Increased Functionality in Lightweight Fibre-Based NVH Packages

Stricter fuel economy legislation and increased part design and material requirements are driving the evolution of current and future interior NVH solutions. To this end Autoneum has been developing a new generation of products based on fiber-based technology. It offers a unique balance of light weight, design flexibility and acoustic performance, providing a 30 % weight saving against reference lightweight dissipative solutions.

INTRODUCTION

Although automotive fuel economy can, in principle, be achieved by many means – aerodynamically using underbody shields and heat retention in the engine bay with engine encapsulation solutions – for interior trim and, in particular, NVH treatments, there is only one way to contribute: reduce weight.

Over the last decades, lightweight dissipative constructions for floor trim and dash insulators, which rely on fibre-based insulators with enhanced acoustic absorption performance and moderate sound transmission loss performance, have been gradually replacing conventional barrier-based systems, thus allowing OEMs to save vehicle mass, improve fuel economy and meet interior noise expectations.

More recently, several other trends have required further evolution of the characteristics of such lightweight packages. Firstly, the addition of a wide range of safety and entertainment equipment has led vehicles, generation by generation, to become larger, leading in turn to a growing demand for both weight and cost saving within the NVH package. Secondly, the geometric complexity of interior NVH parts has strongly increased compared to the past. The capability of filling very high thicknesses while also being able to remain very thin locally, and consequent part shape definition, challenged the basic airlay fibre-based production technologies of these lightweight dissipative systems and resulted in an increased interest in products based on injection technologies (foams/felts).

This article provides an overview of the activities aimed at expanding the

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capabilities of dissipative systems, which have resulted in the definition of a novel configuration that fulfils these requirements and that furthermore allows extended design capabilities to match a very broad spectrum of acoustic absorption/acoustic insulation balance in the same packaging space.

A rebalance of the acoustic material properties, together with the definition of an innovative solution of cotton and synthetic fibre blends, have allowed the realisation of a high-performing lightweight dissipative system that is approximately 30 % lighter compared to the previous dissipative lightweight technology, while proving to be acoustically equivalent and thus enabling fuel economy benefits according to upcoming emission regulations.

LIGHTWEIGHT NOISE CONTROL SYSTEMS

In general, vehicle interior acoustic technologies are categorised depending on their approach to mitigate noise. The two main approaches are conventional barrier-based solutions and lightweight dissipative technologies. In addition, hybrid variants (e.g. absorber-barrier-absorber) have evolved as a result of combining both of these noise abatement approaches into one solution.

The conventional barrier-based approach, which functions according to double-wall Sound Transmission Loss (STL) theory, relies on achieving a high level of STL as the means of stopping unwanted noise from entering into the interior of the vehicle. Gains in acoustic performance are achieved mainly by increasing the mass of the walls, or by modifying the composition and thickness of the decoupler. As a result, conventional acoustic systems are quite effective in controlling interior noise at the expense of system mass.

Alternatively, lightweight dissipative treatments are usually composed of two layers of blended cotton and synthetic fibres, engineered to balance material properties (fibre density, porosity, tortuosity, etc.), to achieve high levels of sound absorption and moderate performance in STL. The dissipative methodology generally preferred in the automotive market is a two layer ("dual density") composite construction. The material and physical make-up of the product, manufactured by Autoneum, is referred to globally as Ultra-Light ECO+ (Ultra-Light) [1], and is produced in around 19 million components throughout the world each year for over 100 vehicle models of more than 20 car brands. In many applications, the use of this Ultra-Light technology provides acoustic performance equivalent to conventional systems while reducing mass by more than 25 %, depending on the vehicle performance level. Furthermore, other assets of this technology are the high percentage, over 50 %, of recycled material content embedded into the product and also low Volatile Organic Components (VOC) emission levels.

