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BEYOND MEASURE

DESIGNING THE SOUND EXPERIENCE WITH NVH SIMULATION

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ABSTRACT

Creating the perfect vehicle sound is a critical challenge that needs the buy-in of diverse decision-makers to establish targets, and greater inter-departmental collaboration to realize them. Free-driving sound simulation captures subjective sound preferences with real-time modification. It helps to cascade that target sound down to subsystem or component level, and provides a focal point where all relevant and available data (CAE or test-based) can be assessed for its impact on sound style. In this way, NVH simulators can reduce uncertainty throughout the vehicle development programme: from target setting to delivery. This reduces the need for prototypes by more completely marrying the virtual-world design process with the real-world results, and enabling assessment of NVH predictions from CAE models.

INTRODUCTION

Designing the overall sound of a vehicle is more critical than ever, yet prototypes are hugely costly, and their availability is limited. Making prototypes for sound styling that are representative is also very difficult, and added to these circumstances is the difficulty of actually understanding the collective final consequences of small design decisions and individual changes to the whole prototype – especially for decision-makers. All of which makes vehicle sound design notoriously difficult in the real world. Simulation of potential design strategies is therefore an attractive prospect, in order to experience the projected outcomes of the latest design iteration.

PROBLEM DEFINITION

The first requirement for a vehicle programme team is to define the target sound style. Diverse interests are often involved, and capturing their subjective decisions can be very difficult. Typically, the initial definition from the marketing or styling department is based on descriptive words, images, and possibly the identification of a benchmark vehicle or two to help define a type or feature of the sound they want. Translation of that into a defined engineering target or set of sounds is a huge challenge.

One issue is that our overall impression of the sound of a vehicle is based on a combination of driving conditions and actions. While NVH departments continue to use specific, repeatable tests such as WOT (Wide-Open Throttle) tests in low gear to engineer the powertrain sound of the vehicle, the way people actually drive during an assessment process in a final vehicle appraisal is far more involved, and even somewhat individual – depending on the assessor. It follows that working to define a target sound, and evaluating how your vehicle design matches up to it, ideally needs to done with a similar degree of assessment flexibility. Free-driving simulation is attractive, as long as it is quick to use and comes early enough in the development process to lead the design, rather than verify decisions after they have been taken.

Free-driving scenarios result in different perceptions of the sound characteristics, as drivers can experience the full range of driving conditions such as acceleration and deceleration, and gear shifts, at a variety of speeds, and in their own driving style

For simulation to be useful for sound styling, it has to synthesize sound with sufficient fidelity that it can be used for evaluating the emotional reaction to that sound. It has to be able to audition the results of alternative designs and subtle new design variations, faithfully. And as well as capturing decisions, it has to be able to take design information from the simulation back into the real world to verify and validate the simulation, ideally at any point during development.

SOLUTION (HIGH LEVEL)

The solution to this issue is to work using a free-driving, virtual sound model in an NVH simulator, backed up with a tested methodology and set of tools. With these, the NVH simulator can be a cornerstone of the development process, allowing collaborators of all levels of expertise to intuitively experience design iterations. The Brüel & Kjær NVH Simulator rapidly enables identification of the desired sound quality – in itself a challenge – by auditioning alternatives based on benchmarked vehicles, which can be modified in real-time. It subsequently provides a focal point where all the latest data can be assessed for impact on sound style, by experts and non-experts from different departments, at any stage of development.

Through its revolutionary ability to assess NVH data of any type (CAE or test-based) and from any measured source in the real or virtual world, combinations of future and actual designs can be intuitively trialled in a full context. This enables effective decisions to alter specific design parameters and then experience the re-

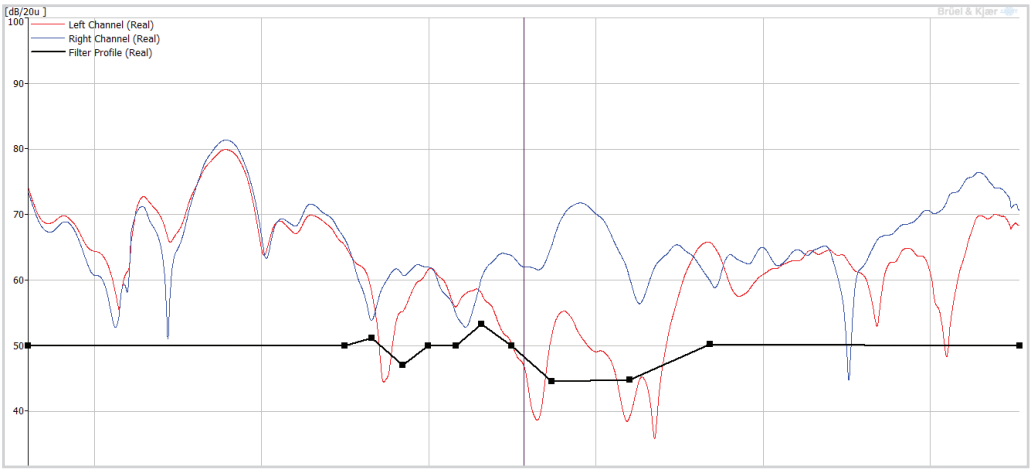
sults – throughout the vehicle design process. Ultimately, it allows detailed sound characteristics to be more actively designed into a vehicle, rather than emerging from experimental changes to a prototype.

