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DETERMINING THE ABSORPTION COEFFICIENT OF ACOUSTIC MATERIAL

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INTRODUCTION

The sound intensity measurement can be applied to different problems of practical acoustics. The employment of a two-channel technique makes it possible to obtain information about a sound field, the reactivity of the sound field being of particular importance. In a given point of the sound field and a given direction of measurement, the reactivity of the sound field is defined as a ratio between sound pressure and sound intensity or as a difference between sound pressure level and sound intensity level. The difference of these levels contains three important pieces of information: about the sound source, the environment of the sound source and the accuracy of the sound intensity measurement. This information can be used to investigate the absorption of sound energy by different materials, and the absorption area can be understood as "a negative sound source". This paper describes a simple measuring procedure and its application to three practical problems of technical acoustics, where the random incidence sound absorption coefficient is to be found out.

THEORY

<u>The reactivity of the sound field</u>

The application of the method of sound intensity measurement offers new views of the physical action of a source radiating sound into its surroundings. The sound source produces in its surroundings a sound field, whose properties are determined not only by the sound source itself but also by the environment in which the sound source is placed. Essentially the sound field consists of two parts: the active and the reactive part of the sound field. A two-microphone probe makes it possible to determine the rate of total sound energy to the energy of the active part of the sound field. The intensity of sound energy flow Ir in a given point and direction r can be expressed [1] as

$$Ir = Prms / (\rho . c . k) \cdot \partial\Phi / \partial r \qquad (1)$$

where $\partial\Phi/\partial r$ is the phase gradient of the sound field in the direction r, Prms the mean square pressure, $\rho \cdot c$ the inpedance of environment and k the wave number. If r is the distance of a given point of sound field from the point source, and $\Phi = k.r$, then the sound intensity in direction r is $Ir = Prms/(\rho.c)$. In a Cartesian system having its origin in the sound source, for direction x, the sound intensity is

$$Ix = Prms/(\rho.c.k) \, . \, \partial\Phi/\partial x = Prms/(\rho.c).x/(x^2+y^2+z^2)^{1/2}$$

$$Ix = Prms/(\rho.c).\cos\beta = Prms/(\rho.cx) \qquad (2)$$

for $r = (x^2 + y^2 + z^2)^{1/2}$, where β is the angle between the direction of the spreading sound wave and direction x, and cx is the phase velocity in direction x. Fig.1 shows that $c = cx.\cos\beta$

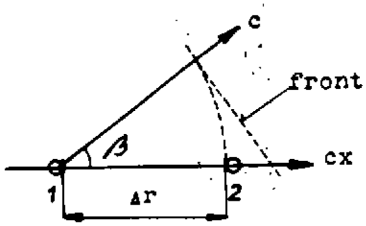

Fig. 1 Intensity probe orientated in direction x

The phase difference $\Delta\varphi x$ measured on the intensity probe orientated in direction x with distance Δr between microphones 1, 2 can be written as

$$\Delta\varphi x = \omega . tx = \omega . \Delta r/cx = \omega . \Delta r.\cos\beta/c \Rightarrow \cos\beta = \Delta\varphi x/(k. \Delta r) \qquad (3)$$

DETERMINING THE ABSORPTION COEFFICIENT

Using equation (2) and (3), the sound intensity in direction x will be

$$Ix = Prms/(\rho.c).\Delta\varphi x/(k.\Delta r) \quad (4)$$

where $k.\Delta r = \Delta\varphi$ is the phase difference for a plane wave in a free sound field. The reactivity of sound field K is defined [1] as

$$K = k.\Delta r/\Delta\varphi x = Prms/(\rho.c)/Ix \quad (5)$$

Using the logarithmic form of equation (5) with $\rho.c = 400$, the reactivity index will be

$$LK = 10 \log K = SPL - SIxL , \quad dB \quad (6)$$

where SPL is the sound pressure level ($pr = 2.10^{-5}$ Nm^{-2}) and SIxL the sound intensity level ($Io = 10^{-12}$ Wm^{-2}) measured in direction x. For the intensity probe orientated in the direction of a spreading plane wave in a free field LK = 0. The value $LK \neq 0$ indicates that the sound field has a more complicated character but, at the same time, contains information about the sound source and the environment. An example of using the information content of the reactivity index is presented in the following paragraph.

<u>The sound field near a sample of material</u>

The broad band sound source excites a diffuse stationary sound field in the reverberation room. A sample of absorption material placed in the diffuse sound field will absorb an amount of sound energy proportional to the size of the sample and to the sound absorption coefficient α of the used material. The sound coefficient α is defined by the ratio of absorbing sound power Wa and incident sound power Wi.

$$\alpha = Wa/Wi, \; Wa = Da.c.S \; , \; Wi = Di.c.S/4 \quad (7)$$

The density of sound energy measured on surface S (Fig.2) at a

DETERMINING THE ABSORPTION COEFFICIENT

short distance from the surface of the sample is D. The sound field on surface S is described by formula

$$D = Di - Da \Rightarrow Di = D - Da = p^2/(\rho . c^2) - pa^2/(\rho . c^2) \qquad (8)$$

where Di is the energy density of the incident sound and Da the energy density of the absorbing sound. From equation (7) and (8) we can derive the formula for the random incidence sound absorption coefficient α.

$$\alpha = 4/(p^2/pa^2 + 1) = 4/(10^{0.1LK} + 1) \qquad (9)$$

where LK = SPL - SIaL is the reactivity index on surface S. Sound pressure level SPL and sound intensity absorbing level SIaL is found by the method of sound intensity measurement.