SOUND PACKAGES FOR THE PASSENGER COMPARTMENT

More recently, the advantages and capabilities of lightweight dissipative constructions, compared to other technologies, have been progressively reducing. On the one hand, injection-based technologies of both foams and fibres allow placement of material only where needed to fill the packaging space and respect NVH requirements, thus supporting weight reduction even if still not totally solving the impact on part cost due to process complexity, and with some technical limitations: for foam injection, the minimum filling thickness below which no foam areas are present and, in the case of felt injection, strong thickness varia-

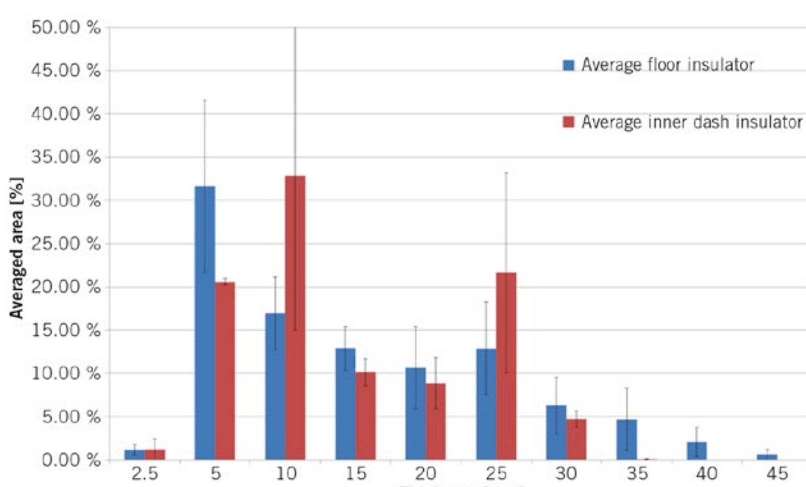

FIGURE 1 Average thickness map distribution for an inner dash and floor sample population of serial solutions on the market (© Autoneum)

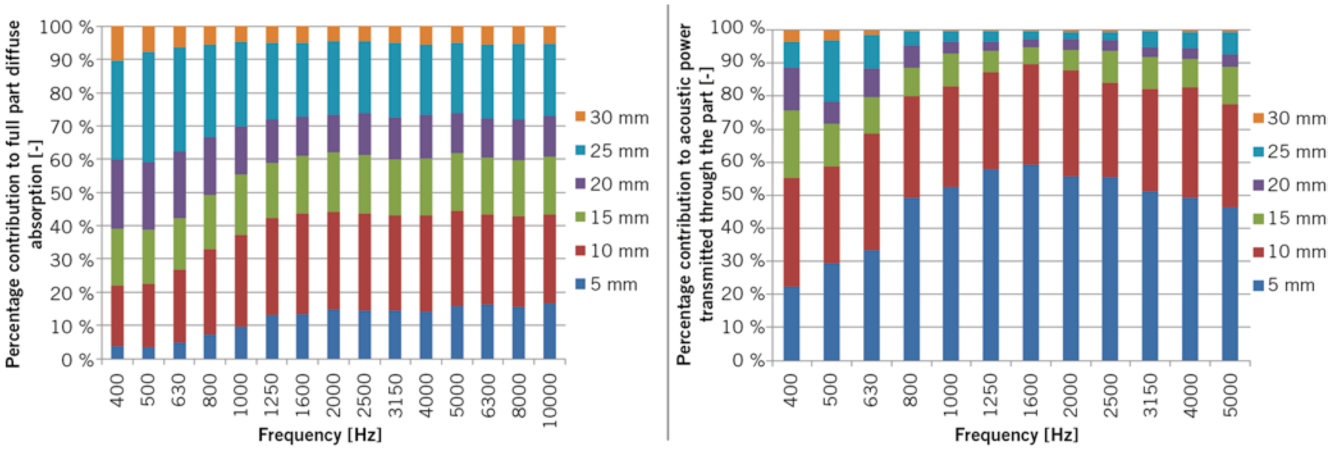

FIGURE 2 Absorption and sound transmission contribution map of a given Ultra-Light treatment applied on sample dash packaging space (© Autoneum)

tions and their tolerance with respect to part geometry still remain. On the other hand, increasing clashes with all accessories present in the passenger compartment for safety, comfort and entertainment constantly leads to an increase in the geometric complexity of NVH parts.

