Multiphysics

Unleashing the new era of NVH simulation: A partnership between Hexagon and Autoneum

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The beginning of a partnership

Noise and vibration have become an essential consideration for vehicles, and Original Equipment Manufacturers (OEMs) strive to produce vehicles that create as little noise as possible inside and outside the car. At the same time, the world is moving away from vehicles powered by traditional Internal Combustion Engines (ICE) to electric vehicles. The noise characteristics of these categories differ massively. The main characteristic of ICE-powered vehicles is the dominance of the noise produced by the engine, especially in the low-frequency part of the spectrum, around 500 Hz. The noise of the internal combustion engine was capable of masking most other noise sources, such as road noise and tire noise, both in the interior and the exterior of the vehicle. Electric vehicles are powered by largely silent motors, especially at low frequencies. Hence other noise sources such as the ones mentioned above, as well as wind noise and noise from the air-conditioning system, become more prominent.

Typically, the noise from different components, such as the powertrain, has two transmission paths. Noise can be transmitted through the air (airborne noise) as well as through the vibration of structures (structure-borne noise). Different approaches are used to minimise the noise from the various transfer paths and increase passenger comfort. These include engineering the vehicle body to vibrate less, using damping pads to reduce vibration and applying high-performance acoustic treatments to lower both noise and vibration. However, since the weight of the vehicle is an important factor for fuel consumption, OEMs are focusing on reducing component mass without sacrificing noise and vibration performance.

Electric vehicle architecture also differs considerably from ICE-powered vehicles. Besides the various possible motor distributions (one motor in the front axle, one in each axle, wheel-mounted motors, etc.), there is now a large and heavy battery pack that needs to be included. Electric vehicles are not designed from scratch, but the body design and performance tend to be significantly different from ICE-powered cars. To meet all targets, simulation is heavily employed by OEMs. Among other topics, performing high-accuracy Noise, Vibration and Harshness (NVH) analyses during the early design phase is crucial to achieving the increasingly demanding targets, reducing prototypes and costs, and accelerating the design phase.

Figure 1: Models for evaluating vehicle NVH performance.

In an effort to help shorten the development process for vehicle manufacturers and to mitigate vehicle noise and vibration as early and effectively as possible, Autoneum and Hexagon are relying on their combined strengths through a partnership that will allow vehicle manufacturers to benefit from Autoneum's decades of experience in designing tailored sound packages and Hexagon's world-class simulation capabilities. The partnership aims at integrating Autoneum's validated methodologies for optimising damping and sound absorbing materials within Actran, the industry-leading simulation software for acoustics and vibroacoustics. Manufacturers, therefore, not only gain easier access to more accurate and production-based data: the precise prediction of vehicle performance early in the development process also allows them to significantly reduce design and lead times in addition to the cost and weight of noise-reducing materials.

Engineering tools for damping pad optimisation

When designing an optimal damping package to minimise the structure-borne noise, which dominates the low-frequency spectrum, several factors must be considered. The most important one is weight, which will dictate which solutions are more effective for a given frequency range. For the low-mid frequency range, between 100 Hz and 500 Hz, the primary influence comes from local damping and stiffening, and as we move above 500 Hz, the NVH trim impedance is more prominent. The trim impedance has an important effect on the vehicle body panel vibration and the corresponding radiated noise due to its transmissibility and it depends heavily on the trim packaging space and trim weight.

The first step when designing a vehicle for low vibration is the appropriate design of the body-in-white. Under various loads, either at the powertrain mounting points or the suspension interface, the goal is to reduce overall vibration from the main radiating modes and interior body panels. Once this process is done, a refinement process takes place, including positioning the damping package by applying materials with stiffness and damping properties that strongly depend on frequency and temperature. The objective is to identify the best possible location and amount of stiffness and damping to minimise the vibration of the interior body panels.

