Aero-acoustic wind tunnels

Broadband compact absorbers can be used to achieve high sound absorption in acoustic test cells during vehicle development

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Aero-acoustic wind tunnels have been gaining more and more importance in the development of vehicles as end customers make higher demands on noise reduction. With regard to test cells, this means that side noise has to be absorbed as much as possible. This can be achieved using highly efficient materials and by the optimal coordination of all soundproofing measures.

A ride in a 30- or 40-year-old car on the highway underlines that earlier generations of cars were much louder. The noise levels of these old models would not be acceptable to consumers nowadays. Even in the compact class, car buyers expect a quiet and pleasant driving noise when driving at speed.

So one of the tasks of a car manufacturer is to reduce the noise sources in and around the vehicle to a minimum level. This is even more demanding as other technical trends are making this job difficult. One of these trends is the increasing denseness of 'packaging' in the vehicle. Another trend is lightweight construction, which means, for example, that car body components vibrate more easily. Moreover there are various auxiliary and comfort drive systems that might be considered as a potential noise source.

But car manufacturers don't only focus on pure noise reduction. 'Sound engineering' is now in demand – this means that the developers want to create an individual, characteristic soundscape, especially in the case of sporty vehicles. For this purpose, the acoustic properties have to be carefully tuned.

These are the reasons why aero-acoustic wind tunnels are gaining more and more importance in the development of vehicles. This highly demanding test rig technology has been clearly enhanced in recent years.

In the 1990s, a typical acoustic wind tunnel in the automotive industry generated a sound level of approximately 70dB(A) at a wind speed of 120km/h in the test section. In 1997, there was a developmental leap as the first wind tunnel with broadband compact absorbers (BCA) was introduced. This technology, which has been intensely used by Faist Anlagenbau since then, achieves a very high rate of sound absorption, particularly in the low-frequency range, providing low installation depth and a smooth surface at the same time.

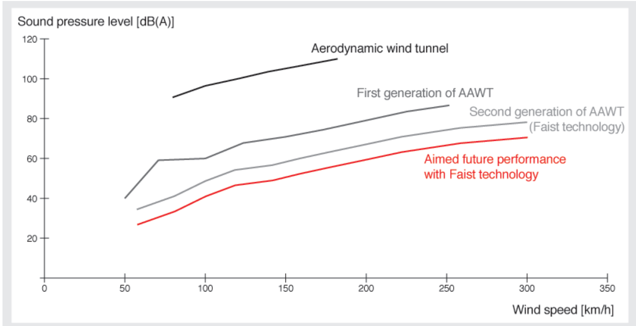
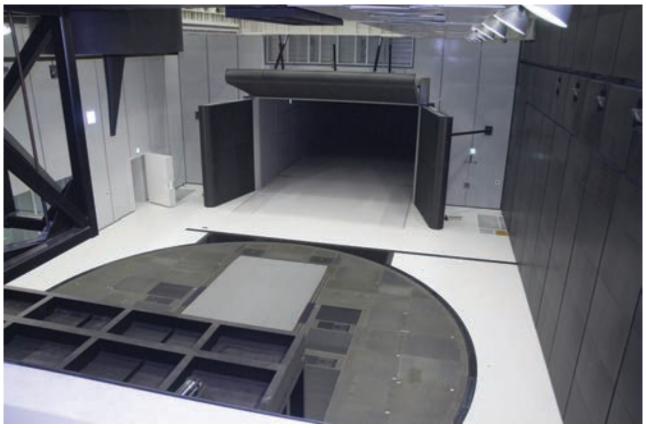


FIGURE 1 (ABOVE): Acoustic comparison of wind tunnels

FIGURE 2 (BELOW): Plenum of an aero-acoustic wind tunnel, equipped with BCA technology



The result of all this is the wind tunnel that was built at Audi in Ingolstadt, Germany, which sets standards even today with approximately 55dB(A) at a wind speed of 120km/h. In the short to medium term, however, further noise reductions up to 10% are to be expected, mainly by an ideal adjustment of all sound proofing measures (Figure 1).

The technology in the broadband compact absorbers, which is based on a reactive mass-spring system, was developed by the Fraunhofer Institute for Building Physics. This acoustic lining consists of modules or panels in a layered structure with a smooth surface that doesn't reveal its sound-absorbing function at first glance. Its intelligence is hidden in the layered structure of the modules.

On the layer that is attached closest to the wall, there is a resonator sheet. This layer is called a compound panel absorber. In order to cover a broad frequency range, additional absorber layers are added and completed to the broadband compact absorber. The appropriate modules have a standard construction depth of 250 or 350mm. They are installed in an acoustically neutral, perforated sheet metal basket for the linings of walls, floors and ceilings in anechoic rooms.

