Live webinar
Address NVH Engineering issues of Hybrid and Electric Vehicles
Wednesday February 28, 2018

Unrestricted

www.siemens.com/simcenter
Electrification is here to stay

Hybrid and electric vehicles share could range from 10-50% of new vehicle sold in 2030

Source: Bloomberg New Energy Finance
Electrification
Trends & Engineering implications

No convergence yet on battery, cells and thermal management system

- Many architectures possible with optimal trade-off cost/performance required

Weight reduction an important design driver for range

- ...yet cost of weight reduction plays important role

Electrified Powertrain
Solution areas

- Battery Design
- Motor Design
- Vehicle Systems Integration
- Energy Management
- Thermal Management
- Controls V&V
- NVH & Acoustics
Shifting focus in NVH development effort
From powertrain towards road noise and aero-acoustic noise reduction

Source: Leading the Charge – The Future of Electric Vehicle Noise Control
Greg Goetchius, Sound & Vibration, April 2011
Vehicle NVH & Acoustic Innovation Area
Electric and hybrid electric vehicles – Challenges

Electric motor
Wind Noise
Road Noise
Other, HVAC, battery cooling, steering systems, ...
Warning sounds
Vehicle NVH & Acoustic Innovation Area
Electric and hybrid electric vehicles – Challenge

Electric motor

Sound levels may be lower but the high frequency tonal components make them quite annoying
Electric motor

Sound levels may be lower but the high frequency tonal components make them quite annoying.

- How to control the Sound Quality of the motor?
- How to optimize electric motor noise radiation?
- How to integrate the electric motor into the car?
What is Sound Quality?

Objective assessment
Analyze your sound with measures that can be quantified

Subjective assessment
Study the perception of the sound
What are the positive and negative contributors to your products sound

Psychoacoustics is the science of sound perception. It studies the psychological and physiological responses associated with sound.
Benchmarking & Target Setting
Interior noise replay, overall levels, sound quality metrics

Objective assessment
Analyze your sound with measures that can be quantified
Sound Quality - Subjective Analysis - Jury Testing

Gather subjective opinions on your product
Benchmark competition
Consistency and statistical analysis
Automated reporting

Understand the expectations of your customers and design the product that exceeds them

Listening tests
NVH & Acoustic solution areas
Electric and hybrid electric vehicles

Design space
- Motor Design
- Electric Design
- Controls Design

1D Simulation
- Functional Motor Model
- Thermal Model
- Vehicle Energy Model

Electric system models including controls and extendable to thermal and energy management

3D Simulation
- Electro-Magnetic simulation
- Vibro-Acoustic Model

Vibro-acoustic models based on electro-magnetic loads calculation

Test
- Full vehicle diagnostics
- Acoustic characterization
- Phase current
- Acceleration
- Sound
- From sub-system characterization to full vehicle diagnostics using TPA, ODS, OMA,...
Electric Motor Noise Radiation Optimization
Punch Powertrain cut time-to-market by factor 2

“Thanks to Simcenter Engineering services and the optimization process they used with Simcenter 3D software, we are now working on a new generation of commercially competitive switched reluctance motors for automotive propulsion.”

Diederik Brems, Mechanical Engineer
Hybrid and electric drives call for new testing and analysis techniques

**Support to handle new sound signature**
- Support high-frequent off-zero orders coming from power electronics
- Support to switch RPM axis between different shafts (for HEV)

**Support of new sensors**
- e.g. ability to derive rotational speed from available resolver
- Reuse resolver that is already present at electric motor
- Derive rotational speed and shaft position from electric motor without any additional sensors

**Handling new important noise sources**
- Gear whine analysis
- Battery cooling system noise
- Electric Motor TPA analysis
- …
Investigation of electrical motor noise
Source-Transfer-Receiver methodology

- Traditional TPA technology applied to electric vehicles
- Identification of major noise contributors up to high frequency (up to 100\textsuperscript{th} engine order)
- Electro-magnetic forces, gear whine and PWM switching as noise generating mechanisms

Applying TPA and ASQ methodologies on an electric vehicle

Investigation of airborne and structure borne source contributions from the powertrain to the interior by applying common TPA technologies.