When it comes to the sound package design of electric vehicles, many factors affect the decisions taken to tackle NVH issues. The rear of the vehicle requires particular attention due to the market trending towards crossover SUV designs, which feature a connected trunk cavity with the main passenger compartments. Due to this connection, the rolling noise, especially from the rear tyres, will be enhanced. Further to that, for the majority of current and future electric vehicles, the electric motor is on the rear axle, which further increases the importance of the rear of the car for NVH purposes. Finally, since new electric vehicles are embracing more lightweight structures and panels to combat rising prices and reduce the carbon footprint of vehicle production, new countermeasures will likely be required to tackle structure-borne noise problems.

Autoneum's engineering process for NVH starts by setting and cascading targets focusing on airborne noise for the complete NVH package in terms of transmission loss and absorption in the full frequency spectrum. Then, dedicated parts are designed to fulfil these requirements and to identify the lightest bill of materials that satisfies them. Finally, the selected package, which meets the requirements for airborne noise, is applied to the structure-borne noise simulation model, and further optimisation is carried out to enhance the performance in the lower frequencies.

Autoneum has developed various technologies for the different parts of the process, and the democratisation of these technologies is the objective of the partnership between Autoneum and Hexagon. The first part of the process to be tackled is the module that handles the damping package design, including positioning and optimisation known as Autoneum SILVER. This tool is used to identify the size, shape and ideal location of damping pads based on a finite element simulation with MSC Nastran. With the help of a tailored Direct Matrix Abstraction Program (DMAP), MSC Nastran exports the contribution to major vibration

peaks considering multiple loading conditions. With dedicated post-processing, engineers are guided in positioning the damping pads to the highlighted areas. MSC Nastran can then be relaunched to evaluate the performance improvement provided by the newly placed damping pads, and engineers can compare the new and old damping packages, considering weight reduction and NVH performance. Using this process, an OEM obtained a 37% damping package weight reduction with even better NVH performance.

While this process is largely automated, disparate software packages are involved in the process. Hexagon and Autoneum are partnering to provide everything within one unified interface, streamlining the process and eliminating the need to jump from one tool to another.

Industrialising the process

Autoneum SILVER is a process or workflow, most of it automated with a few manual parts. The Actran Workflow Manager is a perfect fit for packaging it into a single application. The Actran Workflow Manager is the newest part of Actran, and it provides access to unified interfaces customised for vertical applications. More specifically, it provides a framework that can integrate various user interface elements such as user input prompts, graphs, and 3D viewports with meshing capabilities, which are necessary for pre and post-processing within certain workflows.

While the Actran Workflow Manager first appeared as part of Actran 2021 with the pass-by noise workflow, it has since grown as an ecosystem with several workflows such as:

electric motor noise, vibration for space components and the newest workflow on transmission loss-based statistical energy analysis (TL-based SEA) for fast, high-frequency airborne noise prediction. The new damping pad positioning workflow, developed in partnership with Autoneum, was released as part of Actran 2022.1.

The workflow is split into different tabs or screens where engineers can set parameters for the damping pad package. The engineer starts by loading their Nastran model files as part of the first step. The purpose of this step is to have the modes and elementary matrices of the model available, so it is possible to either run the model directly from the workflow manager to retrieve them or import them if available. Thereafter, the parameters of the model need to be applied; engineers need to provide the materials for the damping package as well as the corresponding body panel. The next step of the workflow is the definition of the damping configurations, where engineers can interactively choose the size and position of the damping pads based on a calculation of the bare model. In this section, engineers can also get information on the mass of the original panel as well as how much mass is added by the damping package. Once selected, the Workflow Manager calculates the performance of the damping package quickly and efficiently within the user interface. The pads are calculated as numerical elements based on the available information from the original MSC Nastran model. This reduces the complexity of the model and allows for the solution time to be reduced significantly. After the performance of the damping package is computed, engineers can visualise the results in the form of plots,