EXPERIMENTS AND RESULTS

Experiments

A few experiments have been made with instruments of Messrs. Brüel and Kjaer (Fig.2) to demonstrate practical application. Objects of the experiments were:

I - a rubber mat 1.2 x 0.7 m

II - a polyurethane layer, thickness 50 mm, covered with aluminium folio, thickness 0.05 mm,

III - an open window 1.5 x 0.5 m linking the reverberation room with free space.

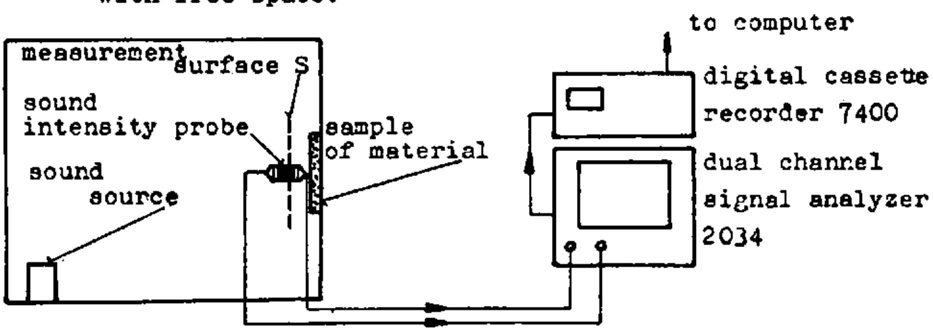

Fig. 2 Measuring set-up

DETERMINING THE ABSORPTION COEFFICIENT

Results

The values of the reactivity index measured on surface S, fig.2, were used to calculate the sound absorption coefficient of the used material. The results can be seen in fig. 3. They show a good reaction of the sound intensity probe to the sound field properties at a small distance from the sound absorption surface. This method enables us to determine the sound absorption coefficient α for a random incidence of the sound wave, the error being dependent on the residual intensity index of the measuring instrument LKmax and on the reactivity index. The errors of the sound intensity measurement in logaritmic form are defined [1] as

$$L\varepsilon \pm = 10 \log (1 \pm 10^{0.1(LK - LKmax)}) \qquad (10)$$

The correct value of the reactivity index LK for positive and negative deviation is

$$LK^{\pm} = SPL - (SIaL \pm L\varepsilon \pm) = LK \mp L\varepsilon^{\pm} \qquad (11)$$

The bands of the deviation for LKmax = 15 dB, and LKmax = 20 dB are shown in fig. 4.

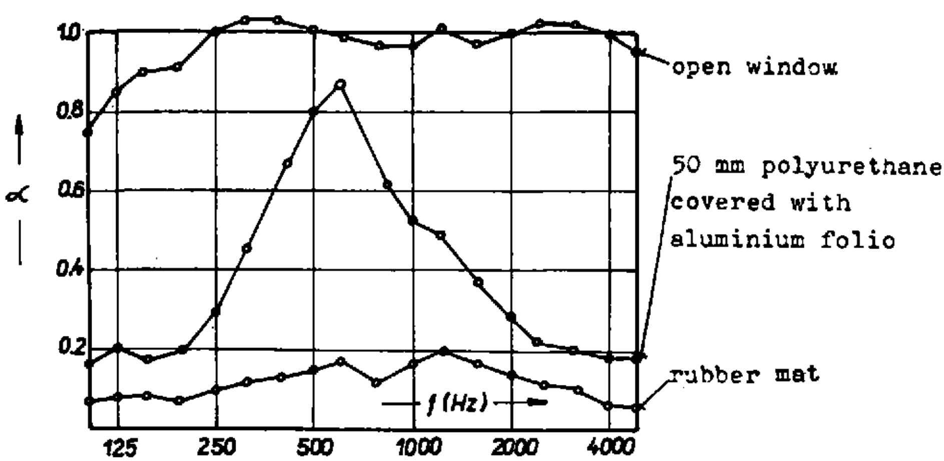

Fig. 3 The random incidence sound absorption coefficient

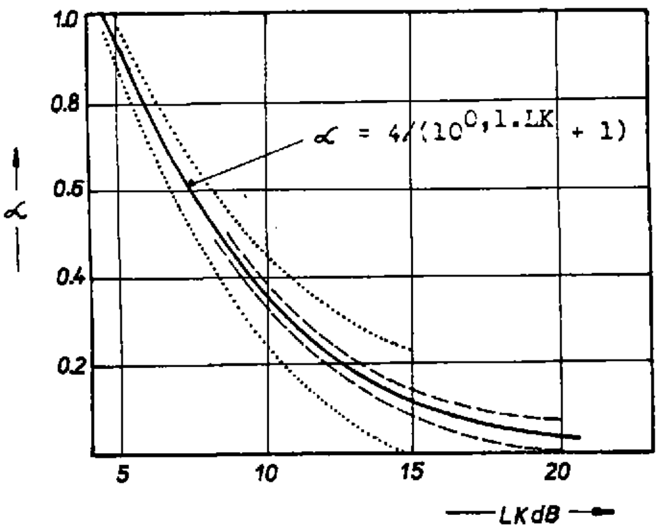

Fig. 4 The random incidence sound absorption coefficient

..... the band of deviation for LKmax = 15 dB

----- the band of deviation for LKmax = 20 dB

CONCLUSION

The procedure to determine the sound absorption coefficient of a sample of material placed in a reverberation room is very simple. We can use the values of the reactivity index measured near the sample. The area of the sample is five to ten times smaller than the area needed for the reverberation method.

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