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Online Configurator for the Acoustic Management of Vehicles

With Acoustic Garage, Autoneum offers a web-based configuration platform for vehicle acoustics that meets the requirements of today's professionals, scientists and end users alike. The 3-D application is based on the company's acoustic simulation expertise and allows each user to design an individual noise control package.

IDENTIFIED NEEDS AND THE TECHNICAL SOLUTION

The inspiration for Acoustic Garage [1] stems, among other things, from Autoneum's experience in acoustic product development for new automobile manufacturers. These OEMs have limited resources available, especially when it comes to developing noise control components. Having a reference or prototype vehicle may not be possible until the development matures. Additionally, engineering teams are quite small compared to those of traditional OEMs. Therefore, supporting NVH engineers in acoustic pre-development of future vehicle models was one of the reasons to build the web portal.

The system offers a comprehensive information and product experience on various aspects of acoustic management of vehicles. Among others things, interested parties can design an individual noise package through a step-by-step configuration, starting with the choice of the vehicle body, a powertrain type and followed by a customized NVH package

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based on Autoneum's product and technology portfolio – with over one billion possible combinations. To calculate the individual part performance based on the user's selections, the Transfer Matrix Method (TMM) is used. Finally, the sound signature of the virtual car is simulated using a Statistical Energy Analysis (SEA) model. This article is focused on the technical aspects associated with each step of configuration in Acoustic Garage.

SELECTION OF THE CAR BODY: STUDY FRAMEWORK

To offer a comprehensive experience and a realistic setup, different NVH design and technology modifications were integrated into an SEA model containing all the vehicle's characteristics. Considering all parts simultaneously, however, has technical limitations particularly in terms of the simulation model's sensitivity: The model assumes specific energy passages depending on the selected vehicle type. It is therefore more difficult to visualize some NVH changes because fixed panels could "hide" some effects.

The vehicle currently available is a C-segment hatchback. The topological model of this car type simplifies the car geometry into a set of meshed acoustic panels and cavities and thereby defines the study framework. Here, the topological model is composed of 264 meshed panel and 36 cavity groups. For each part, the surface/volume is relevant for the simulation, not the shape. **FIGURE 1** shows the topological vehicle model in which an example of the outer panel (the roof), of the inner panel (the console) and of an acoustic cavity are illustrated.

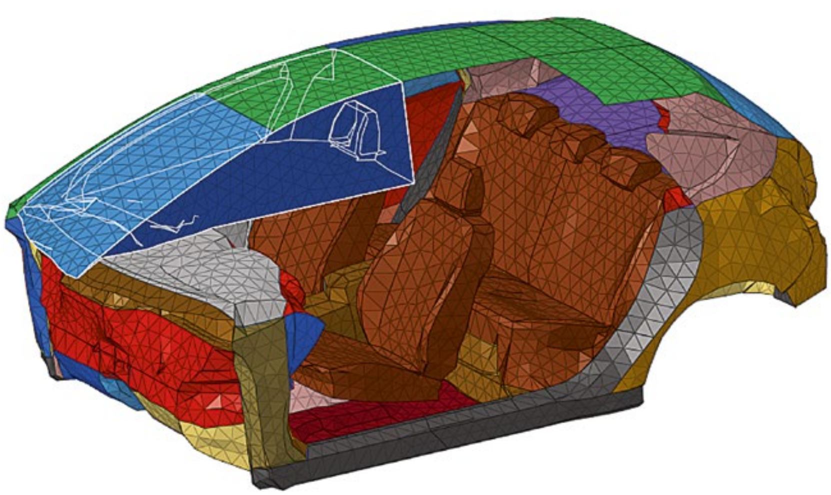


FIGURE 1 The topological model of the C-segment hatchback vehicle as applied in the Acoustic Garage (© Autoneum)

SELECTION OF THE POWERTRAIN: THE ACOUSTIC EXCITATIONS AND TRIM PARTS DEFINITIONS

Selecting the powertrain type – either an Internal Combustion Engine (ICE) or a Battery-electric Vehicle (BEV) – is the second step in the acoustic configuration. In terms of SEA modelling, the choice of engine significantly influences the acoustic loads applied on the external panels. Furthermore, the engine selection leads to a modification of the acoustic components that are available for the vehicle model. In a BEV, certain parts in the engine bay and underbody are no longer needed or will have alterations (such as heatshields) while the inner dash and carpet remains unchanged. Components such as the outer tunnel insulator are therefore only available for the ICE.

