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THE ACOUSTIC IMPEDANCE MEASUREMNET SYSTEM USING TWO MICROPHONES

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ABSTRACT

In this paper, the two-microphone transfer method based on the standing wave impedance tube method is mentioned in order to determine the acoustic properties, i.e. absorption coefficient, reflection coefficient, surface impedance and surface admittance.

Using this method for acoustic material testing, it is very simple and convenient to determine the normal acoustic properties. It is very fast and accurate method to determine the acoustic properties, and is applicable in large frequency range, as well.

The theoretical background of this method based on the transfer function between two microphones is discussed, and the sample experiment is carried out to verify the user interface of this method, as results.

INTRODUCTION

With today's growing focus on noise control issues and the emergence of sound quality as an important aspect of product design, acoustic material testing is becoming increasingly relevant to engineers, designers and manufacturers from a broad range of industries. Acoustic material testing is the process by which the acoustic characteristics of materials are determined in terms of absorption, reflection, impedance, and admittance.

There are many different methods to determine the acoustic properties of materials by exposing them to sound field and measure the effect caused by their presence. Concerning to the acoustic material testing methods, they have to be done according to the Standards (ISO 10534-2, ASTM E 1050-98) describing well-defined acoustical conditions and special instrumentation to ensure a high and known degree of repeatability and reproducibility.

Absorption Coefficient varies with the frequency and angle of incidence of the sound. Sound is absorbed when part of the sound energy striking a surface or an object is converted into heat energy in the pores of the material.

Generally, higher frequencies are more easily absorbed than low frequencies. Materials that are good absorbers permit sound to pass through them relatively easily; this is why sound absorbers are generally not good sound barriers. They reduce the level of noise inside an enclosure, because while the sound waves are being reflected from the surfaces in the room, they interact with the sound absorbing materials and lose some energy each time. However, it requires large thickness or many paths for the sound energy to be significantly reduced.

Materials that prevent the passage of sound are usually solid, fairly heavy and non-porous. Sound-absorptive materials are used to reduce the level of steady sound in a room, from a machine for example, and to reduce the reverberation.

The sound absorption for a material or an object is measured in sabins or metric sabins. One sabin may be thought of as the absorption of unit area (1 m^2 or 1 ft^2) of a surface that has an absorption coefficient of 1.0 (100%). When areas are measured in square meters, the term metric sabin is used. The absorption for a surface can be found by multiplying its area by its absorption coefficient. Thus for a material with an absorption coefficient of 0.5, 10 ft^2 of this material has a sound absorption of 5 sabins and 100 m^2 of 50 metric sabins. When sound waves strike one side of a partition, the pressure variations cause vibrations in the partition, and part of the power in the sound wave is transferred to the partition. All or part of this vibration energy, depending on the construction, will reappear at the opposite surface, where it is re-radiated as sound.

THEORETICAL BACKGROUND

Two-microphone impedance tube method

Two-microphone impedance method is based on measuring sound pressure in an impedance tube at two flush-mounted microphone positions. It determines the acoustical characteristic quantities such as the absorption coefficient, reflection coefficient, surface impedance and surface admittance for small size objects exposed to plane waves at normal sound incidence, referring to the Fig.1.

Acoustic Properties

1. Absorption Coefficient: The fraction of sound energy that is absorbed at any surface. ($0 =< \alpha <= 1$ [-])
2. Complex Reflection Coefficient: The ratio of the pressure amplitude of the reflected wave to the incident wave. (0 <= r <= 1 [-])
3. Complex Acoustic Impedance: The ratio of the surface sound pressure to the sound particle velocity through the surface. (Z = R+jX [Pa*s/m^3])
4. Complex Acoustic Admittance: The ratio of the sound particle velocity through the surface to the surface sound pressure. (G = g -jb [m^3/(Pa*s)])
5. Transmission Loss: The ratio of the airborne sound power incident on the partition to the sound power transmitted by the partition and radiated on the other side. (TL [dB])

Frequency Range & Spacing between Tow Microphones

The upper working frequency is chosen to avoid the occurrence of non-plane wave mode propagation and to assure accurate phase detection.

