Broadband compact absorbers for anechoic linings

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Introduction

Valid standards [1] and popular dogmas [2] urge upon an even distribution of $\lambda/4$ – deep wedges of fibrous/porous material as anechoic lining for Anechoic Test Cells ATC. The main problems in building ATC therefore emerge from the low-frequency domain. Conventional acoustic lining covering a frequency spectrum down to around 100 Hz consumes as much as 1/3 of the room's raw volume. A space-saving alternative is described in [3]. Measurements, show that the absorption coefficient α_θ of a structured porous lining decreases with increasing angle of incidence θ [4]. Computer simulations, on the other hand, indicate that the freefield situation is more critical when a test configuration is made completely symmetric but less critical when more practical situations are envisaged [5]. Close to the source, where a majority of tests are to be performed, the pressure level decay with distance r according to –20 lg r from both the real and a distant image source helps a lot to fulfil the freefield conditions [3]. In a transient field at some distance from the source and the boundary the problem is mainly due to the room modes [6] dominating at low frequencies. Since the mode field is extremely inhomogeneous it is necessary to choose a highly inhomogeneous lining in contradiction to [1]. A more intelligent anechoic lining must take care of the individual mode structure and specific test configuration in every single ATC.

Asymmetrically Structured Absorber ASA

A novel porous absorber with a specially corrugated surface (see [7, Fig. 1])was initially developed for a pass-by automobile test facility in the VW Acoustics Centre [8]. It was designed and optimized to cover mid and high frequencies with a considerable advantage over conventional wedges assuming comparable depths (Figure 1). Its acoustic performance at oblique sound incidence is discussed in [4] together with some draw-away measurements with sine signals in a pass-by facility [8].

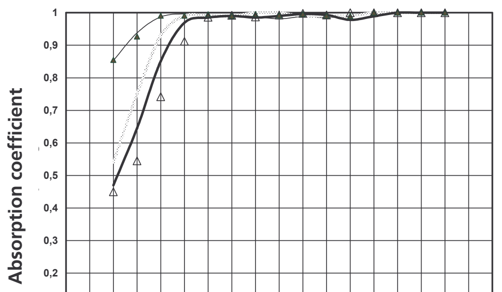

Figure 1: Absorption coefficient α_0 of structured porous fibrous linings in a 200 x 200 mm impedance tube [3]
ASA: 520 mm (▬▬); 650 mm (·········); 780 mm (——)
Wedges: 680 mm (△); 1075 mm (▲).

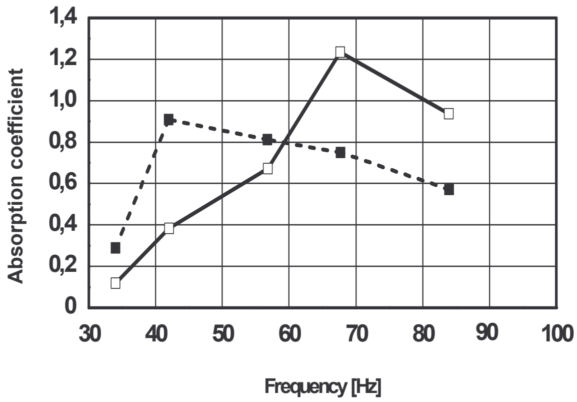

Figure 2: Effective absorption coefficient α_e of 100 mm thick CPA with 1 (□) or 2.5 mm (■) thick steel plates according to [11].

Compound Panel Absorber CPA

The main advancement over conventional fibrous wedges, however, was achieved by the implementation of the CPA in the back of the porous material. This complex resonator consists of typically 1 x 1.5 m large and preferably 1 to 2.5 mm thick naked steel plates backed by a porous or fibrous layer no thicker than 100 mm [9, Fig. 3]. Both react together in a mass-spring manner with low-frequency sound waves that would pass any thin porous/fibrous layer unimpaired. When the plate is not fixed nor clamped, all of its manifold vibrations are heavily damped by the intimate adhesive coupling with the back layer. In addition, impinging mid-frequency sound waves are bent around the plate's edges to be propagated and thus dissipated as in a very deep passive absorber layer. Both of these heterogeneous absorption mechanisms combine in a very effective broadband (50 – 500 Hz) module. Its absorption characteristics is superior to that of a simple 10 cm thick porous/fibrous layer below 300 Hz, be it structured or not (see [10, Fig. 3]). The effect of different plate thicknesses in CPA is demonstrated by "effective" absorption coefficients α_e as derived from decay time measurements at the lowest axial modes of a 5 x 4 x 3 m room according to [11] (Figure 2).