By varying the resonance frequency of the resonator sheets and by their positioning on the walls, it is possible to adjust the sound absorption measures to the mode field of the respective unlined measurement room. This also applies to aero-acoustic wind tunnels with a plenum verified according to ISO 3745 or VDI 3760 (Figure 2).

But the acoustics of a wind tunnel are not only defined by the lining of the plenum. The flow noises must be minimized in the complete interior room, meaning the flow noises must be minimized in all air-ducting sections if significant results of the aero-acoustic noise measurements are to be gained. This requires effective sound absorption over the complete frequency range.

The BCA absorbers offer the advantage in the linings of the tunnels that the soundproofing measures do not significantly reduce the cross-section of the tunnels and the wind speed. In addition, deep frequencies are effectively suppressed at the same time.

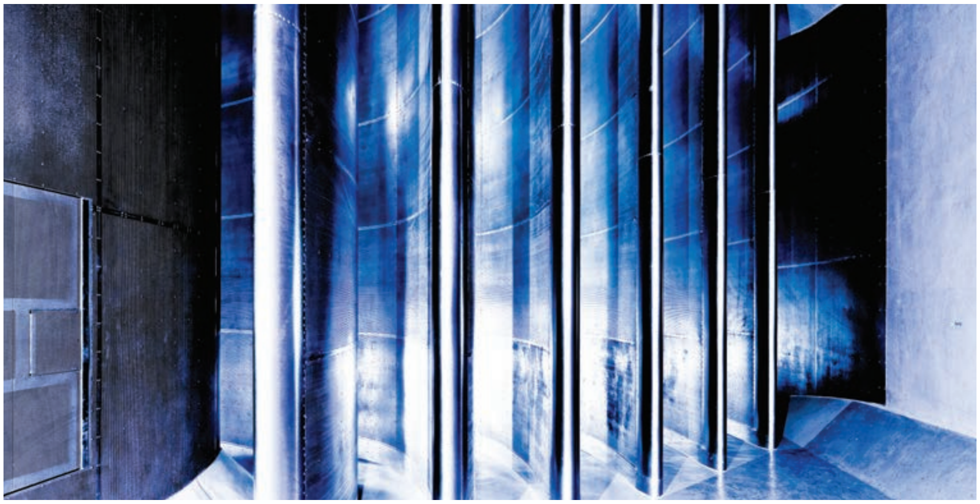


FIGURE 3 (ABOVE): Absorbing turning vanes and wall lining in an aero-acoustic wind tunnel

FIGURE 4 (BELOW): Fan discharge silencer

"The interior comfort of a vehicle is becoming more and more important, and passengers in a car expect a hushed and pleasant soundscape"

Turning vanes and profiles must be exactly adjusted to the flow conditions and wind speeds. A high degree of know-how is required when these components are designed and calculated. The profiles can be provided with foam layers in order to minimize pressure losses and to reach an additional absorption of medium and high frequencies. Depending on the design, BCA modules may also be used in this case. They are integrated in baffle silencers that are mounted diagonally in the turning vanes in order to increase the deep-frequency absorption there (Figure 3).

The fan discharge silencer reduces the sound propagation close to its source. They are designed as special duct silencers. In this case, the design is also optimized to achieve a reduction of very deep noises (Figure 4).

If the soundproofing measures listed here are planned from a single supplier, there's every chance that all the potential means to reduce noise will be employed. In this scenario, absorber materials can be precisely coordinated, for example.

The application of the broadband compact absorbers alone is highly effective. The quietest aero-acoustic wind tunnel designed for the automotive industry was achieved using BCA linings, and this technology has now established itself worldwide. In the past few years, several wind tunnels have been built with BCA technology in Asia.

The trend toward noise reduction in acoustic test cells where BCA technology is used will continue in the future. Passengers in a car increasingly expect a hushed soundscape without being disturbed by unnecessary noise. In order to meet these expectations, manufacturers are striving for an active 'sound design' – a targeted influencing of the perceived noises of the vehicle. This kind of design, aimed at optimizing the sound quality, takes place in aero-acoustic wind tunnels.

Legislation is also speeding-up the advancement of noise reduction, as well as increasing driving speeds: at the moment test cells are under construction that will be able to take measurements at very high speeds (more than 300km/h).

The issue of noise reduction is even more acute in vehicles that are equipped with alternative drive systems. If the noise of the combustion engine disappears, other noises will come to the fore caused by factors such as wind, electric drives, converters and auxiliary drive systems. This soundscape may cause a feeling of unease for the passengers and must be metrologically analyzed so that vehicle manufacturers can take appropriate measures. ❮