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Acoustics — Sound-scattering properties of surfaces —

Part 1:
Measurement of the random-incidence scattering coefficient in a reverberation room

Acoustique — Propriétés de dispersion du son par les surfaces —

Partie 1: Mesurage du coefficient de dispersion sous incidence aléatoire en salle réverbérante

Reference number
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Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17497-1 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

ISO 17497 consists of the following parts, under the general title *Acoustics — Sound-scattering properties of surfaces*:

— *Part 1: Measurement of the random-incidence scattering coefficient in a reverberation room*

The following part is under preparation:

— *Part 2: Measurement of the directional diffusion coefficient in a free field*

Introduction

The degree of acoustic scattering from surfaces is very important in all aspects of room acoustics (e.g. in concert halls, sound studios, industrial halls and reverberation chambers). Insufficient scattering may cause strong deviations from exponential sound pressure decay. On the other hand, an approximately diffuse sound field may be obtained with highly scattering surfaces in a room. The degree of scattering in a room can be an important factor related to the acoustic quality of the room.

The scattering coefficient is introduced as a new concept in this part of ISO 17497. Together with the absorption coefficient, the scattering coefficient will be useful in room acoustic calculations, simulations and prediction models. For some time it has been known that modelling of the scattering from surfaces is very important for obtaining reliable predictions of room acoustics. This part of ISO 17497 presents a measurement method to quantify the scattering properties of a surface to replace formerly applied but not generally accepted estimation methods.

The work has been coordinated with the working group of the Audio Engineering Society, AES SC-04-02 for the Characterization of Acoustical Materials. This group emphasized the development of a measurement method for the directional diffusion coefficient, which is different from (but related to) the random incidence scattering coefficient. While the scattering coefficient is a rough measure that describes the degree of scattered sound, the diffusion coefficient describes the directional uniformity of the scattering; i.e. the quality of the diffusing surface. Therefore there is a need for both concepts and they have different applications.

Acoustics — Sound-scattering properties of surfaces —

Part 1:
Measurement of the random-incidence scattering coefficient in a reverberation room

1 Scope

This part of ISO 17497 specifies a method of measuring the random-incidence scattering coefficient of surfaces as caused by surface roughness. The measurements are made in a reverberation room, either in full scale or on a physical scale model. The measurement results can be used to describe how much the sound reflection from a surface deviates from a specular reflection. The results obtained can be used for comparison purposes and for design calculations with respect to room acoustics and noise control.

The method is not intended for characterizing the spatial uniformity of the scattering from a surface.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 354, *Acoustics — Measurement of sound absorption in a reverberation room*

ISO 9613-1, *Acoustics — Attenuation of sound during propagation outdoors — Part 1: Calculation of the absorption of sound by the atmosphere*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 354 and the following apply.

3.1
specular reflection
reflection that obeys Snell's law, i.e. the angle of reflection is equal to the angle of incidence

NOTE Specular reflection can be obtained approximately from a plane, rigid surface with dimensions much larger than the wavelength of the incident sound.

3.2
diffuse sound field
sound field in which the incident sound intensity on a plane surface is equally distributed over all solid angles covering a hemisphere

3.3
scattering coefficient

s_θ

value calculated by one minus the ratio of the specularly reflected acoustic energy to the total reflected acoustic energy

NOTE Theoretically, s_θ can take values between 0 and 1, where 0 means a totally specularly reflecting surface, and 1 means a totally scattering surface. The subscript θ may be used to indicate the angle of incidence relative to the normal of the surface. Random incidence is understood if there is no subscript.

3.4
random-incidence scattering coefficient

s

value calculated by one minus the ratio of the specularly reflected acoustic energy to the total acoustic energy reflected from a surface in a diffuse sound field

3.5
random-incidence absorption coefficient

α_s

value calculated by one minus the ratio of the total reflected acoustic energy to the incident acoustic energy, on a surface in a diffuse sound field

3.6
random-incidence specular absorption coefficient

α_spec

value calculated by one minus the ratio of the specularly reflected acoustic energy to the incident acoustic energy, on a surface in a diffuse sound field

NOTE This is the apparent absorption coefficient when the losses include the scattered as well as the absorbed acoustic energy. α_spec may take values in the range from α_s to 1.

