Cadillac LYRIQ show car - Image Courtesy of Cadillac - Cadillac Pressroom

Comfortable EV design – a frequency shift

By Kevin Miller, Director - Virtual Body Systems, Interior & N&V General Motors

"There is a strong match between the N&V needs for Electric Vehicles and Actran technology. The recent inclusion of Actran in our toolkit has improved our ability to predict mid-frequency issues and confidence that we can develop solution sets and vehicle level performance that will delight our customers. The N&V team is now looking at developing workflows for a number of applications based on a combination of component and system level simulations, both for exterior and interior propagation."

Cadillac LYRIQ show car - Image Courtesy of Cadillac - Cadillac Pressroom

Background

General Motors is strongly engaged on a journey to reduce the CO_2 footprint of their global vehicle fleet so that the future generation can inherit a healthier planet. In order to successfully achieve this journey, it is critical to develop and deploy advanced new technologies to satisfy GM customers' requirements. While it is obvious that product quality paves the road for successful customer adoptions, the past few years have seen the emergence of the perceived sound quality as an essential driver.

To cope with market expectations, GM designers and engineers must deal with new Noise, Vibration and Harshness (NVH) challenges introduced by electric vehicles. The replacement of conventional internal combustion powertrains by electric propulsion is making vehicles much quieter with higher customer expectations in terms of interior comfort.

By partnering with Hexagon – MSC Software, the GM NVH team leverages advanced capabilities and expertise allowing them to ensure their future electric vehicles meet their customers' expectations.

Industry challenge

With new body architectures, different types of noise and vibration sources, and different interior design requirements, electric vehicles bring new challenges in terms of passenger comfort. When it comes to NVH, it
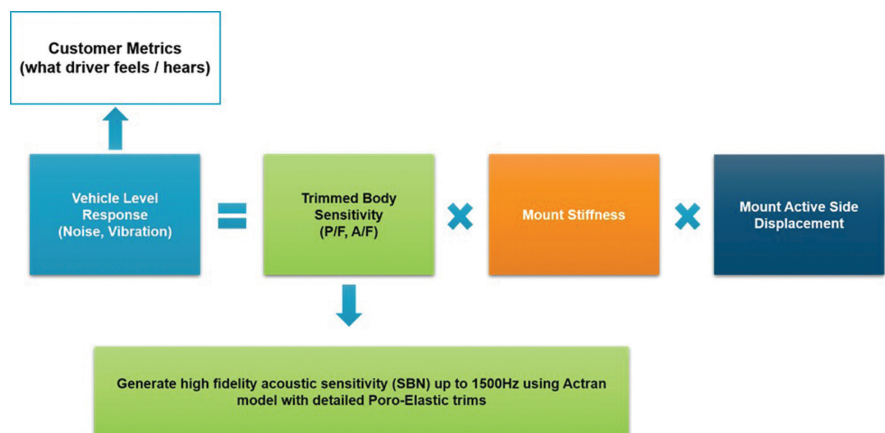

Transfer Path Analysis workflow

is common to associate specific requirements with specific frequency ranges and transmission paths.

With traditional ICE vehicles, the low frequencies are mainly influenced by structure-borne excitations coming from the powertrain and can be studied through a deterministic approach based on finite element models. The high frequencies are mainly influenced by air-borne excitations and are usually studied through statistical energy analysis approaches, allowing engineers to design acoustic treatments for optimal sound transmission and absorption performances.

