SIEMENS

Automotive and transportation

WorldAutoSteel

LMS Engineering services helps advanced steel technology project reduce body structure weight by 35 percent and achieve NVH targets

Product

LMS

Business challenges

Provide NVH expertise

Strike balance between achieving lower mass and acceptable NVH performance

Keys to success

Use LMS Engineering capabilities to balance multiple performance attributes in parallel

Use LMS Virtual.Lab early in concept design

Focus on localized body design improvements to exceed targets

Determine whether glued damping treatments reduce motor noise

Results

Enhanced NVH performance

Helped achieve a 35 percent reduction in body structure weight

Enabled engineers to identify and analyze specific NVH problem areas

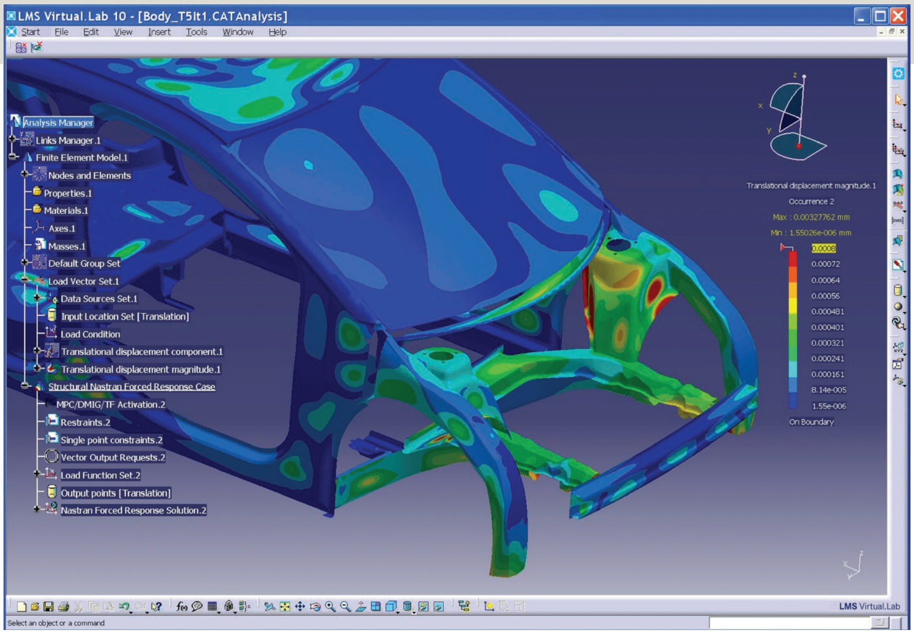
Siemens PLM Software solution enables WorldAutoSteel to identify and analyze NVH problem areas for FutureSteelVehicle project

Pursuing seemingly contradictory objectives

Commissioned by WorldAutoSteel, a consortium set up to promote the use of steel in the automotive industry, the FutureSteelVehicle (FSV) project set out to highlight the potential of advanced steel technology in vehicle body designs by developing a concept vehicle platform to suit a range of alternative powertrain configurations.

The challenge set by WorldAutoSteel was to design a concept vehicle that had low mass – the target body-in-white (BIW) mass for the battery electric vehicle variant was <190 kilograms (kg) – while maintaining functional performance levels expected from a car today.

At the request of WorldAutoSteel, Siemens PLM Software provided the noise, vibration and harshness (NVH) engineering expertise for the concept design phase of the project. It was decided that the FSV project should take a holistic multi-attribute approach to the vehicle and body concept design, including front loading NVH engineering to prove that a lightweight vehicle concept could achieve the multi-functional performance (including crash, comfort, noise, etc.) expected of a modern automobile while reducing body mass.



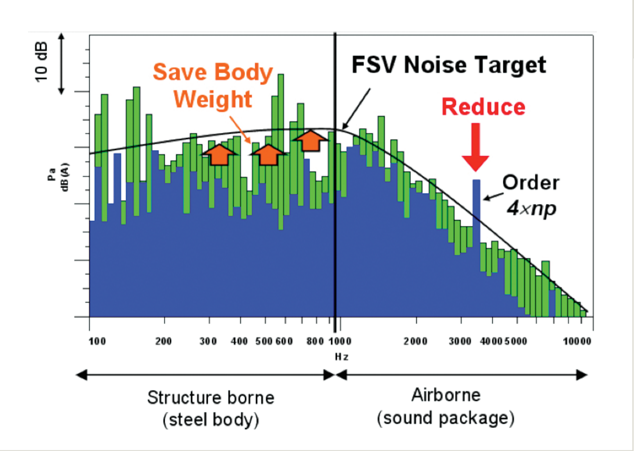
The high-frequency pure tone noise generated by the electric motor is a problem that will be faced by the NVH departments of automotive manufacturers now and in the future. The high-frequency pure tone noise can easily be controlled with absorption materials, but the downside is generally an increase in mass.