3.7
physical scale ratio

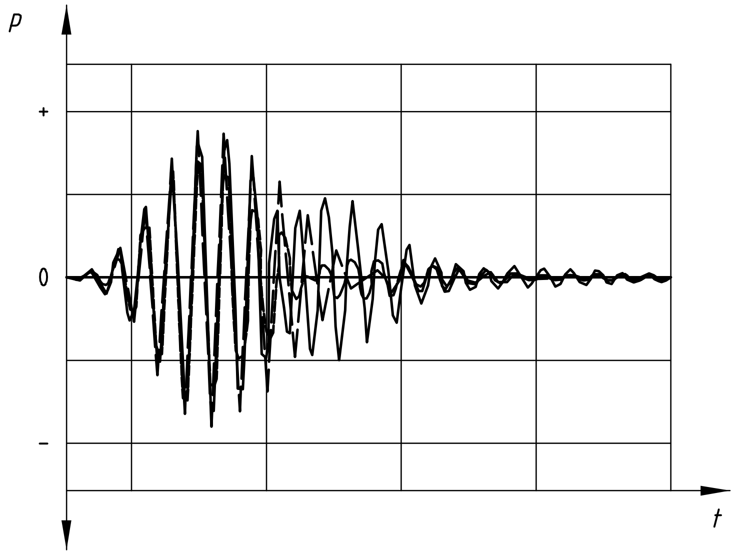
$1{:}N$

ratio of any linear dimension in a physical scale model to the same linear dimension in full scale

NOTE The wavelength of the sound used in a scale model for acoustic measurements obeys the same physical scale ratio. So, if the speed of sound is the same in the model as in full scale, the frequencies used for the model measurements will be a factor of N times higher than those in full scale.

4 Principle

The general principle of the method can best be explained by looking at the effect of reflection and scattering in the time domain. Figure 1 shows three bandpass-filtered pulses which were reflected from a corrugated surface for different orientations of the test sample in the free field.



Key

p sound pressure, in pascals

t time, in milliseconds

Figure 1 — Examples of band-pass filtered impulse responses measured at three different positions of the test sample

Obviously, the initial parts of the reflections are highly correlated. This coherent part is identical with the specular component of the reflection. In contrast, the later parts are not in phase and depend strongly on the specific orientation. The energy in the “tail” of the reflected pulse contains the scattered part.

The principle of the measurement method is to extract the specular energy from the reflected pulses. This is done by synchronized (phase-locked) averaging of the impulse responses obtained for different sample orientations.

The principle can be directly applied to measurements in the reverberation room. In addition to conventional measurements of absorption coefficient, the (circular) sample is placed on a turntable and impulse responses are obtained for different sample orientations. By synchronized averaging of the pressure impulse responses, the specular components add up in phase, whereas the scattered sound interferes destructively.

Assuming statistical independence between scattered components, it can be shown (see [1]) that after synchronized addition of n room impulse responses, the initial decay is related to the combined effects of absorption and an apparent energy loss due to sound scattered from the sample.

5 Frequency range

The measurements should be performed in one-third-octave bands with centre frequencies covering the frequency range from 100 Hz to 5 000 Hz. This refers to full-scale measurements. If a physical scale factor of 1:N is used, the centre frequencies should cover the frequency range from $N \times$ 100 Hz to $N \times$ 5 000 Hz.

NOTE If the scale model is filled with a gas in which the speed of sound is different from that in atmospheric air, the measurement frequencies should be chosen in such a way that the wavelength obeys the physical scale ratio 1:N.

NOTE High frequencies may be omitted from the measurements if the attenuation in the air is too high; see 6.1.3.

6 Test arrangement

6.1 Reverberation room

6.1.1 General

The specifications for the reverberation room are given in ISO 354. Diffusing elements shall be in fixed positions; i.e. moving diffusers like rotating vanes shall not be used. The room and its contents should be invariant, as far as possible. The temperature and humidity have a very significant effect; see 7.4. Any devices such as circulation systems that cause movement or change the properties of the air in the room should not be operated.

6.1.2 Volume of room

The volume V of the reverberation room, in cubic metres, shall be at least

$$V \geqslant 200 \times N^{-3}$$

6.1.3 Absorption in empty room

The equivalent absorption area of the empty room, A_1, including the air attenuation, should not exceed

$$A_1 \leqslant 0{,}30 \times V^{2/3}$$

NOTE According to the requirements for sample size in 6.3.1, this leads to the rule-of-thumb: $A_1/S \leqslant 1$, where S is the area of the test sample.

6.2 Turntable and base plate

A turntable is required in order to rotate the sample. The turntable shall be provided with a circular rigid base. The base plate shall be symmetrical with respect to the axis of rotation. The size of the base plate shall correspond to the maximum dimension of the test sample; see 6.3.

No part of the turntable may be closer than $N^{-1} \times 1{,}0$ m to the walls of the room; see Figure 2.

The scattering coefficient for the base plate itself shall be measured to check the quality of the arrangement; see 8.1.4. The frequency-dependent values listed in Table 1 shall not be exceeded.