FIGURE 1 provides an overview of packaging space requirements in terms of thickness map distribution for a sample population of inner dashes and floor insulators currently in production. Very low thicknesses (< 5 mm) as well as high thicknesses (> 40 mm), which are used to recover as much NVH performance as possible, are present in significant areas of different acoustic parts in the interior of a car.

On the other hand, if we observe purely the performance breakdown of NVH systems as a function of their packaging space, we can more correctly evaluate the impact of these extreme thickness classes composing a 3D component. In **FIGURE 2**, such an evaluation has been carried out for each thickness class composing the sample population of inner dashes reported previously, taking into consideration the flat sample performance of an Ultra-Light Technology, with a reference area mass of 1850 gsm, for the overall construction. It can be seen that the acoustic absorption performance is driven by areas with 10 and 25 mm along the full frequency range, while the analysis of sound transmission through the part shows that between 80 and 90 % of the sound power filters through the 5 and 10 mm thicknesses. Thus, merely from the acoustic STL perspective, the areas in the part with thicknesses > 30 mm are not helpful, and also from an absorption standpoint, they do not make a significant contribution.

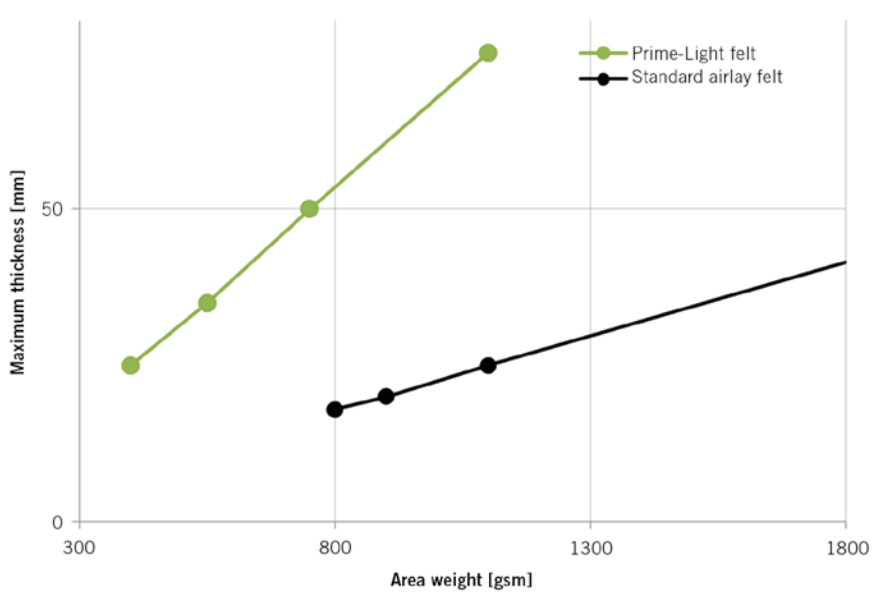

FIGURE 3 Filling rate airlay standard fibres, vs. new blend (© Autoneum)

An additional concern coming from the high thickness area in the current NVH interior package involves the area mass of the fibre-based layers needed to fill in a given packaging space. **FIGURE 3** depicts the maximum thickness that a standard airlay felt layer can fill as a function of its area mass. For each additional 5 mm packaging space, the engineer has to take account of an additional approximately 200 gsm area mass to be added to the layer.