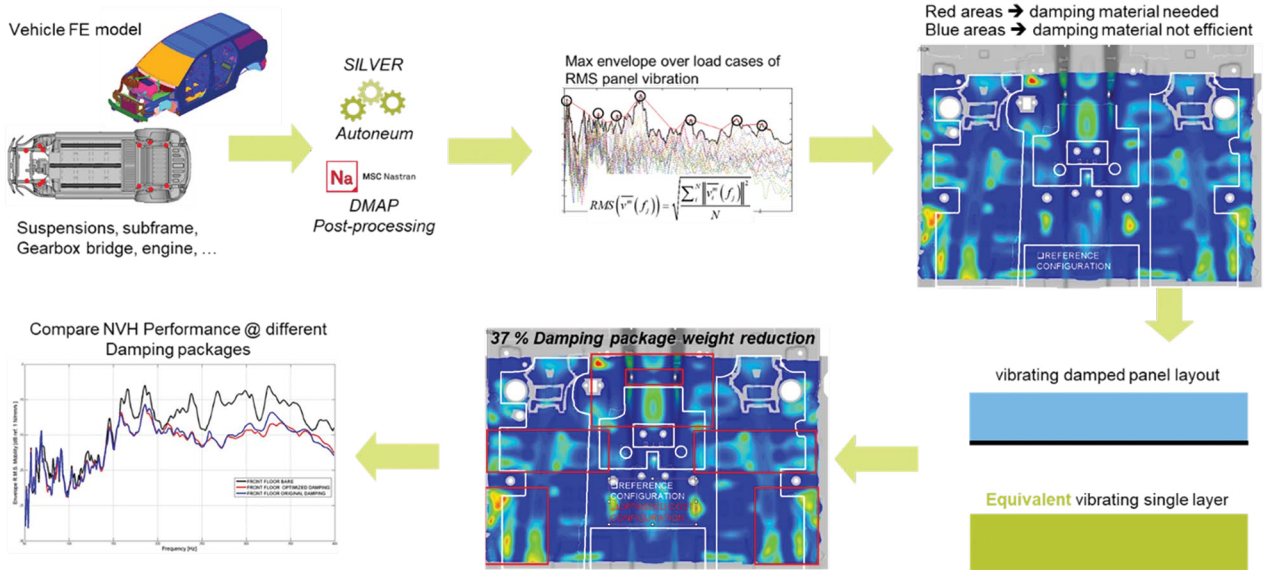

Figure 2. Autoneum SILVER process.

Figure 3: Damping pad positioning workflow within the Actran Workflow Manager.

where the envelope and peaks of the mobility are shown, and maps, where the mobility is shown as a colourmap on the part of interest. The mobility contribution maps are the most crucial element of the workflow since they show where damping is required. Engineers can create multiple possible damping configurations and compare them quickly at the end to find the best solution.

With this workflow, Hexagon and Autoneum are democratising a unique solution that could help automakers reduce costs, minimise development and iteration time and design vehicles that produce minimal structure-borne noise and vibration.

What comes next

Integrating Autoneum SILVER into the Actran Workflow Manager only marks the first successful milestone of the partnership between Hexagon and Autoneum. The excellent collaboration and working relationship between the team has built a high level of trust, pushing us further to create and integrate new products and processes that could provide value to our customers.

In the near future, the currently available process which involved positioning of noise-reducing materials will be enriched to include optimisation, via automated positioning for maximal impact with minimum cost and weight additions. Further down the line, new optimisation strategies including materials and structures could be integrated to provide a complete solution for low-frequency structure borne noise.

Finally, this partnership does not only focus on democratising already existing products and processes. As collaboration is enhanced and trust is further built, new opportunities are explored that could give birth to revolutionary products with the help of emerging technologies such as cloud computing and artificial intelligence. Hexagon and Autoneum have made the first step in realising this potential and look forward to building the next generation of NVH simulation solutions that will provide the highest cost saving for optimal NVH designs.