AUTOMOTIVE APPLICATION

Electric and Hybrid Vehicle Technology Testing

ACOUSTIC SENSORS FOR PREMIUM NVH DATA

GRAS Sound & Vibration

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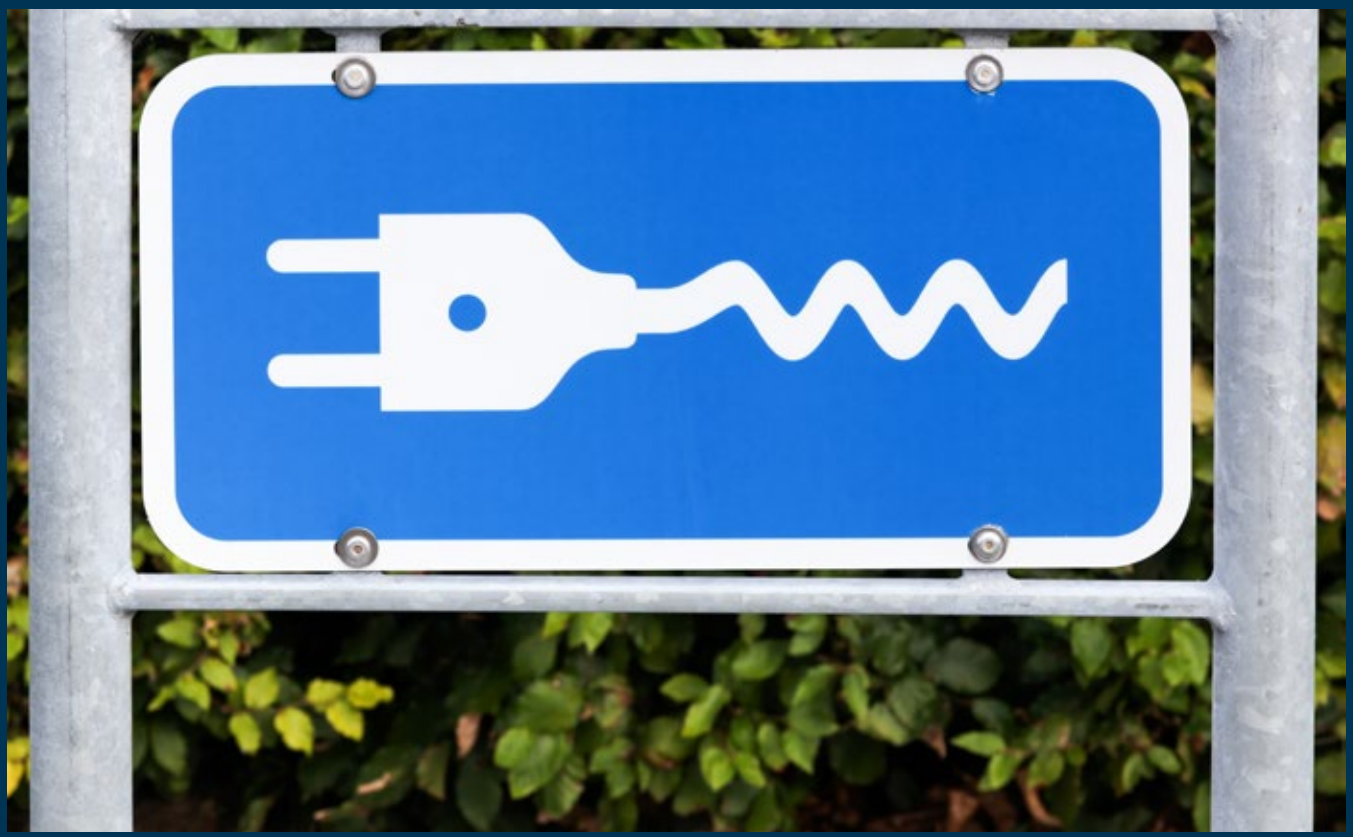
Electrical propulsion is rapidly becoming more or less mandatory to include in every OEM's vehicle range. Many naming conventions exist for the different vehicle technologies presently available. The main categories are the battery electric vehicle (BEV) and the hybrid electric vehicle (HEV) which also includes an internal combustion engine (ICE). The main difference between traditional powertrain testing and HEV/BEV testing is this addition of one or more electric motors, including inverter technology, battery cooling and the transmission design. The electric motor means new challenges compared to the combustion engine.

