Noise reduction and anechoic linings in aero-acoustic wind tunnels

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Introduction

The increasing demand for noise reduction and sound design at vehicles requires adequate test conditions in wind tunnels and test beds. A special broadband resonant absorber has been developed [1] that shows high absorption efficiency down to 20 Hz with a total lining thickness of only 250 mm and an even surface.

Absorber principle and construction

The principle construction of the new Compound Panel Absorber CPA is shown in Figure 1. It consists of a rectangular foam layer with a steel plate fixed on top by an adhesive layer. The foam layer itself is fixed to a hard wall. The complete absorber is produce in elements with a size of at least 1.5 m by 1 m and a depth of typically 100 mm. The absorption capability of the CPA is provided by two well-known mechanisms. The first is a mass-spring resonator with the plate acting as mass and the foam layer acting as spring.

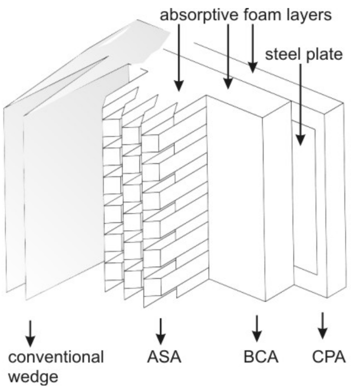

Figure 1: Construction principle of Compound Panel Absorbers (CPA), Broadband Compact Absorbers (BCA) and Asymmetrically Structured Absorbers (ASA) according to [2].

The second mechanism is due to the free vibrations of the plate which is undergoing elastic bending deformations as reaction to the incident sound and has an increased inner friction provided by the adhesive connection with the foam layer. Even at low frequencies, many modes are present on the plate that may couple to room modes, for example, and thereby increase the absorption at these room modes considerably. By variation of the plate thickness and dimension, the CPA may be tuned for optimized absorption in a specific frequency band. For the construction of the Broadband Compact Absorber BCA, a second layer of foam with a thickness of typically 150 mm is fixed on top of the steel plate as an additional layer (Figure 1). An efficient sound absorber for the whole frequency range with a total thickness of only 250 mm is achieved by this sandwich construction. The CPA may be combined with a structured layer forming the Asymmetrically Structured Absorber ASA which is used for higher non-standard acoustic requirements [3].

Applications in wind tunnels

With these new absorbers several wind tunnel plenums have already been completed. The first plenum fully equipped with BCA modules as wall lining is that of the AUDI aero-acoustic wind tunnel [4]. Figure 2 shows a picture with the BCA behind a perforate protection layer and in the background the movable absorber wall in front of the windows to the monitoring room. With this installation the plenum fulfils the requirements for a class 1 semi free-field room down to 63 Hz in 1/3-octave bands. A new application of BCA modules is their integration as splitter silencers. Figure 3 shows a view to one of the two corners of the AUDI wind tunnel with such silencers placed diagonally into the corner. The silencer consists of double BCA modules enhancing the low frequency performance [5]. The remaining two corners were equipped with foam coated turning vanes similar to the FKFS wind tunnel at Stuttgart University [6]. The coating delivers additional attenuation in the mid- and high frequency range and a reduced pressure loss compared to the uncoated turning vanes. All these measures, together with a carefully chosen fan, lead to the by far quietest wind tunnel in the world [7].

Figure 2: Plenum of the AUDI aero-acoustic wind tunnel with BCA modules as wall lining [5].

Figure 3: View to one corner of the AUDI aero-acoustic wind tunnel with BCA modules as splitter silencers [5].

The high demands on abrasion at the flow surface linings due to the simulation of driving speeds up to 300 km/h [8] led in 2001 to the installation of the BCA also at the DaimlerChrysler aero-acoustic wind tunnel in Detroit. Similar to the AUDI wind tunnel, not only the plenum of this facility as shown in Figure 4 was equipped with BCA modules but also the duct walls were covered to a great extent with BCA linings and the fan discharge silencer was built from Alternative Fibreless Absorber ALFA modules. Some results of the commissioning measurements performed in 1/3-octave bandwidth are presented in Figure 5 for the shortest and thus most critical path from the centre of the floor to the edge (with BCA lining at the control room windows and door). Free-field conditions according to [9] were met on all paths in the extended frequency range down to 50 Hz and for a measurement radius of 7 m (required: 80 Hz, radius 5.5 m).

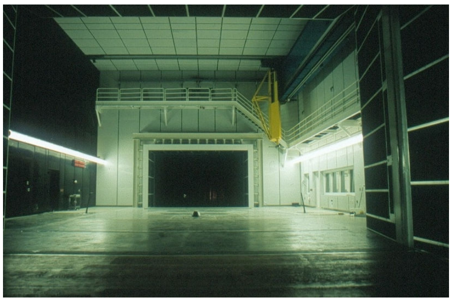

Figure 4: View from the collector to the plenum of the DaimlerChrysler aero-acoustic wind tunnel at Detroit.

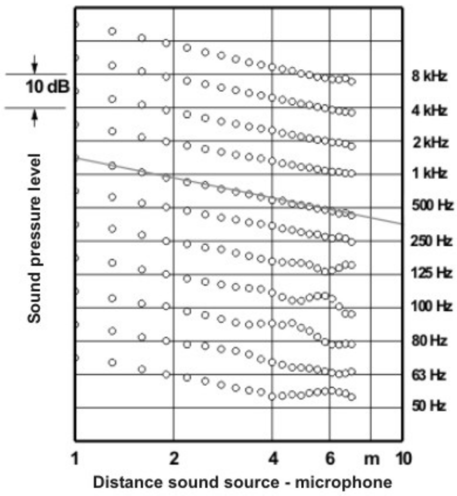

Figure 5: SPL decay curves on the shortest path to the control room of the plenum shown in Figure 4.

Free-field conditions according to [9] down to 80 Hz were very important for the owner of the recently completed wind tunnel of PSA Peugeot Citroën, Renault and CNAM in Paris [2] (Figure 6). The free-field conditions achieved allow measurements down to 50 Hz for a radius of 6 m from the centre of the floor.

Conclusions and outlook

The application of BCA absorbers covers a wide range of acoustic test cells and wind tunnel plenums where free-field conditions have to be met. They are further applicable as splitter silencers and as duct linings if the ducts are at least of the same size as the absorber modules. Together with their acoustic performance they offer additional advantages due to their small thickness saving a large amount of space and their fibre-free design. So far, over 70 anechoic test cells and plenums have been completed with room volumes ranging from 45 m^3 up to 2200 m^3 [10]. Furthermore, pass-by and power-train acoustic test facilities are currently built with these absorbers at the First Automotive Works FAW in Changchun, mainland China, Tongji University, Automotive Department, Shanghai and DAF Eindhoven, Netherlands.

Figure 6: View to the plenum of the PSA Peugeot Citroën**,** Renault and CNAM aero-acoustic wind tunnel at Montigny le Bretonneux near Paris.

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