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FLEXIBLE SOUND ABSORPTION BY MICRO-PERFORATION

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ABSTRACT

In applied technical acoustics the view is taken that broad-band sound absorption can only be achieved with porous or fibrous materials (mineral wool, glass wool, plastic foam). Thin unpunched or punched panels (resonance absorber), however, are often used for low frequency, narrow-band absorption. Based on the theory of Maa (1987) an absorber system highly independent of the materials is being presented. Proceeding on the well known acoustic design of micro-perforated panels a modification is explained being able to realize effective sound absorption in a broad frequency band. It is therefore possible to achieve each absorption performance known up to now by specific perforation of aluminum for instance. By means of a specifically developed computer program the parameters are calculated. A comparison between measured and calculated absorption is drawn.

1 - INTRODUCTION

In several applications of absorber systems the porous character of conventional absorbers is of disadvantage. Thus, there are fields of applications in which porous absorbers are not able to be employed. Since several years efforts are taken to develop absorbers with the acoustical qualities of porous absorber systems which are at the same time abrasion-resistant, washable and fire-resistant.

The micro-perforated absorber systems, presented by Maa [1] and Fuchs and Zha [2], present a fibre-free conception being able to obtain good sound absorption data. A sound absorption, however, which is known of foams or tiles cannot be achieved by previously published dimensioning of these perforated plates.

The following will demonstrate that by a consequent realization of the Theory of Maa any absorption characteristic can be realized with using materials like aluminum, high-grade steel or plastics like Plexiglas, PP and PU [3].

2 - DESIGN OF PERFORATION PARAMETERS

Any material-independent acoustically hard plate can be designed sound absorbing by specific perforation. The shape of the perforations is only secondary. The important parameters being decisive if the plate has sound-absorbing properties and the quality of the sound absorption are to a great extent dependent on the parameters listed in figure 1.

The frequency response of the sound absorption at a constant wall distance can be flexibly designed by the design of the perforation parameters (figure 2). A very high correspondence between the measurements in Kundt's tube (fig. 2, left panel) and the calculation (fig. 2, right panel) can be seen.

With perforation A a characteristic absorption behaviour is realized, equivalent to a one-layer membrane or foil absorber [4, 5], whereas the graph with perforation B shows the absorption behaviour of a micropore absorber as known from previous publications [1, 2], [6]. With perforation C, however, broad-band absorption properties have been realized which otherwise only seemed achievable by porous or fibrous materials. This is made clear in figure 3.

Sound absorption over an even higher frequency spectrum, as known of considerably thicker porous materials, could be achieved by an arrangement of several micro-perforated layers. The right panel of

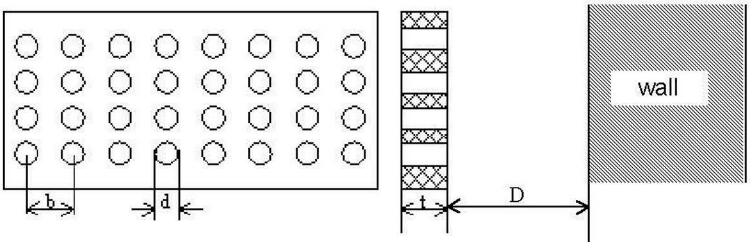
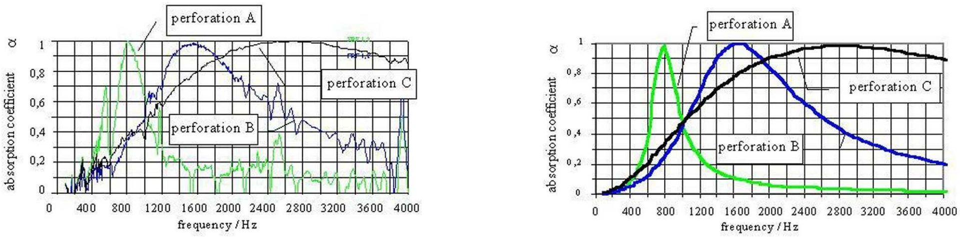


Figure 1: Schematic diagram of a perforated plate with d: hole diameter, b: distance of the holes, t: thickness of the material, D: wall distance, S: component surface, S_0: total hole surface, $\sigma = S_0/S$: hole portion.



(a): Measured in Kundt's tube with D = 20 mm.

(b): Calculated acc. to model of Maa.

Figure 2: Different absorption characteristic of a sample by different design of perforation parameters at same wall distance.

figure 3 shows the measured absorption of a two-layer arrangement in contrast to a PU-foam sample with a thickness of 40 mm.

The possibilities and flexibility which can be achieved by micro-perforated systems are illustrated in figures 4 and 5.

The graph represented in figure 4 documents the absorption coefficient of a four-layer micro-perforated arrangement. At 200 Hz it has already an absorption coefficient of 0.6, whereas the medium absorption coefficient in the range between 400 Hz and 4000 Hz is more than 0.9.

The graphs represented in figure 5 illustrate the equivalent absorption areas of a perforated plate in the diffuse sound field (α-cabin). It can be seen that also a free-standing or hanging perforated plate in the diffuse sound field possesses very good absorption properties. In contrast to the arrangement lying 20 mm above the floor the absorption improves with regard to its broad-band range.