In relation to noise, vibration and harshness (NVH) testing of HEVs and BEVs, there are a number of factors to consider:

- ✓ Common electric motor types are the permanent magnet synchronous motor (PMSM), the induction motor and the switched reluctance motor.
- ✓ The inverter uses pulse width modulation (PWM) technology to transform high-voltage DC battery power into 3-phase AC voltage for the motor. Switching frequency and sidebands may be in the audible range.
- ✓ A gearbox for a BEV, typically, has one and final gear which means that this gear must handle the complete rpm range. A possible transmission error is important to detect, and some suppliers lack sufficient automotive experience.
- ✓ Water or air cooling/heating is necessary for the battery system to run. Furthermore, contactors to connect the high-voltage battery creates an impact noise at start-up/shutdown, which can be very disturbing.
- ✓ Some BEVs have a range extender (RE). This is an auxiliary power unit and generator for charging the battery without access to an electrical supply.



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ACOUSTIC TEST TYPES WITHIN ELECTRIC AND HYBRID VEHICLE TECHNOLOGY TESTING

A number of acoustic test principles are general regardless of the propulsion, but especially electric motor testing and computer model validations need more effort when it comes to BEVs and HEVs. The noise level from the electric motor is much lower, and the tonal noise contains much higher frequencies compared to an ICE. This is mostly noticed while driving at low speed. The dominating sound from the electric motor is the magnetic sound, which generates a whining noise, sometimes called “tram noise”. Noise is also important at regeneration (coast down with battery charging). The control system, i.e. the inverter causes other frequencies. A vehicle running only with the help of the electric motor results in less auditory masking effects at low frequencies, and this means that other requirements for component noise must be changed accordingly. Other new sounds are also introduced such as component noise and water or air cooling/heating for the batteries. A BEV requires electrically-driven accessories like an A/C compressor instead of belt-driven systems for ICE. The A/C compressor can also run during charging to cool down the battery.

BEV and HEV testing

Gearbox whining noise testing is done with similar procedures as for the gearbox for an ICE engine. Tests in a drivetrain test rig, sound power and vibrations, and vehicle tests are performed on a NVH chassis dynamometer.

A range extender has to be analyzed as appropriate depending on type. This component will obviously operate independently of driving speed, which is currently an unusual experience for the driver.

EXAMPLE

Vehicle interior magnetic noise and transmission noise is analyzed as sound pressure level (SPL) and electric motor orders. The order level versus background noise, especially above approx. 1 kHz, is important. The whining can also be analyzed by use of some of the methods for tonality. To this end, it is essential to have access to the electric motor specification to know the main magnetic orders.

The inverter noise as well as switching frequency and sidebands can be analyzed using e.g. fast Fourier transform (FFT) maps.

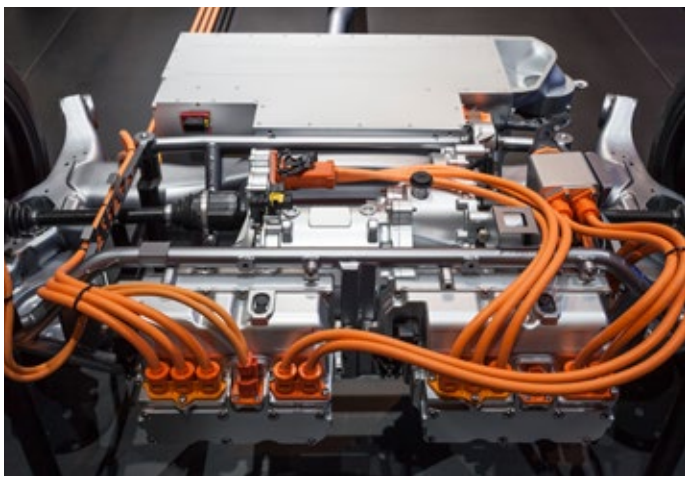
Computer model validation

A lot of the design decisions and verifications are done before any prototype part or vehicle is manufactured. The computer-aided engineering (CAE) models need to cover electric motor control systems and the vibroacoustic behavior of the motor as well as the vehicle. Measurements from existing cars or systems are used to correlate the simulations. Mule vehicles (existing cars modified with new concepts) are also used. Correlation tests include operating tests, source strength and transfer functions.

