ASPECTS OF THE SAMPLE GEOMETRY IN THE MEASUREMENT OF THE RANDOM-INCIDENCE SCATTERING COEFFICIENT

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ABSTRACT

The correlation technique method for measuring the scattering coefficient in diffuse field is already well developed and an ISO standard is about to be published. However, further investigations remain to be done. These are related to geometrical aspects of a sample. Some of these aspects were investigated, as the number of periods (for periodic structures) and an option for measuring square samples. In this case a discussion about edge effects is presented. Also actions in order to have a numerical reference for a sample will be reported.

INTRODUCTION

The importance of the use of scattering coefficient of surfaces in computer room acoustical simulations is already known [1]. With this coefficient, effects of diffuse reflections are taken into account. It is important, however, not to mix up the meaning of the diffusion coefficient compared with the scattering coefficient. Both coefficients are related to diffuse characteristics of a reflection, but they have different definitions. The diffusion coefficient is related to the uniformity of the polar diagram associated with a reflection, while the scattering coefficient is defined as a ratio between the non-specularly reflected sound energy to the totally reflected sound energy [2]. This definition agrees very well with the model of diffuse reflections used in Ray-Tracing programs (see [3]).

The International Organization for Standardization (ISO) is about to publish a standard for measuring the random-incidence scattering coefficient with a correlation technique (in diffuse field). A detailed description of the method, its principle and its application in the diffuse field is given in reference [2]. Although the referred method is already well developed and ready for being standardized, some aspects are still to be better investigated and understood. It is important, for instance, to explain how edge effects can influence the results and to know under what conditions they can be corrected or avoided. Part of this problem is intimately related to the shape and positioning of the sample in the measurement set-up and will be treated ahead in this paper. Scattering coefficients measured with square and circular samples will be presented followed by a discussion of a possible way of avoiding excessive influence of the edges on the results.

First, a study on two kinds of periodical structures will be addressed, where the aim was to determine the minimal number of periods that a test specimen should contain in order to perform measurements which results are representative. For several reasons one of these type of surfaces has a sinusoidal profile. One of the strong motivations of this choice was the attempt to establish a reference, which could be used in different situations and in comparisons between measurements and analytical or numerical solutions.

First results from numerical simulations of the sinusoidal profile and a comparison between simulated and measured scattering coefficients are also presented at the end. Some parameters adopted for the simulation, such as the length of the profile and angular discretization of the points where the scattered pressure were evaluated, are described and commented.

NUMBER OF PERIODS

Periodical structures are frequently present in rooms as, for instance, columns, seating areas or special diffusors. If the scattering coefficient of such structures is to be measured, one is leaded to the question of how many periods should a test specimen contain, in order to assess a representative value. Two kinds of periodical structures were measured with the goal of better elucidate this question. One is a sinusoidal surface and the other is a variation of a square wave profile (made with rectangular battens). Each one of them was constructed using various scale factors, so that the sinusoidal test specimens have eleven, twenty-two and forty-four periods, respectively (see Figure 1). These test specimens are circular, with a surface area of 0,5 m^2 (ϕ = 80 cm). The test samples constructed with rectangular battens are square, with a surface area of 0,36 m^2 (60 cm x 60 cm) and contain six and twelve periods, respectively.

Figure 1. Samples of a sinusoidal surface scaled with three different factors, in order to contain 11, 22 and 44 periods.

In Figure 2 measured scattering coefficients for the sinusoidal samples are shown. Here they are not represented as a function of frequency, but as a function of the ratio between the structure period and the sound wave length (Λ/λ). This kind of representation is useful, as one needs to compare results, which were measured with samples constructed in different scales.

In this case there are practically no differences between the results obtained for the samples with 11, 22 and 44 periods. Almost all differences are within the uncertainties intervals of the measurements.