Upper working frequency (f_u) limited by:
$d < 0.58*\lambda_u \Rightarrow f_u < 0.58*c_0/d$ (Circular tube) (ISO 10534-2)
$d < 0.586*\lambda_u \Rightarrow f_u < 0.586*c_0/d$ (Circular tube) (ASTM E 1050)
$d < 0.50*\lambda_u \Rightarrow f_u < 0.50*c_0/d$ (Rectangular tube) (ISO and ASTM)

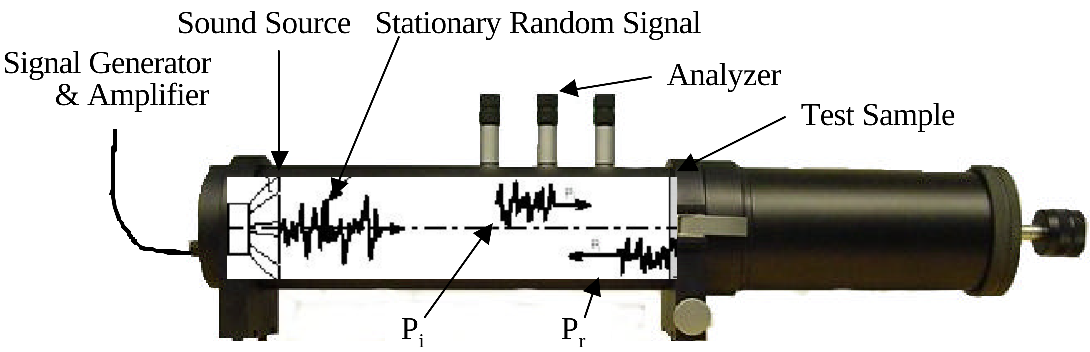

Fig. 1 Conceptual Drawing of Two-Microphone Impedance Method

The spacing between the microphones
$s < 0.45*\lambda_u$ => $f_u < 0.45*c_0/s$ (ISO 10534-2)
$s <= 0.40*\lambda_u$ => $f_u <= 0.40*c_0/s$ (ASTM E 1050)

where, f_l: lower working frequency [Hz]
d: inside diameter of circular tube [m]
f: operating frequency [Hz]
λ_u: max. side length of rectangular tube [m]
f_u: upper working frequency [Hz]
s: spacing between microphones [m]
T: temperature [K]
c_0: speed of sound [m/s]

Impedance Tube
The tube must be long enough to cause plane wave development:
$x_{ms} > d$ (minimum)
$x_{ms} > 3d$ (recommended)

The spacing between sample and closest microphone must be long enough to avoid proximity distortions to the acoustic field:
Non-structured layer: $l > d/2$
Semi-lateral structured layer: $l > d$
Strongly asymmetrical layer: $l > 2d$

where, x_{ms}: The distance between source and closest microphone [m]

They must be placed in the plane wave field. Their membrane diameter should be small in relation to their spacing to reduce the influence of their acoustic centers:
$d_{mic} < 0.2*s$
Their membrane diameter should be small to minimize high frequency spatial averaging across the diaphragm face:
$d_{mic} << \lambda_u$