Figures 2 and 4 demonstrate also clearly that an exact calculation of the absorption coefficient can be carried out by the geometric parameters of the perforated plates. In both cases a very good correspondence is reached between the calculated graphs and the graphs measured in Kundt's tube. For the exact calculation of the absorption coefficient methods for the description of linear time-invariant systems and networks [7, 8] can be used. It has shown that an exact calculation is possible by concentrated elements as well as by distributed elements.

3 - CONCLUSION

By a consequent application of the micropore-absorber theory the material-specific distinguishability of absorbers becomes more and more secondary. By specific perforation of any material (e.g. metals, plastics, glass) sound-reflecting surfaces can be designed in a sound-absorbing way. The absorption which can thus be reached is in no way inferior to conventional absorbers. The absorption characteristics can be exactly calculated from the geometric parameters of the perforated plates by the Theory of Maa and by the application of calculation methods of linear time-invariant systems. The flexibility in the acoustic design and the employment of various materials open up new dimensions in applicability. In fields in which it was not possible to employ sound absorbers for thermal reasons for example, now micro-perforated metals can be employed.

As far as production is concerned it is today possible – without having to use expensive processes (laser drilling) – to carry out a very exact and noise-situation adapted perforation on materials like aluminum, high-grade steel and plastics like Plexiglas, PP and PU.

Free way could be given to the abrasion-resistant, fire-resistant anechoic room.

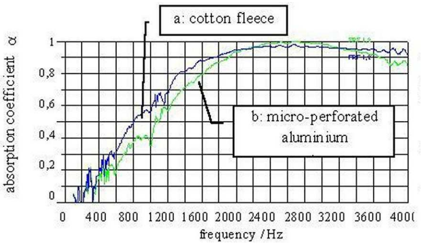


Figure 3(a): Measured absorption coefficient in Kundt's tube, graph a: acoustically optimized cotton fleece, 20 mm thick and 2400 g/m^2 surface weight, graph b: micro-perforated aluminum sheet at 20 mm wall distance.

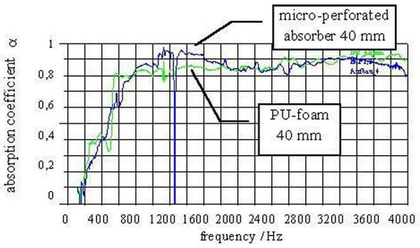


Figure 3(b): Comparison between a PU-foam sample with a thickness of 40 mm and a two-layer micro-perforated arrangement of the same height.

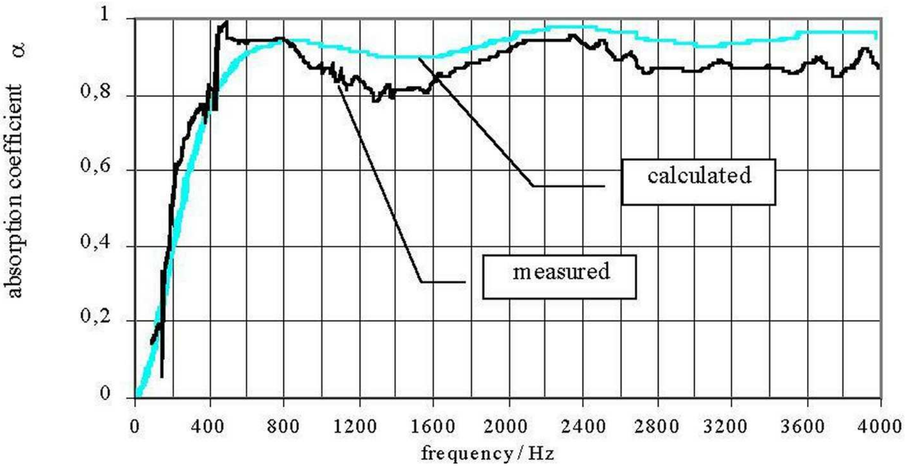


Figure 4: The calculated and in Kundt's tube measured sound absorption of a four-layer micro-perforated arrangement; the total height of the arrangement is 80 mm.

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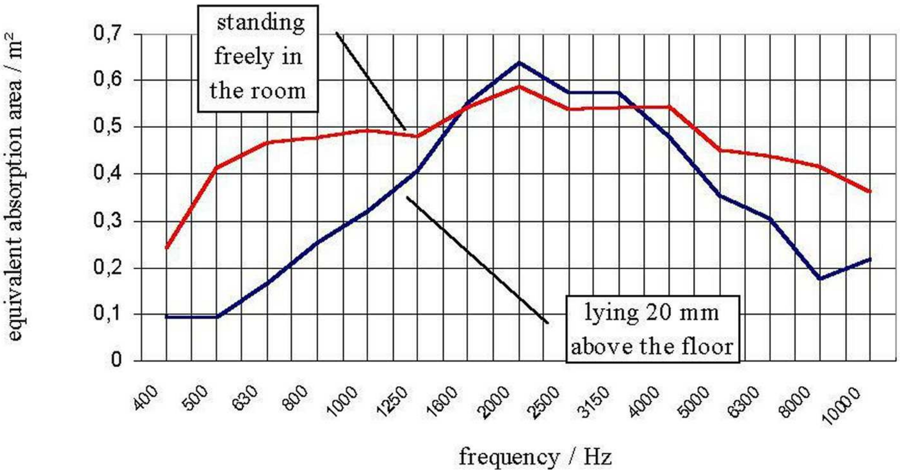

Figure 5: Equivalent absorption area of a micro-perforated plate, measured in diffuse sound field; material area = 0.72 m^2, graph 1: plate lying 20 mm above floor, graph 2: plate standing freely in the room.