The acoustic loads used are derived directly from measurements which are Acoustic Transfer Functions (ATFs). They are carried out as follows: The SEA panels defined in the topological model are replicated on the car in a semi-anechoic room. Several microphones, at least four per external panel, capture a pressure p_i, **FIGURE 2** (right). The sources are monopoles generating white noises of pressure p_s at several positions on the vehicle: inside the engine bay and at the tires, close to the patches [2], **FIGURE 2** (left). For each type of engine, these two excitations (engine and tires) are fed into the SEA model. The format of these ATFs is in this case p_i/p_s. When the user selects the BEV model, the acoustic loads on the floor panels are set to zero. This approximation may seem exaggerated at first glance. However, several studies have shown that placing a battery under the car floor can significantly increase the insulation performance. This is especially true if sealings or a gap filler are additionally installed between the battery and the body-in-white [3]. Therefore, the hypothesis of an almost zero contribution of floor panels to the acoustic management is considered realistic.

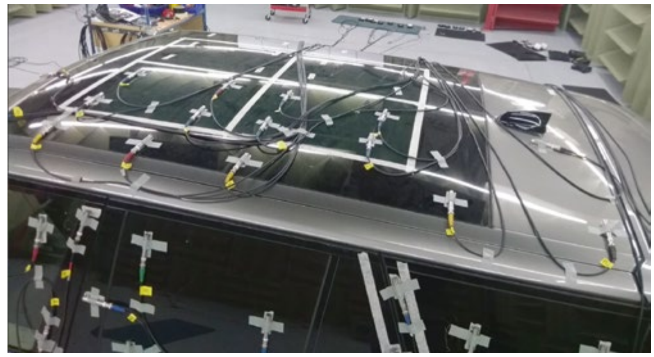


FIGURE 2 Source at the tire (left) and microphones placed on the roof panels (right) (© Autoneum)

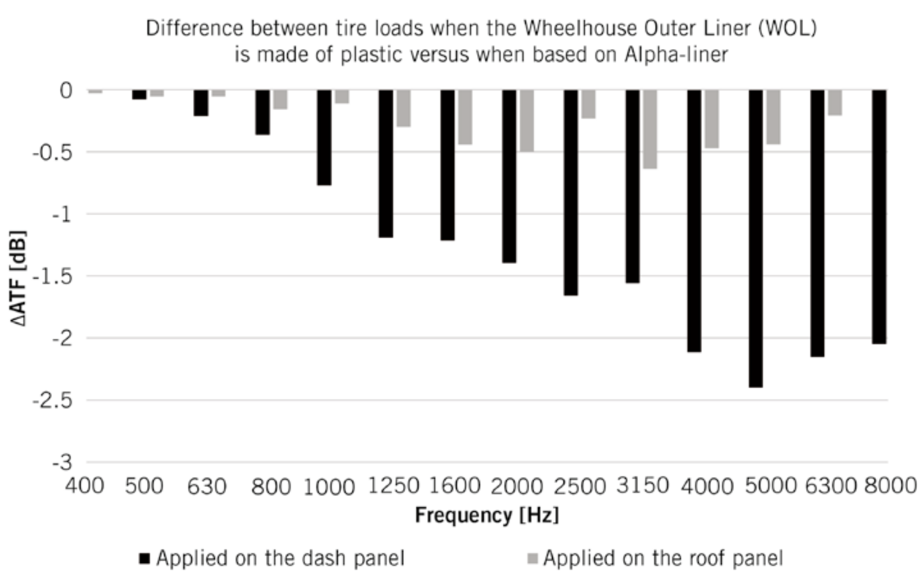
THE PRESETS: PREDEFINED ACOUSTIC SCENARIOS

In this step, the user is able to choose preset vehicle sound packages as starting point. For this purpose, four scenarios have been defined with different acoustic features and weight levels: Baseline, Lightweight, Maximum Insulation and Maximum Absorption. To simulate these scenarios, the SEA model is complemented with further information input. Selecting a preset loads a data set made up of pairs (Transmission Loss (TL); Absorption (ABS)) into the model. Each panel shows the insulative (that is TL) and absorptive performance. The SEA model is not completely empty at first. Several panels such as glazing, doors, pillars and instrument panel have already pairs of data and cannot be changed. Others are adjustable, as their acoustic performance is variable depending on the chosen scenario.