SOLUTION (DETAILS)

Target-setting

Initially, simulation models are based on a previous-generation vehicle, or mixtures of other representative vehicles that have some desirable sound characteristics or features representative of the concept vehicle. Such models are further developed by driving freely in a custom scenario and track, modifying sounds in many different ways while driving, until a desired sound style is achieved.

For benchmarking, engineers can make simple binaural recordings at the driver's ears to capture the driving experience over a range of tests outlining the driving envelope. A complete, free-driving NVH Simulator model of the vehicle, including the performance model of acceleration relative to throttle position, can be recorded and processed in about two days, capturing data from the vehicle's CAN bus.



The driver can modify target sound models on the go, viewing standard NVH data such as time histories, complex spectra and phased orders, and applying filters to achieve the desired sound characteristics

Target evaluation

A suite of jury evaluation tools allows a consensus to be developed among the project team, so that progress can be more rapidly made towards the target agreement. Mark Clapper, Technical Leader, Vehicle NVH, Ford says, "We can actually drive the NVH Simulator with real context and see whether it's sporty enough or if it's too smooth or too rough. We can drive it against key competitors and evaluate it with customers. And we can do all that before we even make a prototype."

In the Exterior Sound Simulator module, the sound model can be experienced from the bystander's perspective, as it performs any driving manoeuvre such as starting and moving away in a car park, rapid acceleration, etc.

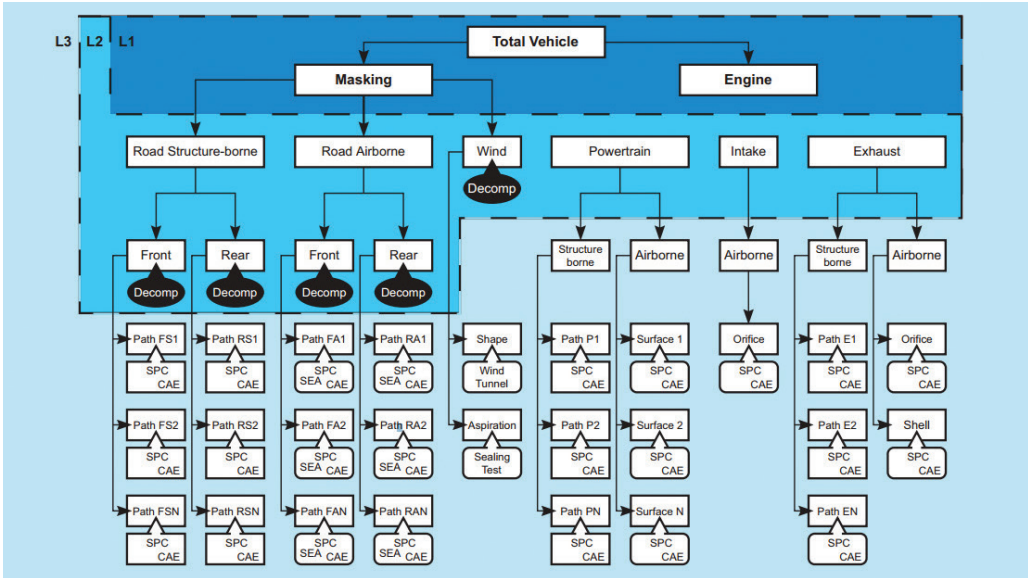
At any time, it is also possible to validate that model in the real-world. A simulator module (VSound) allows the sound models to be evaluated while driving on a real road in a 'mule' car, thus evaluating the target NVH in the full context of ride, handling and acceleration performance. This VSound system seamlessly presents the sound model to the driver by adding the sounds to the existing car. This allows sound design targets to be experienced by busy people in their own, standard car.

Engineers can also switch to the pedestrian perspective using an exterior sound simulation module. In this mode, the vehicle sound model is experienced from the point of view of a pedestrian in a range of different environments such as a town – complete with traffic noise and other sounds for full context. The user can 'free-walk' or pre-define any scenario to allow the observer to move through the scene, be passed by a vehicle, cross the road and so on. The resulting scenarios are presented with a fully authentic sound including sound localization, Doppler shift and other features.

Target delivery

In the NVH Simulator, vehicle sound is decomposed initially into powertrain sound and masking (non-powertrain) sound. In itself, this process allows insights into the vehicle's sound quality. Looking in more detail is useful in identifying which components or subsystems should be modified in order to achieve the desired sound. Source decomposition techniques allow measured vehicle sounds to be separated into contributions of major vehicle subsystems, and even components.