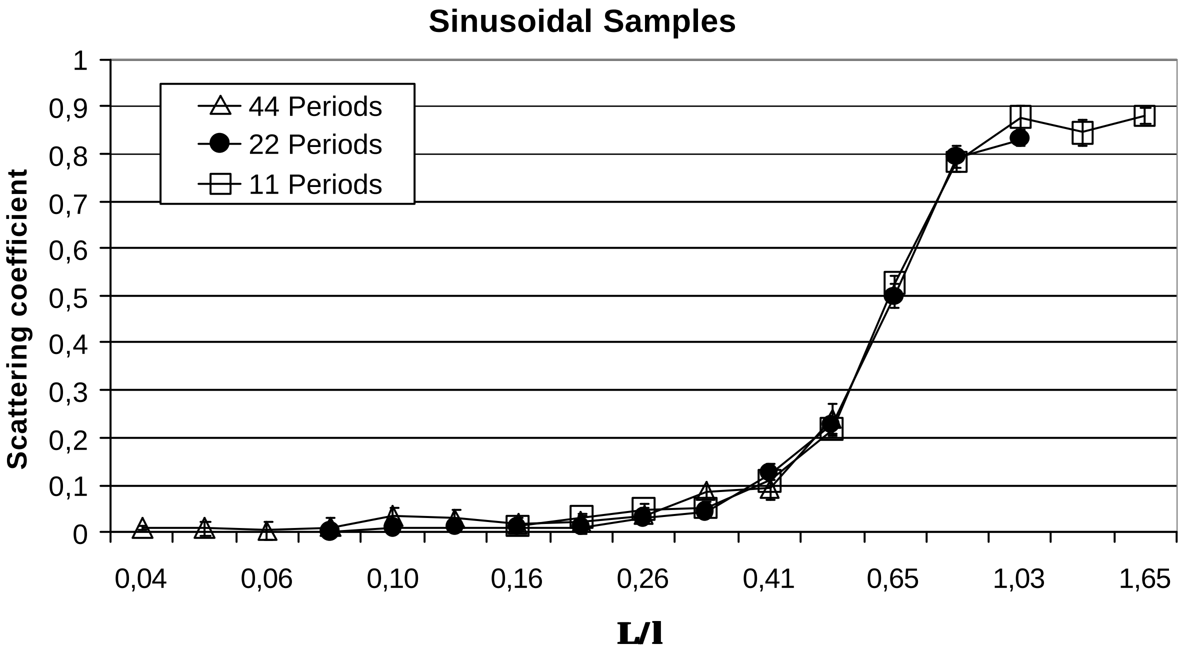

Figure 2. Scattering coefficients from a sinusoidal surface, constructed in three different scales.