People in the automotive industry agree that NVH will remain a critical customer issue for electric vehicles. Electric motors are not completely quiet. Depending on the design of the motor, the electromagnetic (EM) pulses and corresponding torque pulses from the motor can be very strong. These can be radiated as noise directly from the motor housing and can also be transmitted to the support structure through the motor mounts.

Simultaneously achieving low body mass and good NVH performance is perceived to be a contradictory objective. For crash, the reconciliation comes from the extensive use of high-strength steels (HSS) and advanced high-strength steels (AHSS), which provides good crashworthy properties to the FutureSteelVehicle while allowing for thinner gauge materials. Using thinner gauge materials usually detracts from NVH behavior. Therefore, the challenge was to propose a clever body design that struck a balance between low mass and acceptable NVH performance.

LMS™ Engineering services carried out the NVH simulation studies on the FSV project in close collaboration with the consortium performing the crash and rigidity studies. The NVH was front-loaded due to the holistic approach adopted by WorldAutoSteel, enabling significant improvements to be made to the initial design from an NVH perspective while not hindering progress toward the low body-mass targets. Overall, the final body concept was 35 percent lighter than the benchmark platform the FSV was evaluated against, demonstrating that steel technology is an excellent choice for meeting stringent body mass reduction targets, and that front loading NVH provides an early-stage benefit to platform concept design.

The use of LMS Engineering services helped reduce the body structure weight by 35 percent.



A comparison of EV- and ICE-powered class A/B car concept to enable target setting.

Benchmarking highlights differences

While electric vehicles (EV) are quieter than those with an internal combustion engine (ICE), during operation they produce noise at frequencies that are well above the norm for automotive applications. There is an expectation that high-frequency pure tone noise emitted by electrical components will be a nuisance to NVH engineers as the peaks will be significantly above the background sound level in the high-frequency range. These high-frequency tones will adversely affect the comfort and experience of the passengers. It was important to ensure that the FSV body concept design was tailored to sufficiently eliminate these effects by optimizing the sound package.

However, before refining the design, targets had to be set for acoustic performance. To this end, a benchmarking exercise was carried out. A small vehicle platform (referred to as the target class A/B Small EV or ICE), which uses the same body for both ICE and EV powertrains, was loaned from a prominent original equipment manufacturer (OEM). This vehicle is in the same class as the proposed FSV. Benchmarking was carried out to highlight the differences between the acoustic signatures of the ICE and EV variants and to provide targets for the FSV concept design.

Physical measurement and analysis revealed that the noise emitted by the electric motor-powered vehicle was significantly less than the ICE-powered equivalent. It also highlighted that there was a distinct, prominent pure tone peak on the EV in the high-frequency range. This related to the number of poles (NP) within the electric motor, which provided an unpleasant listening experience at order 4x NP. Reducing the prominence of this peak was identified as a hurdle to overcome in the FSV body design as it would result in a better overall NVH performance than the benchmarked target Class A/B small EV.

The results indicated though that significant weight savings might be achieved with clever design due to the quieter drive train in an EV by relaxing the NVH upper target limits in the frequency range of <1 kilohertz (kHz). For example, body noise transfer function (BNTF) between the motor mounts and the passenger cabin could have an upper limit raised without impairing NVH targets.

Avoiding compromising on NVH

Low-frequency targets for BNTF were set at 60 decibels (dB), a relaxed value to take into account the relative quietness of the EV. The results showed that while the FSV was within a few dB of this target, it was still 10 dB quieter than the target class A/B ICE vehicle.