For more detail, contributions are added to the simulator model as 'sound objects'. Individual sound objects each represent one collection of sounds from a certain aspect of driving, such as wind noise in a fully sealed cabin or specifically-modelled components or sub-assemblies like exhaust systems, and even specific engine mounts. These are usually derived from a source strength and a transfer function.



Sound objects in the simulator's tree-like structure, which cascades down from large collections of sources to smaller components, reflecting the structure of the vehicle

Evaluations in the NVH Simulator can then take place to identify which components or subsystems can be modified to contribute to the desired sound. Where there are multiple possibilities, a decision can be made on the optimum modifications for cost and complexity; in other words, a strategy is developed.

Sound objects can be based on test data, purely CAE data, or hybrids of test and CAE data. The simulations fuse every aspect of the selected sound objects into the whole sound, in real-time. Each of these discrete

sound objects can be selected, filtered, substituted and combined at will, and all sound objects can be varied as a function of many different parameters (rpm, speed, gear, load, position, operator input). This flexibility is key, and means that physical objects like new air intake designs can be played in precisely the same background noise as their predecessors, and modified based on a new source strength predicted by CAE, while using the same transfer function determined by physical testing. Hybrid CAE/test sound models can thus sometimes be more accurate than CAE alone in covering the entire frequency range.

Some other potential uses include allowing alternative powertrains to be virtually tested in a vehicle, such as using data from an engine on a test bench. Or updated engine mount designs can be played in the simulator so the NVH engineer can evaluate its effect on the overall sound before it leaves the CAE design stage. Dr Garry Dunne, Senior Technical Leader, Vehicle NVH, Jaguar Land Rover says, "Our CAE colleagues really like the NVH Simulator. They can use it to experience the real effects of their predicted CAE modifications. This is a key capability in the decision-making process."

BUSINESS BENEFITS

Simulation generates and sustains buy-in from senior management, and then captures subjective preferences of such non-expert decision-makers, before translating them into engineering targets. With it, diverse stakeholders can easily appreciate the future consequences of early design decisions by intuitively experiencing potential design alterations. As a central reference tool, the NVH simulator facilitates collaboration. As David Quinn, when Manager of NVH Development, Nissan UK said, "With the simulator as a core development tool, the US, Japan and Europe are already sharing road noise models for global benchmarking and target setting. By sharing and comparing data, we can change the global development process and get more accurate results with fewer prototypes."

In operation, engineers can apply their expertise in a targeted manner, and virtually experiment with alternative strategies to deliver the target sound. Prototype requirements are reduced as more development is performed using CAE data, in the virtual world, with more accurate simulations than CAE alone. NVH can also more completely enter the design considerations of CAE departments, by quickly screening design alterations that are made for other considerations like safety, for their NVH performance.

Overall, these improvements to the efficiency of the whole design procedure speed up the process to the point where the final design sign-off evaluations take place. These evaluations are more successful as a result of already having incorporated inputs from decision-makers throughout the development process. And even when targets are not met, juries of non-experts can experience the results and still agree on a consensus of whether the design is good enough or requires further work, as they can tangibly experience the full range of the sound produced in different conditions, making a more realistic and complete evaluation.

SUMMARY

NVH simulation is an effective method of capturing non-expert, subjective opinions in a true context, and helps convert them into clear engineering goals. It targets engineering expertise very accurately, and provides an efficient method of rapidly and cheaply trialling many alternative ways of achieving the desired sound. An NVH simulator can be a focal point in the design process where all design strategies can be referred, and the latest data auditioned for many different stakeholders in the all-important context. This is provided by an interactive driving scenario, from the pedestrian's perspective of the virtual car, and as a real-world driving experience.

The flexibility of the system is key, in allowing a near-infinite scope of combinations of test and CAE data from benchmarked vehicles and future vehicle designs. Using flexible hybrids of test and CAE data in any combination means that it further reduces the need for prototypes and testing at every stage of the iterative design process. And by inserting NVH into the CAE design process it can help CAE designers design with the NVH consequences of their decision more in mind.

OTHER APPLICATIONS

Tier 1 component manufacturers use NVH simulators to create and then test the latest results with their OEM customers. Beyond internal sound perception, there are other applications for NVH simulators, including developing exterior sound quality of electric and hybrid vehicles and internal combustion vehicles. This includes the development of artificial interior powertrain sounds to add character to quiet vehicles. Increasingly, in-car entertainment systems are being used to synthesise and add sounds via the vehicle interior (and exterior) loudspeakers. Brüel & Kjær's VSound system allows engineers to test sound designs directly in prototypes and and even incorporate them directly in production vehicles.

NVH simulators are used to make sound contribution models for vehicle audio system tuning, involving adding realistic car driving sounds for the contextually-correct evaluation of in-car audio systems. Similarly, speech intelligibility testing benefits from NVH simulation. Finally, vibration can also be simulated in full-vehicle simulators, using a static mule vehicle.

For more information, see bksv.com/NVHsimulator

BN 1419 – 11 2014-06

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