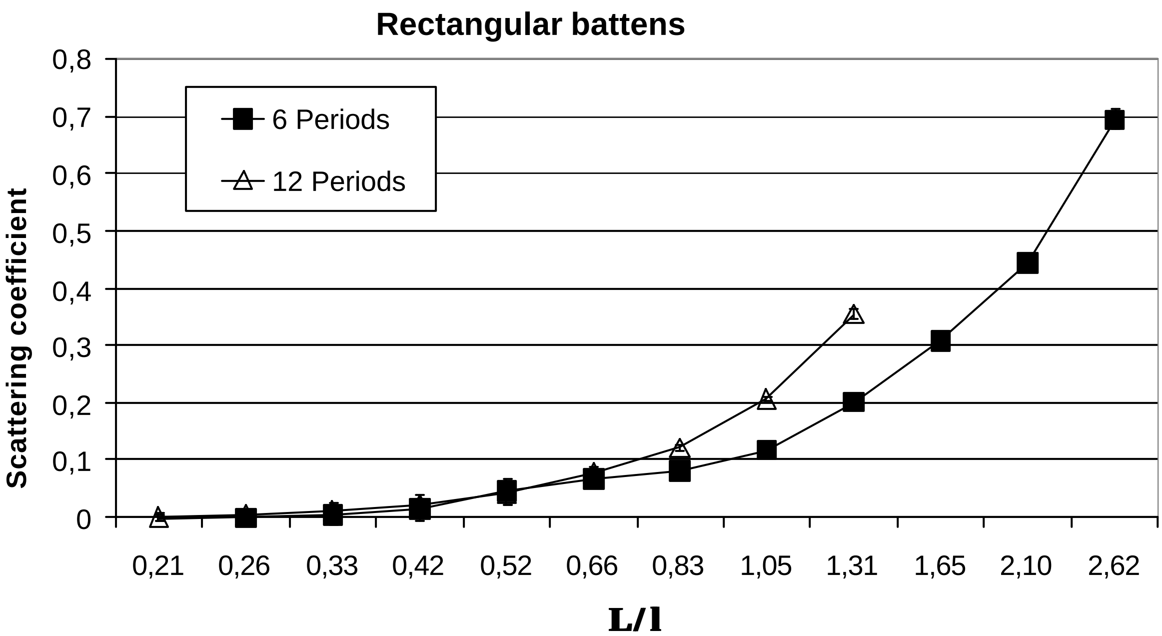

Figure 3. Scattering coefficients from surfaces constructed with rectangular battens in two different scales.

The same doesn't happen with the samples constructed with rectangular battens, as can be seen in Figure 3. From Λ/λ = 0,83 the differences between the scattering coefficients become progressively larger. Scattering coefficients measured for the sample with 6 periods are at least 30 % smaller than scattering coefficients measured for the sample with 12 periods, i.e., differences much larger than the uncertainties of the measurements. From these observations it seems that 6 periods are not yet enough for measuring representative values for the scattering coefficient, while with 11 periods this requisite is already reached. The reason and how this transition occurs remains to be closer investigated. Although the sample with rectangular battens has a square shape, possible edge effects do not play an important role here.

SHAPE OF A TEST SPECIMEN

The ISO standard will contain the requirement that a test specimen shall be circular. This guarantees that edge effects have no or only a small influence over the results. Sometimes, however, it is not possible to construct a circular test specimen.

In order to avoid or at least to minimize the effects due to the edges of square samples it should be possible to "hide" the edges, in a similar way as in the measurement of the random-incidence absorption coefficient. By this measurement method, samples that are symmetrical to the axis of rotation are "invisible". Similarly, edges which are symmetrical to the axis of rotation provide no or small influence over the results. With this idea in mind, a new base plate with a square hole was constructed in order to perform measurements of square samples without excessive errors. This hole should be closed with a square flat plate when performing the reference measurements and afterwards with the square test specimen placed in it (see Figure 4).

Figure 4. Arrangements for measuring the scattering coefficient of a square test specimen. First picture: without any correction. Second and third pictures: with correction.

Results of measurements performed with a circular and a square test specimen (with and without hiding the edges) are shown in Figure 5. The results obtained from the circular test specimen are the reference and, in this sense, it is visible that the error present in the measurements of the square specimen, performed without hiding the edges, are extremely large. In the measurements performed with the new base plate, however, the errors are much smaller and can be considered acceptable. In this measurement the edges of the sinusoidal surface were hidden as much as possible but, because the number of periods was not integer, a considerable area of these edges was still exposed to the sound incidence. That probably leads to the slightly higher coefficients.

The final conclusion is that it is always better to use circular samples. If this is not possible, one possibility for measuring realistic scattering coefficients consists in hiding the edges, for example as presented above.

With this understanding of how the edges can influence the results in this method, an additional remark should be done. This remark is that the center of the specimen should always be placed on the axis of rotation of the turntable. Otherwise errors similar to those observed when measuring square samples without hiding the edges can occur.

Samples from the diffusor surfaces present in the reference room used in the 3rd Round Robin on room acoustical simulation promoted by the PTB (Physikalisch-Technische Bundesanstalt, Braunschweig, Germany) were measured using the idea of hiding the edges of square or rectangular test specimen.