where, d_{mic}: The diameter of the microphone

USER INTERFACE

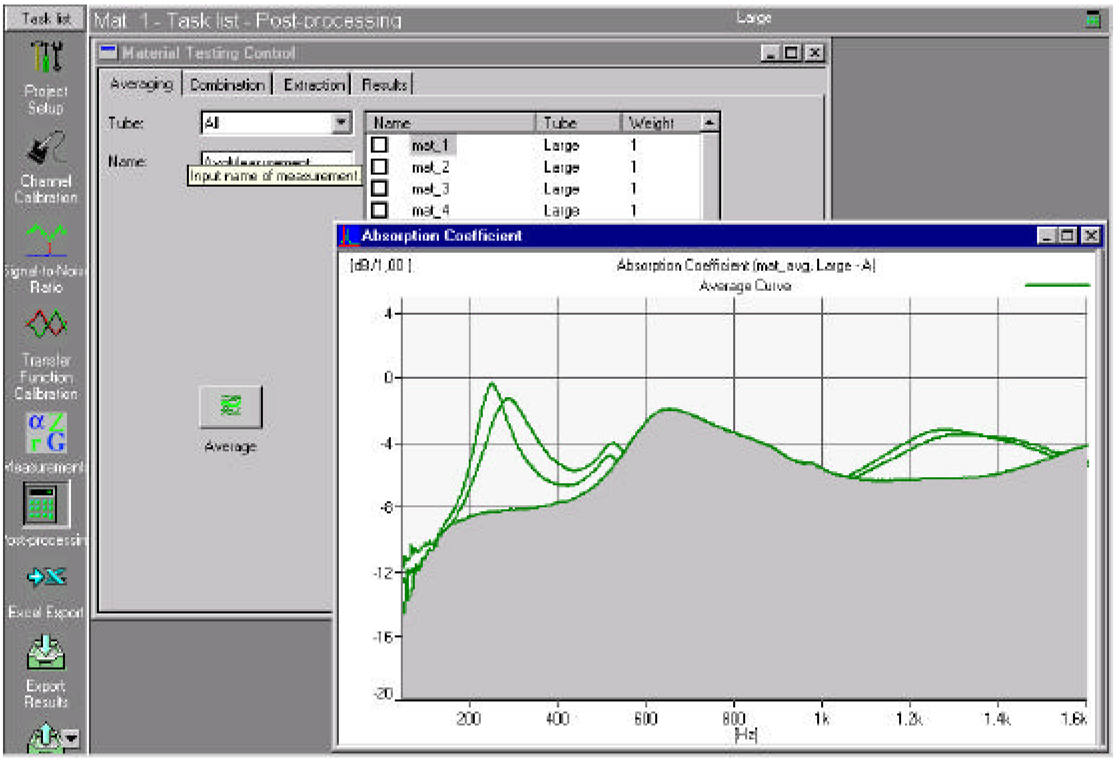

Fig. 2 User Interface of PULSE Material Testing 7758

PULSE Material Testing is the complete and fully integrated system for acoustic measurements on small material samples in the 50 Hz to 6.4 kHz frequency range. The PULSE Material Testing system can be used to measure the acoustic properties of almost any test sample, including composite and irregular materials, using a Brüel & Kjær impedance tube. The tube can replicate many acoustic settings and uses two fixed microphones to make simultaneous measurements at all frequencies of interest, saving time lost on serial testing.

The native Windows 2000®-based PULSE multi-analyzer system gives you a stable, familiar operating system to work with while the task-oriented user interface simplifies the measurement process from setup to documentation of final results via a series of straightforward, intuitive steps. It is shown in Fig. 2 as an example. The Material Testing software is designed to make life easier for the user and includes lots of helpful features including:

- compensation for sample variations and simulations of composite materials by averaging results
- batch support allowing easy execution of groups of measurements
- 1/nth-octave spectrum extraction enabling data comparison with standing wave ratio method
- advanced calibration features to eliminate the need to re-calibrate between tests
- full integration with Microsoft® Word and Excel allowing further post-processing and easy reporting
- on-line, context-sensitive help ensuring quick understanding of software
- support of custom measurement tubes, or tubes from other vendors, allowing greater measurement flexibility

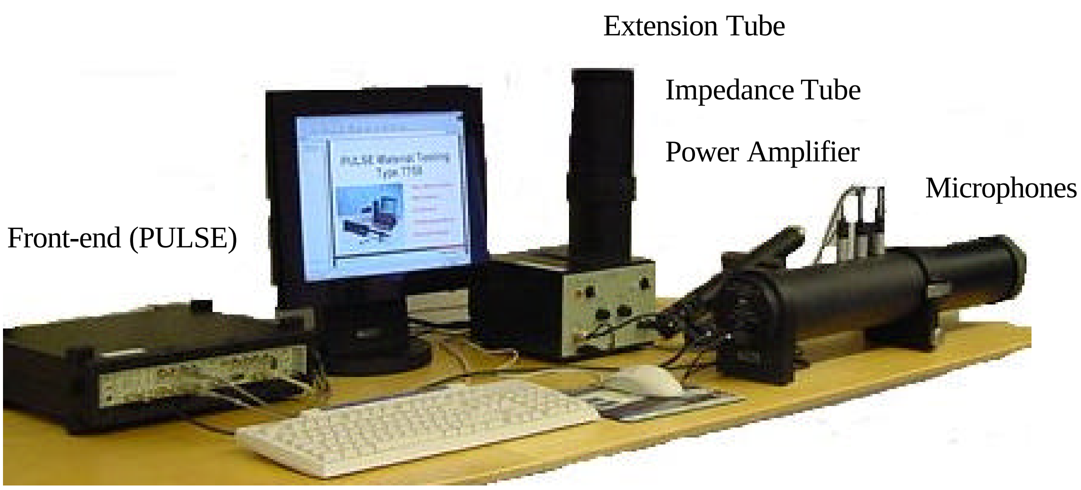

Fig. 3 System Configuration of Acoustical Material Testing Using Two Microphone Method

EXPERIMENT

The system configuration of Material Testing is shown in Fig. 3. The Multi-Analyzer, PULSE is used as a front-end. As typical results, absorption coefficient, impedance, reflection coefficient are shown in Fig. 4 to Fig. 6.