Such a value has to be further increased according to the strict requirements of part shape definition. Ultra-Light technologies, in order to reduce cost and cycle time, are created by moulding flat fibre blanks, using airlay technology, into three-dimensional parts. Standard airlay felts have a lot of advantages (sustainability, acoustic absorption, robustness) but lack bulkiness. In order to fill in a complex 3D shape, a certain degree of fibre overfilling is needed to allow a good part definition towards the B-surface (onto the metal body). Such a requirement is becoming increasingly stringent for different reasons: for inner dash parts to allow good sealing conditions towards the grommets and pass-through, while in the case of floor insulators, it reflects not only NVH require-

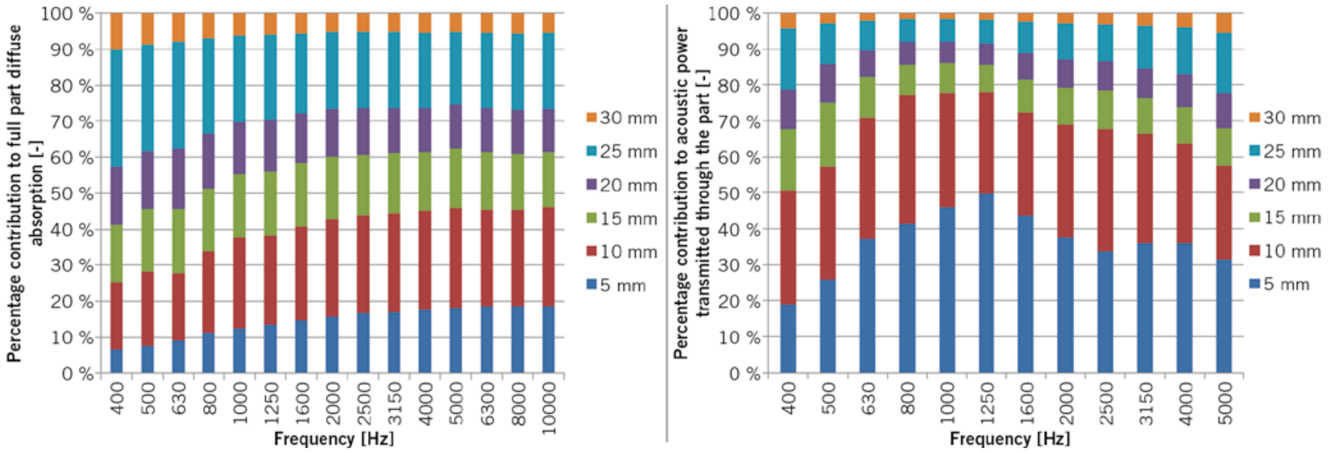

FIGURE 4 TL and absorption contribution map of Prime-Light blend (© Autoneum)

ments (e.g. vibration damping) but also perceived quality by the customer due to carpet floor stability.

TECHNOLOGY OUTLOOK FOR NOVEL FIBRE-BASED NVH PACKAGES

With the above new requirements and challenges in mind, Autoneum has developed a new family of lightweight dissipative solutions which represent the next step of Ultra-Light technology: Prime-Light.

The development of this new product family has achieved the following targets:

- Retaining part (inner dash/floor insulator) 3D performance (as per Ultra-Light technology)
- Reducing part weight by at least 25 %
- Improving fibre blend bulkiness to improve part 3D definition.

The development of the Prime-Light family has been conceived by analysing the acoustic performance of the original Ultra-Light part construction and consequently aiming at re-balancing the contribution to the acoustic performance of the different thicknesses and, in particular, at improving low thicknesses for both acoustic absorption and insulation.

The outcome of such a development is depicted in **FIGURE 4**, where a Prime-Light inner dash, with a reference area mass of 1300 gsm, is seen to be fully equivalent at part level to a 1850 gsm Ultra-Light solution in acoustic absorption and insulation performance, according to the same hypothesis considered in **FIGURE 2**. Indeed, a noticeable improvement in the acoustic performance for low thickness is evident, especially with regard to the sound transmission performance, where there is now an approximate 10 % reduction in power transmission.

This rework process has been managed by balancing material properties such as porosity, tortuosity, stiffness and density of a cotton and synthetic fibre blend in combinations of two layers. The thermoforming process of converting this fibre blend into three-dimensional insulators for floor trim and inner dash treatments has also contributed towards achieving an acoustic performance improvement at low thicknesses.