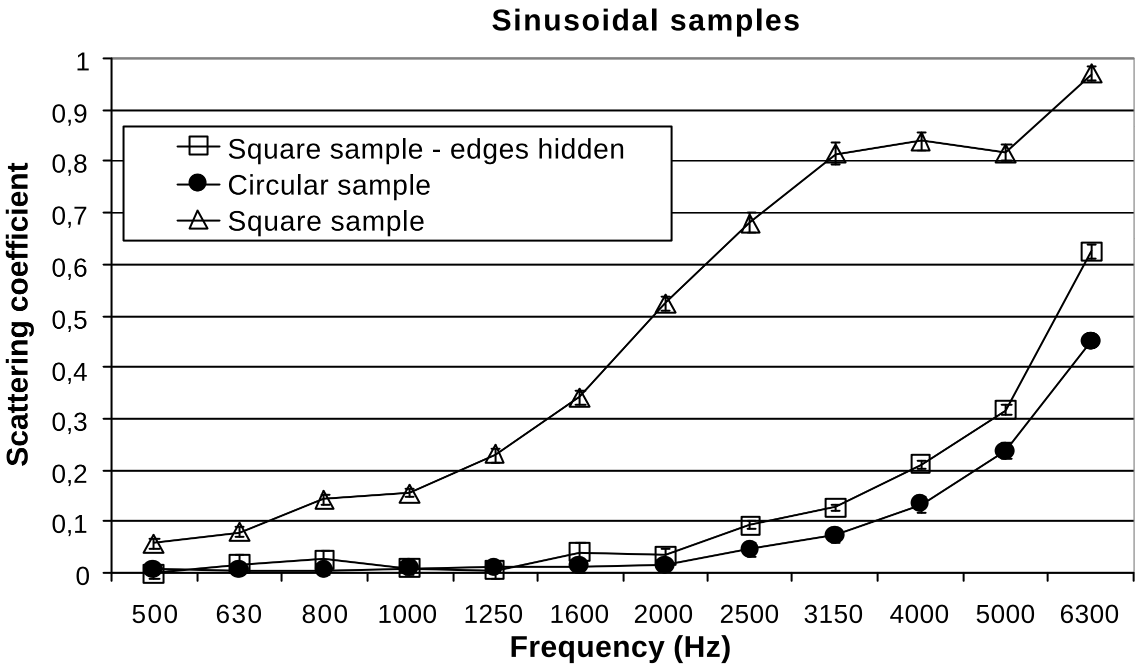

Figure 5. Scattering coefficients of a sinusoidal surface, measured with a circular and a square test specimen (edges hidden and not hidden).

NUMERICAL SIMULATION OF A SINUSOIDAL PROFILE

A numerical estimation of the scattering coefficient was always wanted for several reasons, such as the search of reference values or for consolidating the theory behind its definition. Beyond that, it would be helpful to develop further the ways of designing diffusors and the establishment of a more clear relation between the methods of measuring scattering coefficient and diffusion coefficient. With a valid numerical model it would be also possible to better investigate, for instance, the influence of the edges and the number of periods over the final results.

The problem proposed here is the determination of a random incidence scattering coefficient from calculations of the scattered sound pressure in the free field. This involves three main steps. The first is the calculation of the scattered pressure itself for one angle of incidence, which can be done with different methods, such as the Kirchhoff Approximation (see [3]) or the Boundary Element Method (see [4]), among others. Then it is necessary to process these results with an equation proposed by E.Mommertz [5], revised by J.J.Embrechts, D.Archambeu and G.B.Stan [3], to assess the scattering coefficient. After this procedure is repeated for different angles of incidence one must average the scattering coefficients obtained in an appropriate way. One option is to use the Paris Formula [6], but the question of how to perform this average is still opened.

To begin with a simple case, a two dimensional problem was solved. The scattered pressures for a reference plane and the sinusoidal surface (given by y=0,028sin(35,4x), x and y in m), for 45° sound incidence were determined in the far field in steps of 5°, using the Boundary Element Method from the software Sysnoise. The length of the surfaces was about four times larger than the sound wave length of the lowest frequency used (L_x=4,37λ), which corresponds to 6m. The surfaces were discretized so that the sound wave length of the highest frequency is more than 12 times larger than the size of the element. This discretization also guarantees that the sinusoidal profile is also well represented.

The discretization of the scattering angles was checked through the calculation of scattering coefficients when using steps of 1° and the differences produced lie around 1% of the maximal possible value for the referred coefficient (which is 1). In Figure 6 a comparison between the coefficients calculated for this problem with those measured in the diffuse field is shown. Of course the results are not expected to be exactly the same, but some facts may show that we are in the right way. Two of them are remarkable: the magnitude of the maximum values are not very different (about 6%) and the numerical results seem to behave more or less like asymptotic values of the measured ones. Further simulations will investigate the influence of the length of the surfaces over the results, consider more angles of incidence and finally treat the three dimensional case.