Traditional TPA methodologies prove well capable of investigating high frequency noise content as seen in electric vehicles if measurements and analysis are done with appropriate care.
Vehicle NVH & Acoustic Innovation Area
Electric and hybrid electric vehicles – Applications

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Simulate and/or test electric motor noise from current to ear
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Wind Noise
Lower powertrain noise lets wind noise become apparent from lower speeds
This results in new investments in Aero-acoustic testing

Challenges:

• Increase further the return out of each test

• Get more work done in the wind tunnel

• Reduce the number of iterations and modifications made to the vehicle
Layout example of next generation aero-acoustic wind tunnel

- **In vehicle**
- **Turntable & Traverse**
- **4 exterior Arrays**

Online and offline Analysis system

- Integrated with wind tunnel controller
- Automatic processing
- View & analyze processed results in 10 seconds
- Data management
Wind noise simulation offering in Simcenter
Combined expertise on flow and acoustics

Source

Transfer

Receiver

SAE-2015-01-2330
Test or Simulation?

Test:
+ Testing 100’s of configurations/campaign
+ Results in few seconds
+ Any frequency range
  – Only once prototype available
  – Expensive

Simulation
+ Early predictions
+ Without expensive wind tunnel
  – 1 week to finish one simulation
  – Challenging for high frequencies

INCREASE EFFICIENCY & EFFECTIVENESS by combining TEST & SIMULATION:
• Use more and more simulation to simulate before prototypes
• Reduce pressure on testing time in wind tunnel by reduction of prototypes thanks to simulation
• When you test, highly increase the outcome
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Test the right thing in an efficient way
Simulate as much as you can prior to prototypes

Road Noise

Other, HVAC, battery cooling, steering systems, …

Warning sounds
Road Noise
Less masking and low rolling resistance tires make road noise more important
Road and Tire noise
Types of noise resulting in exterior and interior noise

**TIRE NOISE** = airborne
Originates from tire surface vibrations and aeroacoustic events

**ROAD NOISE** = structure borne
Originates from tire patch forces → wheel hub → car body → occupants ears/passenger compartment

Air-borne Noise

Structure-borne Noise

Wheel forces
Road and Tire noise
Lower road noise levels by combining test and simulation

Test models
Body, Tire

FE model for subframe

Test model
Operational Forces from Test or Simulation

FE/Test Mount description

Test/FE model
(solved in NX Nastran)

Minimize SPL by optimizing mounts, sub-systems & interaction

Original
Modified
Target

<table>
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<th>Frequency (Hz)</th>
<th>SPL (dB)</th>
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FE model for subframe
Fiat Group Automobiles SpA
Delivering extraordinary NVH performance across product lines

Eliminating annoying road noise

- Optimized design validation with minimal errors
- Achieved all NVH performance targets
- Now delivering solutions to road noise problems in days instead of weeks

Road noise transfer path analysis

- Use Simcenter simulation and testing solutions to deliver a robust, virtual validation process and develop the best-in-class NVH performance

Competition creates the need for much shorter timeframes

“All Simcenter solutions help us prove that our NVH performance is solid in regards to the chassis and underbody. This is a clear benefit if you look at the number of variations we do.”

Roberto Mangiantini, NVH Manager for Vehicle Concepts and Integration
Vehicle NVH & Acoustic Innovation Area
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**Road Noise**
- Identify the root causes and verify chassis and body modifications to increase passenger comfort

**Other, HVAC, battery cooling, steering systems, …**

**Warning sounds**
Vehicle NVH & Acoustic Innovation Area
Electric and hybrid electric vehicles – Challenge

Other

‘New’ noise sources, such as HVAC, battery cooling, steering systems, wiper motors,… are more noticeable and pose a complex problem to solve
Mechatronic system integration