FIGURE 5 shows the behaviour of Prime-Light (in green) versus the Ultra-Light solution (in black) for each final part thickness in terms of air-flow resistance (AFR), against the reference AFR of an 1850 gsm Ultra-Light solution. Also here, it can be observed that, thanks to the new fibre blend and moulding process, AFR in the Prime-Light solution behaves linearly even at low thicknesses, thus supporting the maintenance of good acoustic properties.

In particular, when considering the fibre mix and blend, the Prime-Light solution has achieved a big improvement in bulkiness against standard airlay felt blends. In **FIGURE 3**, it can be seen that, owing to the improved bulkiness, the same packaging space can now be filled

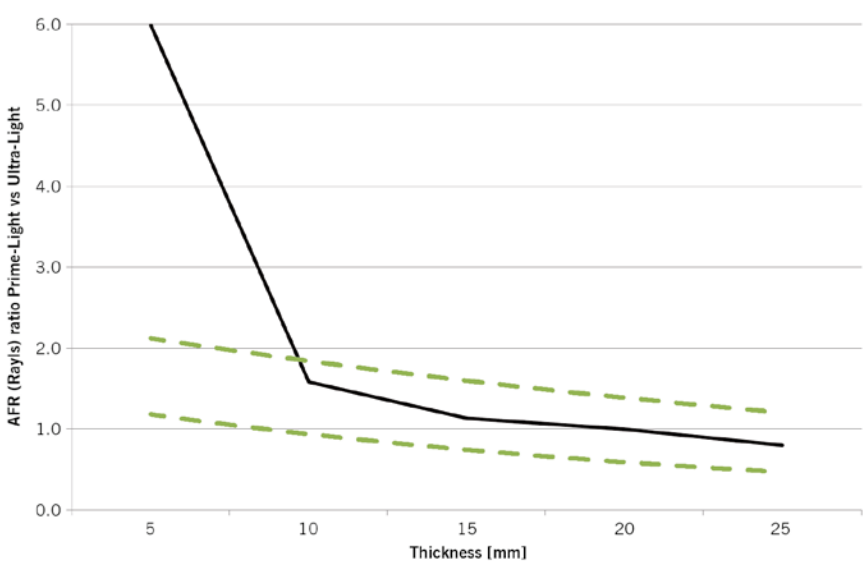

FIGURE 5 Ratio of air flow resistance vs. packaging space, Prime-Light solutions family (green line), Ultra-Light 1850 gsm solution (black line) (© Autoneum)

FIGURE 6 Example of packaging space filling capability onto same NVH part: original Ultra-Light (top) configuration which needs an added die-cut patch on top to fill packaging space vs. Prime-Light blend (bottom) version which does not require an added pad, delivering better shape definition and filling (© Autoneum)

with a two to three times lighter fibre mat. A first consequence of this is a minimised densification effect on a 3D part in low thickness areas, which allows AFR to still behave linearly.

The second impacted property is the improved part definition (good fit with body-in-white and surrounding parts) and therefore sealing, which can be achieved even at a mid-high thickness area, without having to overlay die-cut patches in these areas, as often happens in production, **FIGURE 6**. As final remark regarding floor application, where part density is generally tailored in order to achieve given static stiffness properties: also in this case, Prime-Light blends tend to have higher compression hardness and recovery than standard airlay material at the same area weight, thus supporting the achievement of lower part weight also in this specific application.