In addition, a distinction was made between exterior and interior part calculation. Components inside the passenger cabin such as the inner dash and carpet have different TL and absorption values with respect to the selected preset. Exterior parts in the engine bay (for example outer dash and hoodliner) or underbody parts (outer tunnel insulator, underbody shield) will affect the acoustic loads on the exterior panels. This aspect is explained in detail in the following section.

PART SELECTION AND TUNING

In this penultimate step of the configuration, users can customize various acoustic components according to individual requirements. For the interior and exterior parts of the passenger compartment, different technologies are available. Additionally, specific key values (empirical values ranging from 0 to 10) are defined for each product-technology combination and depicted in radar charts. An exterior part is taken into account in the SEA simulation by reducing the model's acoustic loads by linear regressions with respect to its absorption area as well as its location. As an example, **FIGURE 3** (left) shows how the ATF is reduced when the user changes the Wheelhouse Outer Liner (WOL) technology from standard plastic to the Autoneum technology Alpha-Liner. The acoustic loads from the tires are reduced up to 2.5 dB at 5 kHz on the dash panel and up to 0.6 dB at 3.1 kHz



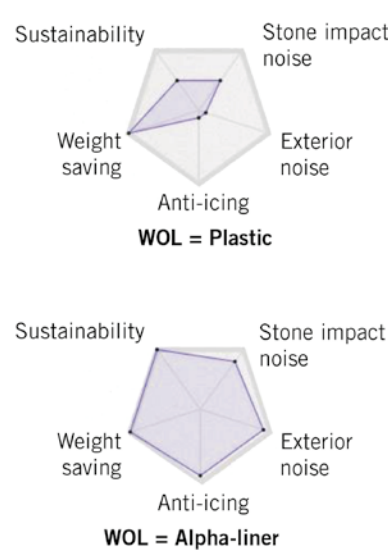


FIGURE 3 Exterior parts (here WOL) reduce the loads (here tires) on the exterior panels (here dash and roof) (left); at the same time, the radar chart of key values is updated (right) (© Autoneum)

Geometrical settings	Description	Number of variables
Carpet face	Linked to other characteristics than acoustics. This is not impacting transmission loss and the absorption.	2 (carpet)
Pass-through	Openings in the dash panels. A pass-through performance is defined by its surface times a transmission coefficient. Moving from "poor" to "best-in-class" changes this product.	3 (inner dash)
Coverage	Area covered by the treatment. The performance of the trim (dash or carpet) is associated with an exposed steel performance defined by the product between the uncovered area and the transmission coefficient of the bare steel. Moving from "low" to "high" changes the coverage from 92 to 100 % for the dash and from 95 to 100 % for the carpet.	3
Packaging space	Thickness distribution of the trim. Starting from a distribution of average thickness varying from 5 to 30 mm. Moving to "low" or to "high" changes respectively the distribution by removing or adding 5 mm to each thickness respectively.	3
Technological settings	**Description**	**Number of variables**
Insulative	Spring-Mass technologies. A foam (FLEX) or a felt (ECO) decoupler with a heavy layer on top. The density of the heavy layer varies from 2 to 6 kg/m^2 for the dash and from 2 to 4 kg/m^2 for the carpet.	3 × 2 × 2
Absorptive	Autoneum technology Prime-Light. Three layers' technology made of two felts with a film in between. The area weight of the felt can vary from 0.5 to 1.4 kg/m^2.	3
Hybrid	Autoneum technology Hybrid-Acoustics. A foam (Hybrid-Acoustics FLEX) or felt (ECO+) decoupler with a film and a felt dynamic stiffness layer (DSL) on top. The DSL is either compressed or lofty and therefore have insulative or absorptive properties.	3 × 2 (inner dash) or 2 × 2 (carpet)

TABLE 1 Inner dash and carpet system settings (© Autoneum)

on the roof panel. In **FIGURE 3** (right), the difference of key values between plastic and Alpha-Liner is demonstrated.

For inner dash and carpet, the user cannot only customize technology but also part features. As these components are taken into account in the SEA model by performance pairs (TL;ABS), all combinations are pre-calculated. For this purpose, simulations were executed with Autoneum's VisualSISAB software that is based on TMM [4]. However, some features such as Pass-throughs (PT) and coverage are not intrinsically linked to the part but rather to the car. Therefore, they are only considered for the acoustic performance at vehicle level in the SEA model. **TABLE 1** gives an overview of the geometrical and technological settings for the inner dash and carpet. In total, there are 567 and 342 possibilities for the inner dash and carpet individualization, respectively.

