at the opposite side a sample of the test material is placed. In the tube a standing wave pattern is formed, being the result of a forward travelling sound wave p_A, and a backward (or reflected) sound wave p_B. The frequency of the sound waves is kept lower than the cut-off frequency to assure the generation of plane propagating waves in the tube.

The reflection coefficient of the test sample at the end of the tube can be determined if the forward travelling sound wave and reflected sound wave can be measured separately.

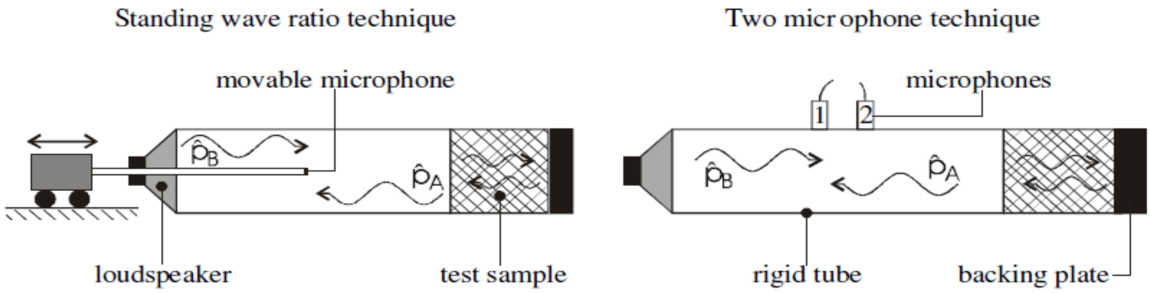

Figure 2 Schematic representations of two measurement techniques in an impedance tube [1]

In 1980 Chung and Blazer [2], [3] presented a technique which is based on the transfer function of two fixed microphones which are located at two different positions in the tube wall (see right-hand side of Fig. 2). This method will be called the two position method. The standing wave pattern is built up from a broadband stationary noise signal. With the measured transfer function, incident and reflected waves are separated mathematically. This leads to the reflection coefficient of the sample for the same frequency band as the broadband signal. The impedance and absorption coefficient can be derived as well. The method is accurate and considerably fast. [1]

❖ REVERBERANT FIELD METHOD

The so-called reverberant field method is a well-known technique to measure sound absorption coefficients for random incident waves. Experiments are performed in a reverberation chamber in which a diffuse sound field is generated. There are a number of standards available for the procedures as well as for the geometry and dimensions of the test chambers. A known set up is the Alpha cabin (see figure 3). It is a reverberation chamber having linear dimensions one-third of those of an international standard reverberation room. Its volume is 6.4 m^3 and no two walls are parallel. As a result of the size reduction of the room, the sample surface area is reduced to 1.2 m^2 an area that corresponds to that of typical hood- and roof-liners (typical size in a standard room is in the order of 10 m^2). The measurement frequencies are also increased proportionally, so that the useful range lies between 400 and 10kHz [1].

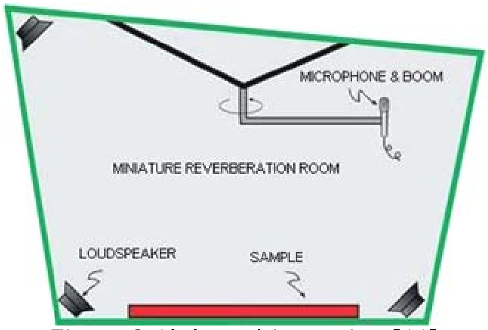

Figure 3 Alpha cabin testing [11]

Usually a (diffuse) sound field is generated with a uniform energy density. This is achieved with loudspeakers that are placed in the corners of such chambers and a number of diffusers to prevent the presence of standing waves in the chamber. A relatively large sample of the sound absorbing material (several m^2) is placed in the chamber and for a given frequency band the reverberation time T_{60} is measured. T_{60} is the elapsed time at which the sound pressure level has dropped 60dB after the shutdown of the loudspeakers. [1]

The same procedure is performed without the sample and the difference is a measure for the absorption coefficient. For highly sound absorbing materials, the absorption coefficient can exceed a value of one because of extra energy loss due to edge effects and diffraction. This can also be the case if the sound field is non-diffuse. Various standards state that at least 20 modes of vibration in the chamber are required in the lowest frequency band. As a result the room volume must be quite large. Nevertheless considerable differences have been observed for measurements on the same test materials in different reverberation chambers. It has been shown that if the total energy (that is the pressure plus the velocity vector) is measured, the accuracy of the measurements increases [1].

❖ AIRFLOW MEASUREMENT AS FUNCTION OF PRESSURE DROP (MICROFLOWN TECHNIQUE)

The Microflown in-situ technique to determine impedance, absorption and reflection makes use of a Microflown particle velocity sensor and a sound pressure microphone. Both sensors are mounted in the PU-mini probe that is positioned close to the material with a sound source positioned at a certain distance (see figure 4 and 5).

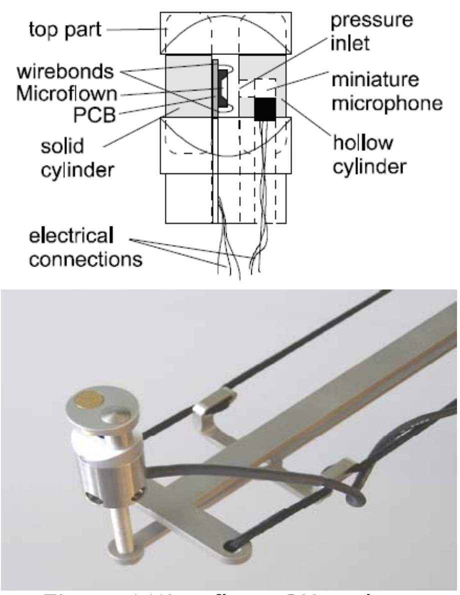

Figure 4 Microflown PU probes: placement of p and u (left); PU-mini (right) [9]

The sound pressure and acoustic particle velocity are measured right at the surface of the material. The impedance can be derived from the ratio of sound pressure and particle velocity. From this, the material reflection and absorption can be calculated. The current usable bandwidth for the method is 300Hz - 10kHz. The method makes possible to measure under different angles, measuring with a high spatial resolution of just few millimeters, measure all type of materials and material sizes. There is also no need to take samples and measurement can be performed when the materials are installed. [8]

Figure 5 In – situ absorption set up [9]

With a small, handheld impedance gun the acoustic absorption, reflection or impedance can be measured, broad banded, under normal and oblique angles. This in situ absorption method is an alternative for the impedance tube methods or reverberant field method.

With a sound source at 23 cm from the probe noise is generated towards the sample. The sound pressure and acoustic particle velocity are measured right at the surface of the material. High spatial resolution allows analysis of inhomogeneous, e.g. perforated, materials. [8]

CONCLUSION

The traditional methods namely the impedance tube methods and reverberant field methods have some disadvantages which are the following:

- Impedance tube methods need uniform samples cut – out from the material that affects the acoustical properties, the mounting problems result in sound leakage, the tubes enable only under 90 degrees incidence and there are also frequency limitations.
- Reverberant field method requires large and expensive facilities, large samples (several m^2) and absorption coefficient can achieve values larger than 100%.

On the other hand the new Microflown based method is portable, enables in – situ and real - time measurements, measurements in normal and oblique angles, measurement of flat and curved samples, broad band 300 Hz – 10 kHz and high resolution.

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