For electric vehicles, different sources and propagation paths become more important. Structure-borne excitations include higher frequency tonal content while air-borne loading becomes more important at lower frequencies. These new requirements call for new tools able to appropriately predict the NVH behavior of the vehicle. "Actran is very useful to solve NVH problems in the mid frequency range (400-1500Hz) that are critical for EV design", said Dave Hamilton, Manager for the Noise and Vibration (N&V) Virtual Design, Development & Validation group, General Motors. "The software complements and integrates very well into our existing processes as it is open and leverages the existing FE and CFD simulation models we have to provide additional
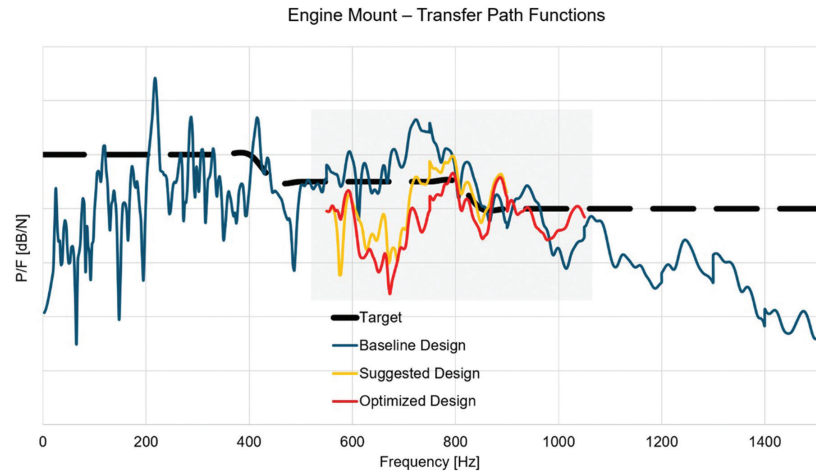
Engine Mount Optimization - Transfer Path Functions – Courtesy of General Motors

insight. The level of support and the partnership we have created with the Hexagon – MSC Software team are also key to the success of the NVH group. They were able to help us manage this year's difficult working conditions by shifting on-site training to virtual and by providing office hours tech support."

MSC Solution

Meet the NVH targets

Electric drive units, such as GM's Ultium Drive, exhibit strong high order content in the vibration and acoustic response. "Without the capabilities provided by Actran, ensuring good NVH simulations in this frequency range would be a challenge" said Kunal Kolte,

N&V CAE Engineer, General Motors. "For the frequencies excited by the Ultium Drive, we need to accurately represent all acoustic treatments present in the vehicle in order to simulate the noise heard by the passengers". A trimmed body model is used to compute transfer functions between the different Ultium Drive mounting points and the acoustic response inside of the vehicle. This model includes a complete description and representation of the different acoustic treatments and can be run at the frequencies of interest for this case (400-1500Hz). The computed transfer functions are then recombined with mount stiffness and Ultium Drive excitations using a transfer path analysis approach to understand what passengers feel and hear.
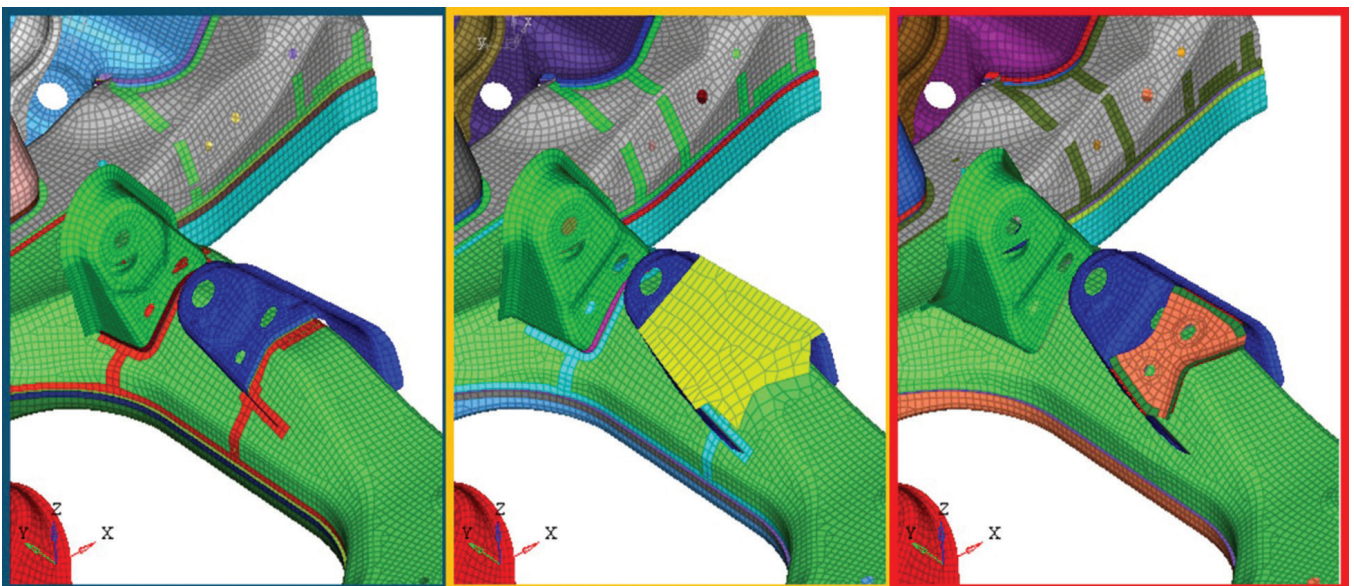
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"We realized our baseline configuration was missing our NVH target since high order noise content could propagate to the cabin." said Kunal. "Reviewing the simulation results, we were able to identify the problematic structural modes contributing to this problem. A solution was devised and quickly proven by modifying and re-running the model." The suggested design could be optimized to meet manufacturing constraints. Significant improvement to the acoustic performances of the vehicle was obtained with little mass addition, conducting to the final adoption of the model. "Integrating this type of models in our engineering process allows us to evaluate the complete vehicle performance, identify a problem, suggest a solution and validate it with a high level of confidence. This new simulation capability is well received and appreciated among the entire NVH department." concludes Kunal.