Example: Steering Systems

System level integration
Component Sizing
Controls integration

Detailed component models
1D and 3D simulation for NVH and acoustic optimization

System validation
Test rig or full vehicle testing

Multi-domain engineering supporting all aspects of development
ZF TRW
Positioning steering systems NVH at the front of the development cycle

Reduced overall resources to solve NVH-related issues
Accurately estimated resources for NVH resolution upfront
Received positive feedback from customers, who appreciate the output data as well as the approach used to gather it

Development of the world’s first NVH steering system bench

Developing a powerful partnership
- Translate NVH recommendations into real and objective requirements and targets
- Integrate test and simulation to determine and resolve the root causes of problems

“We can establish exactly how much force we are allowed to introduce to a particular car to stay below a given NVH target, and we find that our customers appreciate this approach a lot.”

Christian Landsberg, Global Chief Engineer NVH
HVAC Noise
Optimizing driver comfort in terms of climate control and acoustics

• Obtain accurate noise sources using CFD, focusing on the flow problem
• Switch to Acoustic FEM for fast prediction of the noise propagation part

Fast and precise HVAC noise simulation: hybrid CFD - Acoustic FEM
Denso
Releasing products 3 times faster by using Simcenter Engineering services

• Released products 3 times faster than previously possible
• Reduced time it took to measure TPA by 70 percent
• Enhanced collaboration with OEMs

Quantify noise transfer paths in a shorter time

Speeding the release of products
• Develop new approach in close cooperation with Simcenter Engineering services
• Deploy LMS testing methods & tools into Denso’s HVAC system development process

Close cooperation enhances results

“OEMs are really satisfied with the input that we deliver using Simcenter tools. Thanks to the Simcenter solutions, we are able to release our new products three times faster than was previously the case.”

Tomohiro Sudo, Assistant Project Manager NVH
Battery Cooling NVH
Validate modifications to unit design w/o need for full vehicle validation

SOURCE
Inlet & outlet ducts located in cabin interior

Transfer
Measured FRF’s between sources and cabin microphones

Solution:
In vehicle near field sound pressure levels accurately calculated and correlated from unit level source measurement using Airborne Source Quantification Method

RECEIVER
Cabin sound pressure level

Modify the likely effect on cabin sound pressure levels due to modifications of the battery cooling unit ducts without in-vehicle testing
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- Identify the root causes and verify chassis and body modifications to increase passenger comfort

**Other**
- Take control of the variety of ‘new’ noise sources, such as HVAC, battery cooling, steering systems, wiper motors,… that would have gone unnoticed in the past

**Warning sounds**
Warning sounds

Legislation is either already in place or is at least soon to come in many regions to protect vulnerable road users from not noticing electric vehicles.
### Warning sounds
Minimum Noise requirements for EV & HEV

**UNECE suggests minimum noise requirements for silent vehicles**

- Minimum noise major concern for traffic safety
- Measurement procedures defined in ISO16254 - SAE J2889-1
- US: effective September 2019
- EU: 5 years after final approval proposal of 2014 by member states

“The US has done some analysis and there is twice the likelihood of an accident under certain low speed scenarios with hybrid cars versus traditional ICE vehicle”
Warning sounds
Pass the minimum pass-by noise threshold

Key messages:
• Minimum noise test procedure supported
• Required for homologation
• Test can be done both in-room or exterior

Stopped condition
Frequency shift
Microphones at 2m
Slow speed cruise
eVADER
Studying the exterior sound of electric vehicles

System engineering approach - Sound Synthesis & Propagation

• Simulate and study the detectability, annoyance and brand sound for sound system devices
• Balancing acoustic elements

Speaker directivity
• Simulating emitted noise from a speaker array in the front bumper
• Directing the noise at pedestrians that may be in danger

Sound Reflection and Propagation

European project to address the road safety concerns that pedestrians will have to face with the future marketing of electrical vehicles in Europe.
EC Project eVADER - SCP1-GA-2011-285095

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Siemens PLM Software
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