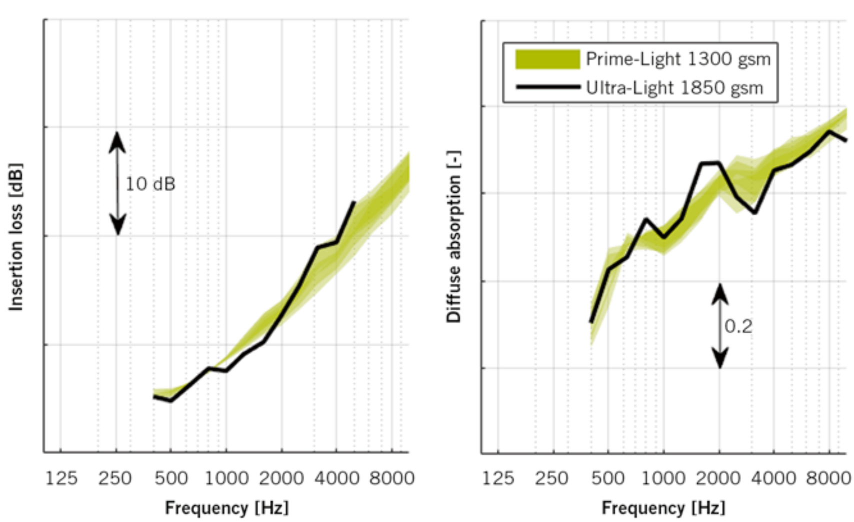

FIGURE 7 Example of a Prime-Light acoustic customisation possibility for a typical inner dash vs. reference Ultra-Light performance construction (© Autoneum)

NVH BENEFITS AND DESIGN FLEXIBILITY

Generally recognised key design variables for lightweight dissipative systems, in the hands of NVH engineers, are relative to component thickness distribution and coverage, initial layer densities and relative fibre blend choice, and the thermoforming process to produce final parts, regulating the densities of each layer of the stack. Another acoustic benefit enabled by this new fibre blend concerns the extended design capabilities in order to match a very broad spectrum of acoustic absorption/acoustic insulation balance in the same packaging space. For example, considering the sample thickness distribution of inner dashes in **FIGURE 2**, while with previous Ultra-Light solution, with a reference area mass of 1850 gsm, only one specific grammage of the top and bottom layer was possible. By employing the Prime-Light solution, the same packaging space can be filled with a 1300 gsm part composed of one of the four combinations derived by the application in both the layers of 400/550/750/900 gsm blanks. In addition, the tuning method, derived from the Ultra-Light production concept and managed by the thermoforming process to produce final parts, is used to achieve the appropriate balance of absorption and insulation.

In **FIGURE 7**, the resulting Prime-Light performance range, obtained by playing with the area weight distribution between the top layer and decoupler, gives an outline of the tuning possibilities of the absorptive and insulative performance at part level.

Indeed, to exploit such increased design capabilities, thanks to well-established internally developed simulation tools, Autoneum can model and analyse the ideal density and thickness of these components during the design phase of new vehicle models. The simulation of the acoustic trim is carried out by means of VisualSISAB, which exploits the Transfer Matrix Method [2] and allows fast identification of component design and bill of material for the achievement of given component targets. Such targets are identified with novel procedures, based on Statistical Energy Analysis, for Vehicle Target Cascading, which allows the identification of the optimal balance between acoustic absorption and insulation for components such as inner dashes or carpet insulators while considering multiple targets derived from different sound transmission paths (engine, tyres, exhaust silencer) [3].

A validated example of this approach is the joint project with an OEM [3] aimed at introducing this novel lightweight acoustic technology (Prime-Light) into premium and luxury vehicles that traditionally use heavy layer constructions. The demonstration of the dissipative system in the Luxury Class Sedan concluded that the interior acoustic parts (i.e. dash and floor trim insulator), tuned to their maximum acoustic performance, contributed a mass reduction of over 30 % (approximately 10 kg), thus delivering fuel economy benefits while maintaining the vehicle interior noise performance expected by customers.

SUMMARY AND OUTLOOK

The combination of stricter fuel economy legislation and increased challenges for lightweight dissipative systems have, in the recent past, demanded the application of novel technologies to enable strong weight reduction contributions for inner dashes and floor insulators while still preserving NVH performance in vehicles.

Prime-Light constitutes an advancement of its Ultra-Light technologies. It offers a unique balance of light weight, design flexibility and acoustic performance, providing a 30 % weight saving against reference lightweight dissipative solutions.

These novel features have recently been acknowledged by GM at the latest Supplier Innovation Award ceremony [5] and have brought this product rapidly into series production for models of US OEMs in North America and China as of 2016.

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