Once the customization is finalized, the SEA model is automatically updated with the relevant acoustic performance. As the configurator offers over one bil-

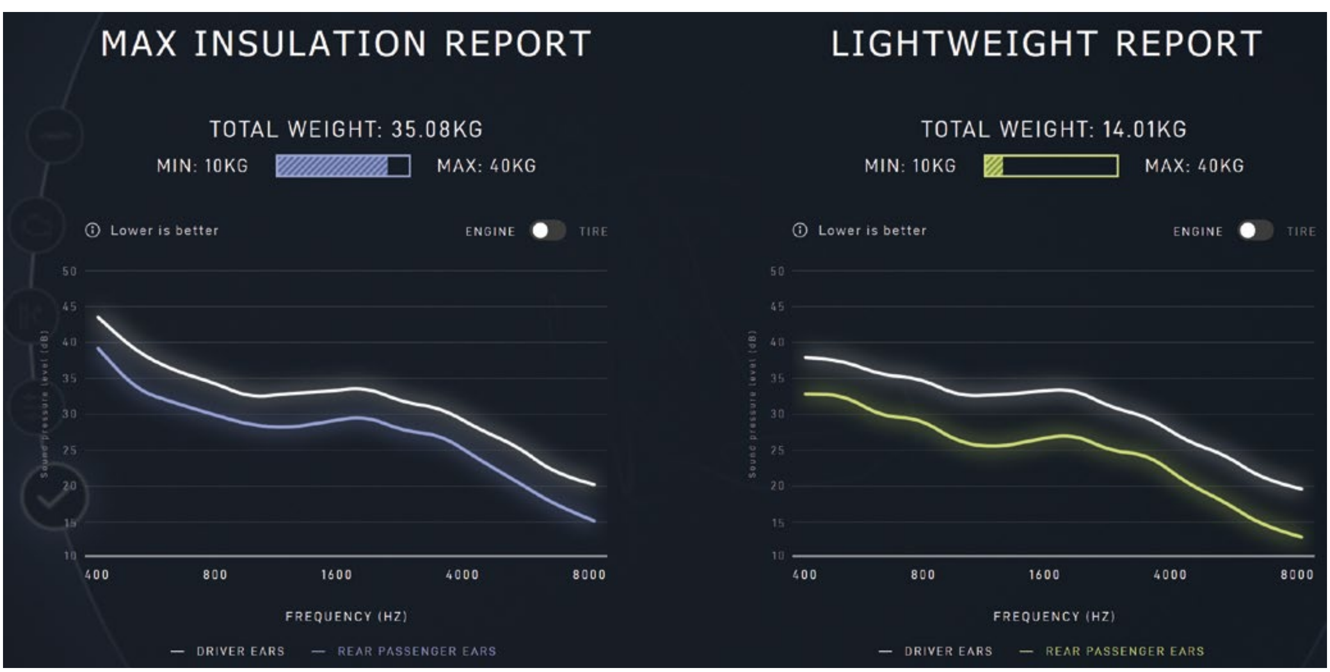


FIGURE 4 Comparison of two presets: "Max Insulation" and "Lightweight" (© Autoneum)

lion possible combinations, pre-calculation was not an option. Therefore, the SEA solving function from Autoneum's Revamp software [4] has been embedded in the website and is calculating all configurations in real time generating a detailed analysis that can be shared and exported. Anyone who uses Acoustic Garage more than once simply accesses configurations again and compares them directly with one another. In this case, a comparison is made between two presets "Lightweight" and "Maximum Insulation," showing visible differences in terms of Sound Pressure Level (SPL), **FIGURE 4**.

Of course, there are limitations to the model. As all NVH parts contribute to the SPL, including the ones that have not been modified in the customization step, largely varying sound performance outcomes at vehicle level cannot be expected for all car configurations.

CONCLUSION

As highlighted in this article, the web-based tool Acoustic Garage is embedding fully developed airborne modelling techniques and processes, which have been exploited in order to provide a realistic vehicle behavior, while requiring very simple steps for the user to perform an NVH simulation and typical variations of the sound package. Thus, Acoustic Garage is an ideal entry point for new NVH engineers or for engineers of other branches linked to automotive in order to learn about different technologies and their material characteristics, to understand the fundamentals of automotive acoustics and to balance the trade-offs many acousticians face today between NVH performance and design constraints.

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