Proceedings of The Institute of Acoustics

AN IMPULSE METHOD OF MEASURING NORMAL IMPEDANCE AT OBLIQUE INCIDENCE

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Introduction

This paper describes the application of digital recording techniques to the measurement of oblique incidence behaviour of sound absorbing materials. The method compares the response of a repeatable acoustic impulse measured at the surface of a sound absorbing material with the response in free space. Unwanted reflections arrive after the impulses have effectively finished and can be gated out.

Theory of the Impulse Method

There are similarities between the method described here and that described by Ingard and Bolt (1).

A source near a reflecting boundary produces a pressure at a microphone near the surface which will be the sum of direct and reflected signals. The spectrum of the total signal is

$$T(\omega) = S_d(\omega) + S_r(\omega)e^{-j\omega\tau} \qquad (1)$$

Where S_d and S_r are the spectra of the direct and reflected signals respectively and τ is the delay time between the signals due to the relative path difference.

Using an image concept the reflected spectrum is that of the direct signal multiplied by a complex reflection coefficient $R(\omega)$, with a correction for distance and polar angle. Thus

$$S_r = S_d\, R\, f\left(\frac{d_1}{d_2}, \theta\right) \qquad (2)$$

From equations (1) and (2) the reflection coefficient is

$$R = \frac{T - S_d}{S_d\, e^{-j\omega\tau}\, f\left(\frac{d_1}{d_2}, \theta\right)} \qquad (3)$$

If the source produces a repeatable short duration signal the free field response S_d can be obtained by windowing out unwanted reflections. If the source and receiver's relative position are constant and they are removed from the surface then the free field response can be found if the source gives an exactly repeatable signal.

Equation (3) simplifies to

$$R = \frac{T - S_d}{S_d} \qquad (4)$$

if the measurement is made at the surface of the absorbing material. With this condition

$$\tau = 0$$

and

$$f\left(\frac{d_1}{d_2}, \theta\right) = 1.$$

Experimental Method

To measure both the free field and 'surface' response with the same source to receiver distance and inclination a small loudspeaker was mounted at one end of a boom and a microphone at the other. This assembly was then offered up to the material under test and the impulse response recorded on an event recorder. The memory of the recorder was dumped on to paper tape and the process repeated with the boom removed from the surface. This arrangement was not entirely satisfactory as the boom was heavy and unstable, also the microphone was liable to be damaged as fine adjustment was difficult. The problem of damage to the microphone was overcome, in part by using a short probe, however this itself introduced problems as the recorded responses consisted of a series of reflections along the length of the tube. A metre long probe tube overcame this problem and this was fixed so the microphone and cathode follower were near the loudspeaker. The loudspeaker and microphone were isolated from each other by rubber blocks.

The angle of incidence of the sound energy is found simply by measuring the height of the source above the reflecting plane and also the distance from the source to measuring point.

The paper tapes containing the digitised data from the impulse measurement were processed on a digital computer using FFT routines and an algorithm to solve equation 4. The complex reflection coefficient can then be used to derive the normal impedance of the material.

Experimental Results and Discussion

There are a number of errors inherent in the method which seem unavoidable. Perhaps the most significant of these is that due to sphericity (2). This problem has been discussed in some detail by Delany and Bazeley (3) who compared computed and experimental results for observations near a locally reacting surface. They concluded that for cases where either source or receiver were more than one half wavelength from the surface then the error in pressure calculated by the image method using a complex plane wave reflection coefficient was negligible for most practical purposes. Bearing this in mind a limit is set on the angles of incidence that can be used with accuracy for any frequency. At 630 Hz the limit is about 70 degrees and at 3 KHz the limit is 86 degrees, however there is obviously no abrupt transition from a region of no error to error and this must be considered when interpreting experimental results.

Figure 1 shows typical time histories of impulses used to measure the normal incidence impedance of a glass fibre material. The full line is the measurement at the surface and the broken line is the free space measurement. The impedance derived from this data is shown in Figure 2, this compares well with measurements made in a standing wave tube apparatus. The oblique incidence behaviour (70 degrees) of the same material is shown in Figure 3.

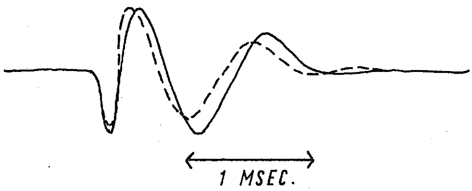

Figure 1. Time histories of pulses
Full line at the surface of Crown 200
Broken line free space.

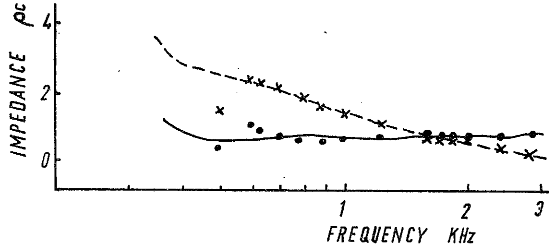

Figure 2. Complex normal impedance of Crown 200 (normal incidence)
Full line - Real part
Broken line - Imaginary part
• - Real part (wave tube measurement)
x - Imaginary part (wave tube measurement)

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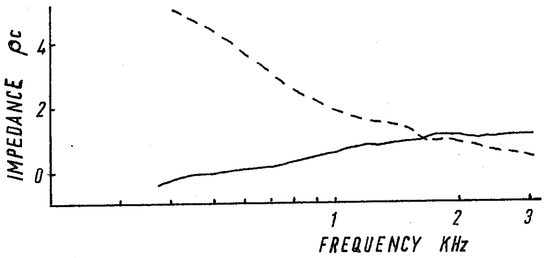

Figure 3. Complex normal impedance of Crown 200 at 70° incidence
Full line - Real part
Broken line - Imaginary part

References

(1) U. INGARD and R.H. BOLT 1951 JASA 23 509. A free field method of measuring the absorption coefficients of acoustic materials.

(2) U. INGARD 1951 JASA 23 329 - 335. On the reflection of a spherical sound wave from an infinite plane.

(3) M.E. DELANY and E.N. BAZELEY 1970 JSV 13 269 - 279. Monopole radiation in the presence of an absorbing plane.