Speech intelligibility
Sound reverberation inside the car impacts many interactions passengers may have within the vehicle (such as conversation or voice command, etc.). With customers expecting better visibility, sunroof options are becoming more common but also have negative impact on interior comfort as there is less surface area with sound absorbing materials.

Full vehicle trimmed body models such as the one described above are not only useful for evaluating the response of the vehicle to structure-borne excitations. Air-borne, wind noise or interior excitations may also be considered. In this case, the vehicle structure was removed from the model and only the car interior volume and acoustic treatments were considered. Acoustic transfer functions between different passengers were then evaluated.

"There was a concern from our program team that the reverberation inside of the vehicle was too high" said Qijun Zhang, Global N&V CAE Simulation Owner, General Motors. Numerical acoustic models were used to assess the optimal way of reducing the interior reverberation. "We first used simulation results to evaluate what was the contribution from the different sound absorbing surfaces to the interior acoustic behavior. By breaking down the different components' contributions, we identified that our best leverage to improve the interior speech intelligibility would be to modify the seat design by increasing the surface area of the seats with perforation to increase sound absorption". Adding perforations on the seats induces trade-offs in terms of acoustics, cost and durability. Using the simulation model, several configurations with different surface areas were evaluated. Thus, an optimized

Baseline Perforated Area

Optimized Perforation Area

Seats - Current production 2020 Chevrolet Tahoe seat images used to illustrate perforation area comparison of future EV program – Courtesy of General Motors.

perforated surface area was identified to reduce reverberation amplitude.

"For these types of studies, it is extremely valuable to accurately represent our acoustic treatments in the complete frequency range of interest and provide direction to the program design team in the early stage of the program" said Qijun.

Future challenges

"We are very satisfied with the value brought by Actran for these applications. We plan to expand usage to other applications to help us further capture, understand and optimize a variety of other acoustic sources" said Kunal and Qijun. "With these new capabilities we are confident in our ability to create simulation models that will directly inform us on customer level performance whatever the noise source, propagation path or noise reduction strategy."

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It is true that components generating noise inside electric vehicles remain numerous. In particular, the Ultium Drive, its attached driveline and transmission, pumps and compressors will be studied in order to reduce noise at the source to ensure final sound quality. In addition, the ability of Actran to optimize damping pads treatment on the structure while limiting the addition of mass will be used together with the coupling with CFD solvers for wind induced noise studies. "Relying on the ability to command pre-processing, runs and post-processing operations through Python API provides a framework to automate most of these workflows so they can be done more efficiently" concludes Kunal.

About GM

We envision a future of zero crashes, zero emissions and zero congestion, and we have committed ourselves to leading the way toward this future.

General Motors has been pushing the limits of transportation and technology for over 100 years. Today, we are in the midst of a transportation revolution. And we have the ambition, the talent and the technology to realize the safer, better and more sustainable world we want.

As an open, inclusive company, we're also creating an environment where everyone feels welcomed and valued for who they are. One team, where all ideas are considered and heard, where everyone can contribute to their fullest potential, with a culture based in respect, integrity, accountability and equality.

Our team brings wide-ranging perspectives and experiences to solving the complex transportation challenges of today and tomorrow.[1]

References
1   General Motors, About GM, https://www.gm.com/our-company/about-gm.html