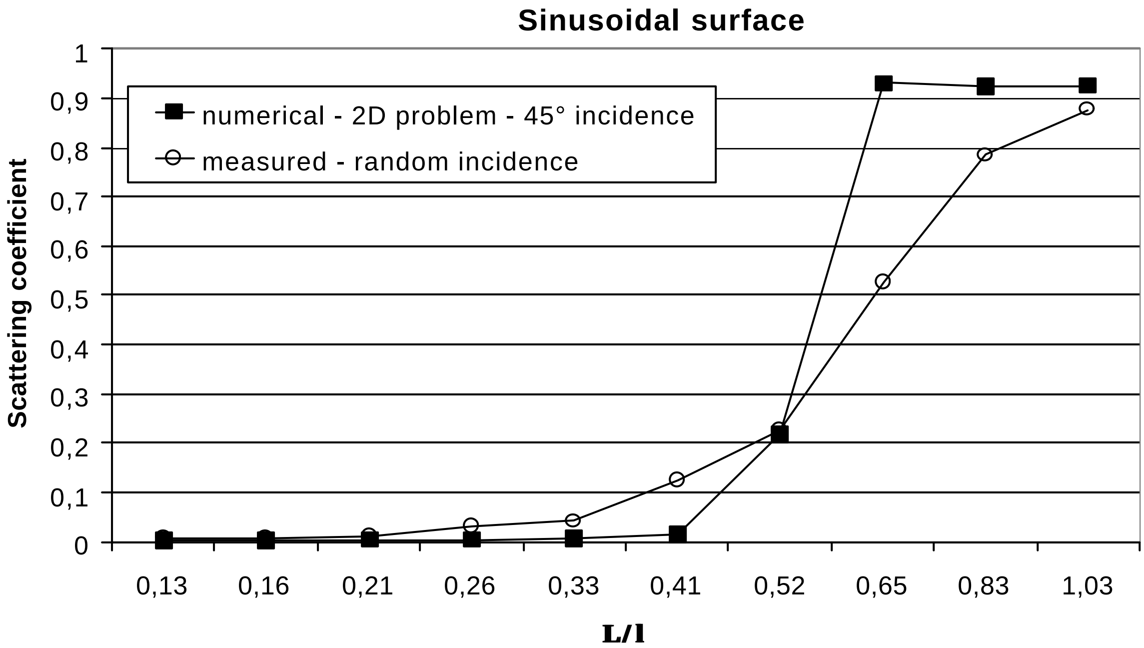

Figure 6. Comparison of the measured and simulated scattering coefficient of a sinusoidal surface. The simulated results were obtained from a solution of a 2D problem and for 45° sound incidence. Here Λ is 0,1775m (for 1000 Hz, $\Lambda/\lambda = 0,52$).

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BIBLIOGRAPHICAL REFERENCES

[1] Bork I., A Comparison of Room Simulation Software - The 2nd Round Robin on Room Acoustical Computer Simulation, Acustica united with Acta acustica 86(2000) No.6 , p.943-956.

[2] Vorländer M., Mommertz E., Definition and Measurement of Random-incidence Scattering Coefficients, Applied Acoustics 60 (2000), p. 187-199.

[3] Embrechts J.J., Archambeu D. und Stan G.B., Determination of the Scattering Coefficient of Random Rough Diffusing Surfaces for Room Acoustics Application, Acustica united with Acta acustica 87 (2001), p. 482-494.

[4] Cox T.J., Lam Y.W., Evaluation of Methods for Predicting the Scattering from Simple Rigid Panels, Applied Acoustics 40 (1993), p. 123-140.

[5] Mommertz E., Determination of Scattering Coefficients from the Reflection Directivity of Architectural Surfaces, Applied Acoustics 60 (2000), p. 201-203.

[6] Kuttruff H., Room Acoustics, Spon press (2000), p.49.