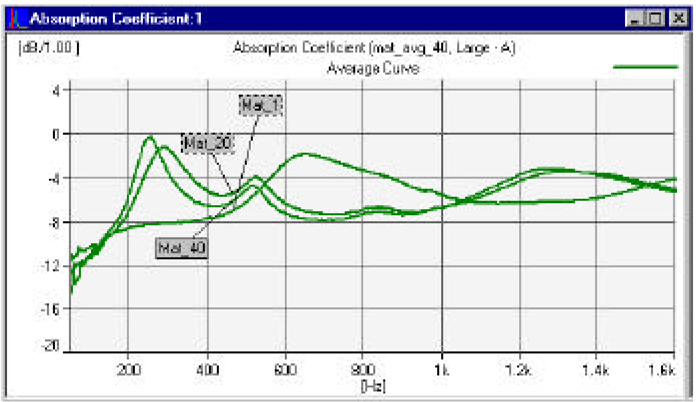

Fig. 4 Measurement Result of Absorption Coefficient

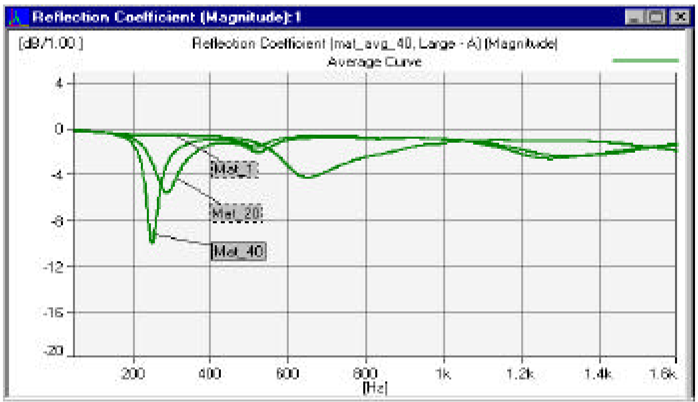

Fig. 5 Measurement Result of Reflection Coefficient

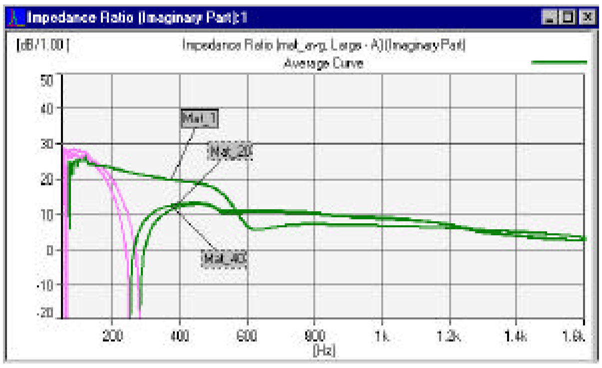

Fig. 6-1 Imaginary Part

Fig. 6-2 Real Part

Fig. 6 Measurement Result of Impedance Ratios

DISCUSSIONS AND CONCLUSION

In this paper, all the theoretical backgrounds of acoustical material testing are represented, and the user interface is introduced. In order to verify the usability of this user interface, the experimental is performed. According to the user interface and the results obtained by this interface, it could be said that the user interface is very effective and reliable to apply it to the acoustic material testing. The major point of this user interface is that it follows the Microsoft Outlook style, which is very well-known in many Windows users. Furthermore, it is easy to use because it is complemented on top of Windows 2000.

The testing procedure is regulated by the International Standards, ISO 10534-2(1998) and ASTM E 1050-98. This user interface is composed on top of these International Standards. It could be a useful and powerful measurement tool for acoustic material testing, we believe.

REFERENCES

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