It was initially assumed that the panel vibration was the most effective focus point for NVH improvements in the mid-frequency range. However, the project demonstrated that work on the transmission path of vibrations (intervening closer to the source with the body parts between the motor mounts and the radiating panels) was more effective than panel design. For example,

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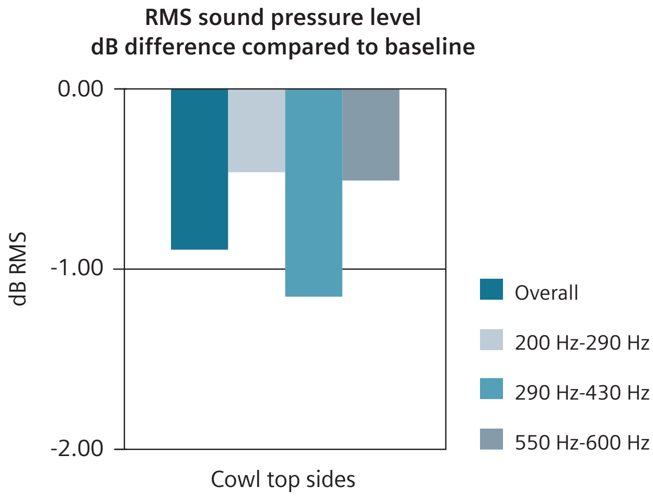
At the beginning of concept design phase, the BIW mass of the EV was over the 190-kg target. However, by the final iteration it had been reduced to 14.6 kg below the target.

attempts at preventing the transmission of vibrations by the front longitudinal member or the cowl top proved to be effective; a 1.4-kg weight saving in panel gauge reduction was gained for a 150-gram (g) increase in the cowl top reinforcement by doubling the gauge to reinforce the connection to the A pillar, proving that focusing on the transfer path is more effective than treating the radiating panels.

Also in the mid frequency, the use of vibration damping steel (VDS) in specific areas was shown to be an effective solution, providing additional mass savings without NVH compromises when compared to traditional damping alternatives. VDS is an interesting prospect for providing a lighter solution than glued treatments: it comprises two steel sheets sandwiching an intermediate layer of polymer on the order of 40 microns thick (dimensions of each layer can be varied to suit the particular application); hence, it is of negligible mass and with a sufficient loss factor. Application of this material varies with body design. In the case of the FSV, the use of VDS in the dashboard panel proved to be the most effective, reducing transmitted noise without adding weight.

The high-frequency pure tone noise generated by the electric motor is a problem that will be faced by the NVH departments of automotive manufacturers now and in the future. The high-frequency pure tone noise can easily be controlled with absorption materials, but the downside is generally an increase in mass. Siemens PLM Software engineers used the tone-to-noise ratio



Reinforcing the cowl top connection to the A-pillar highlighted above combined with gage reductions on the surrounding panels resulted in an overall sound pressure level reduction together with a 1.4-kg weight saving (right).

Solutions/Services

LMS Engineering
www.siemens.com/plm/lms-engineering

LMS Virtual.Lab
www.siemens.com/plm/lms-virtual-lab

Customer's primary business

WorldAutoSteel, the automotive group of the World Steel Association, comprises 17 major global steel producers from around the world. Their mission is to advance and communicate steel's unique ability to meet the automotive industry's needs and challenges in a sustainable and environmentally responsible way.
www.worldautosteel.org

Customer location

Middletown, Ohio
United States

(TTNR) and prominence ratio (PR) to analyze and quantify the problem on the FSV. These figures for sound quality assessment are becoming more widely considered for EV applications as they allow engineers to focus on the detail of the sound quality. It was expected that a 3-dB reduction in the prominent frequencies could be obtained by adding about 1 kg in weight, which is small in comparison to savings elsewhere in the sound package.

Starting early pays off

At the beginning of concept design phase, the BIW mass of the EV was over the 190-kg target. However, by the final iteration it had been reduced to 14.6 kg below the target. Importantly, the NVH performance was shown to positively contribute to the concept body design and mass reduction program by enabling engineers to identify and analyze specific areas in which performance was beyond the targets set and mass could be reduced. LMS Engineering was able to use LMS Virtual.Lab™ software from Siemens PLM Software to simulate design changes as the team worked on them early in the concept design process, meaning that significant design changes could be made to reduce NVH issues without increasing the mass as the design, simulate and analysis activities were carried out in a balanced, iterative loop.

It was found that the FSV did not require glued damping treatments to attenuate motor noise, saving 3.6 kg due to the use of VDS, which contributed to the 14.6-kg total BIW mass saving achieved during the concept design phase. The use of VDS could be a permanent addition to the NVH engineers' toolbox in years to come as the technology advances. It highlights the possibilities for steel in terms of green concepts in vehicle design.

Based on this work, the concept was considered to be ready for prototyping and validation activities. This would provide the information to judge the effectiveness of the analysis in a full vehicle development cycle.

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