Broadband Compact Absorbers BCA

With broadband noise sources, which prevail by far in industrial applications, sound tests are exclusively performed in third-octave bands. For such standard precision tests according to [1] it is sufficient to add in front of the CPA low-frequency modules a homogeneous porous or fibrous layer, 150 mm thick. An unequaled broadband absorber is thus created, the absorption of which exceeds that of the CPA, even at the low- and mid- frequencies (Figure 3). Mind, however, that this novel BCA has little in common with so-called "compact flat absorbers" which seem to rely on conventional resonators with an insufficient narrowband performance at low frequencies [12, Fig. 2].

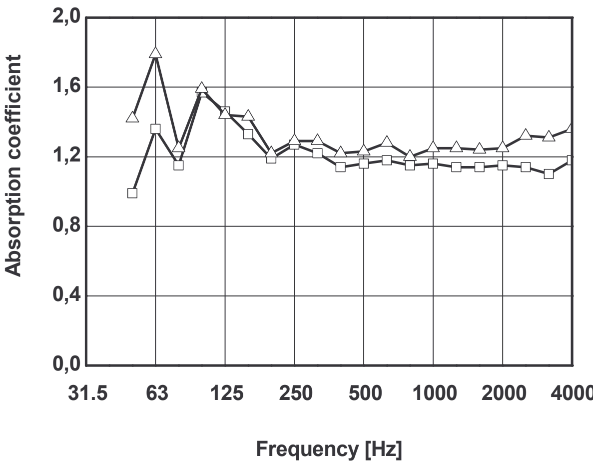

Figure 3: Sabine absorption coefficient α_s of 250 mm thick BCA according to Fig. 3 (□) and 520 mm thick ASA according to [7, Fig. 1] (△), both with 100 mm thick CPA in the back [3].

Specially structured or layered porous/fibrous absorbers come into play only when precision measurements according to [1] are required for tonal sound waves (sine signals), as e. g. for high-performance electromechanical transducers, or when a user demands freefield requirements for third-octave testing beyond those laid down in [1], as was the case e. g. in a project together with VW [8, 13] (Figure 4). For smaller ATC like e.g. the automotive engine test bed of BMW [14] the extraordinarily slim BCA lining has proven extremely useful down to 50 Hz (Figure 5).

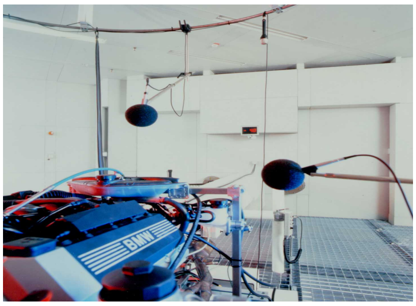

Figure 4: Freefield engine test bed (raw volume 338 m^3) equipped with 250 mm deep BCA anechoic lining in the FIZ of BMW for precision measurements [14] in third-octaves according to [1].

Figure 5: Hemi-freefield pass-by measuring hall (raw volume 3454 m^3) equipped with 620 mm deep ASA + CPA anechoic lining in the Acoustics Centre of VW [8] for precision measurements with tonal (sine) sources according to [1].

Summary

Freefield rooms for acoustic testing are normally provided with voluminous fibrous wedges the depth of which corresponds to λ/4 of the lowest frequency to be measured. When, however, such passive absorbers are combined with reactive/resonant panel absorbers, anechoic linings become possible, which save valuable space and provide a smooth, attractive and resistive surface. When measurements are to be performed in third-octave bands, down to 50 Hz, a lining thickness of merely 250 mm is required. For narrow-band analyses down below 100 Hz the novel lining may be corrugated in a specific manner increasing the total thickness to no more than 620 mm. So far, 4 aeroacoustic wind tunnels and more than 70 test beds in research labs and acoustic centres at 6 automobile manufacturers and several component suppliers have been equipped with the new anechoic linings with excellent acoustic and design features.

References

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