Generally, modal analysis and transfer functions, noise transfer functions (NTF) and acoustic transfer functions (ATF), are measured. Furthermore, impact hammer, shakers and volume velocity sources or the actual component are used for excitation. For prediction and CAE correlation, electric motor surface radiation (sound power) is important and the standardized vehicle verification tests are also used for CAE model verification.

CHALLENGES COMMON TO ELECTRIC AND HYBRID VEHICLE TECHNOLOGY TESTING

The main challenges are the low sound levels and tonal noise at much higher frequencies compared to traditional vehicles. The testing, therefore, requires high-quality equipment and careful measurement setup. Obviously, there is also less experience of customer reactions in this field.



Requirements for electric and hybrid vehicle technology NVH testing

Regardless of the specific test, there are several factors that need to be considered by the test engineer before any test is performed:

- Testing time should be short since the access to prototypes is limited.
- Microphone positioning should be done fast and easy, and in a way to record repeatable results.
- The microphones should be placed so that they minimize structure-borne sound.
- Microphone holders and cables should not introduce any rattling noise.
- The installation should be safe for the test engineer to perform during vehicle testing.
- Calibration verification should be easy to perform.

SELECTING THE RIGHT MICROPHONE

Microphones used for electric and hybrid driveline testing must be robust and handle any electromagnetic fields. A small size is important for easy positioning when measuring acoustic transfer functions. Free-field or random-incidence microphones are most often used, and the choice depends on the test procedures. Low-noise performance and full audible frequency range is also required.

GRAS provides microphones that can be used to overcome the new challenges related to BEV and HEV testing.

Both the 146AE ½" CCP Free-field Microphone Set and the 147AX pre-polarized Pressure Rugged Microphone can be used to test signals down to 18 and 19 dB(A), respectively, and cover the full human audible frequency range. This means that both microphones will be able to measure the entire dynamic range of the characteristic tonal noise components from EVs. The 146AE and the 147AX microphones will be able to withstand dusty and humid environments, very high and low temperatures and possible shocks and drops.

When testing on drivetrain test rigs or dynamometer, the 146AE can be mounted using the AL0006 Microphone Tripod in combination with the RA0093 or the AL0008 ½" Microphone Holders. The AL0008 also requires the use of the AL0005 Swivel Head. This combination will eliminate the possibility of introducing external rattle noise due to poor microphone mounting.

The 146AE can also be mounted in the car interior using the RA0504 GoPro Adapter, which will help place the microphone on the wide variety of GoPro mounts and clamps available on the market. This will help make the microphone positioning inside the car quick and easy.

When a random-incidence microphone is needed, the 146AE can be used together with the RA0357 Random-incidence Corrector to change its response from free field to random incidence (diffuse field). Thanks to its small form factor and MagMount™ mounting system, the 147AX will be better suited for situations where space constraints will limit the use of a standard measurement microphone. For example, when measuring the acoustic transfer functions from the electric motors or A/C compressor.

The power-on LED indicator in both the 146AE and the 147AX will help the test engineers to swiftly check that all microphones are working correctly. In addition, the transducer electronic data sheet (TEDS) capabilities of these sensors will contribute to the fast setup of these multi-channel systems.
The 42AG Multifunction Sound Calibrator can be used for daily sensitivity verification of both the 146AE and the 147AX using the included adapters.

RECOMMENDED MICROPHONES AND CALIBRATORS

BEV and HEV Testing		
	146AE	½" CCP Free-field Microphone Set
	147AX	CCP Rugged Pressure Microphone
	RA0357	Random-Incidence Corrector for 146AE
	RA0504	GoPro Adapter
	AL0005	Swivel Head
	AL0006	Microphone Tripod
	AL0008	½" Microphone Holder, POM
	RA0093	½" 5-click Microphone Holder, Stainless Steel
Calibration	**42AG**	Multifunction Sound Calibrator, Class 1

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About GRAS Sound & Vibration

GRAS is a worldwide leader in the sound and vibration industry. We develop and manufacture state-of-the-art measurement microphones to industries where acoustic measuring accuracy and repeatability is of utmost importance in R&D, QA and production. This includes applications and solutions for customers within the fields of aerospace, automotive, audiology, and consumer electronics. GRAS microphones are designed to live up to the high quality, durability and accuracy that our customers have come to expect and trust.

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