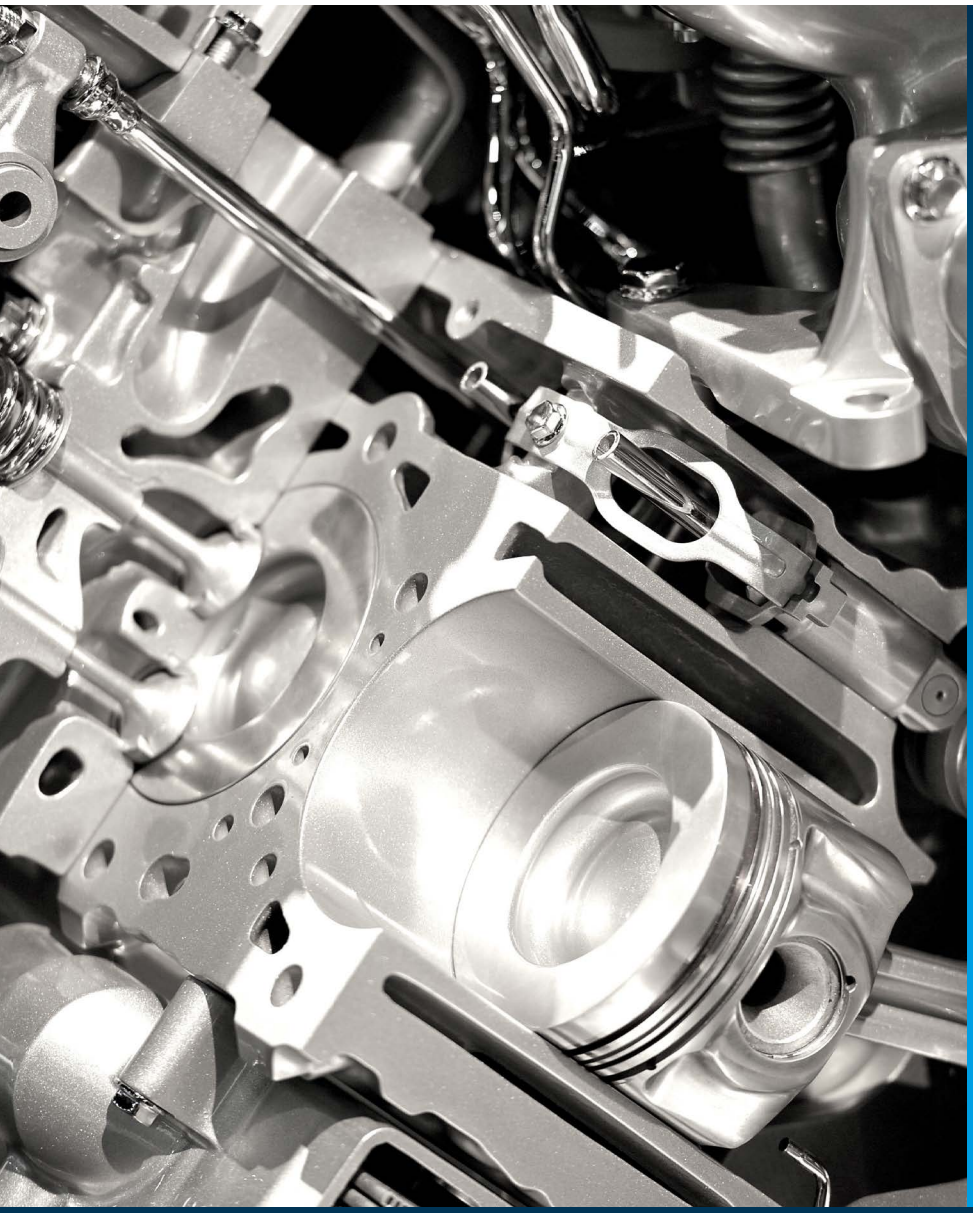
AUTOMOTIVE APPLICATION

Powertrain NVH Testing



ACOUSTIC SENSORS FOR PREMIUM NVH DATA

GRAS Sound & Vibration

Powertrain NVH Testing

Powertrain noise, vibration and harshness (NVH) testing concerns the overall driver experience of the vehicle propulsion system, and this includes everything that makes the vehicle move. The noise level and sound quality are both very important since some parts of the sound provide important feedback to the driver while other parts are just annoying. The noise from all these sources, i.e. the internal combustion engine (ICE) with air induction, exhaust system, tail pipe, gear box, belt drive system, pumps and accessories like cooling systems and fuel pump, is transmitted both airborne and structure-borne into the vehicle and contributes to the vehicle acoustic comfort. The powertrain noise also affects the external noise (the pass-by noise), which is regulated by legislation.

Vehicle interior measurements form the basis for the verification of the vehicle NVH performance. The measurement procedures are developed to provide results that correlate with subjective ratings that are used as customer satisfaction references. Development measurements in the engine bay will provide detailed information about noise source location, source strength, frequency content, engine order content and time variation, and this will explain the physical cause of the noise. The results of all these tests will guide the engineers how to reduce unwanted noise.

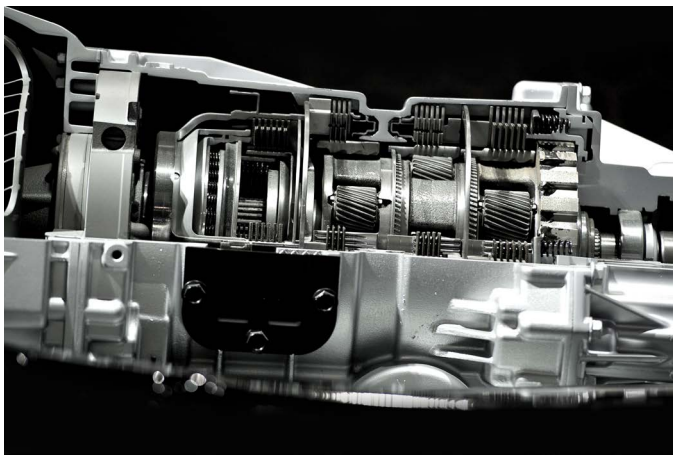
Engine bay measurements in combination with interior or exterior measurements will provide information about the performance of how well acoustic packages work. These packages provide sound insulation or sound absorption. The measurements are done both on the OEM's development test vehicles and on the production follow-up vehicles as well as for benchmarking to make sure that the customer's expectations for a new vehicle can be fulfilled.

ACOUSTIC TEST TYPES WITHIN POWERTRAIN NVH TESTING

It is important to develop validated test procedures that are fast and easy to perform, and it is good practice to use a standardized selection of transducer types and transducer positions. The main tests include sound pressure level (SPL) and order content from the powertrain at different load conditions like drive away, steady state, acceleration, part load and maximum load wide open throttle (WOT). The tests are performed both for the engine separately in an engine NVH test cell and for full vehicle integration tests on a NVH chassis dynamometer or on road.*

Complementary vehicle measurements in the engine bay area includes:

- Near-field measurements close to the different sources
- Far-field measurements for sound power estimations
- Sound intensity measurements
- Microphone arrays for sound source location
- Acoustic transfer function measurements (ATF)



When testing transmission noise, the verification of the gearbox design is tested in a NVH drivetrain test rig where noise emissions and vibrations at the interfaces to the engine can be investigated. Furthermore, the vehicle integration is verified with the complete car driven on a NVH chassis dynamometer or on road.

The transmission noise from manual or automatic gearboxes must be low. Gear whine originates from gear meshing and often produces high frequencies where less masking from other sounds help. Gear rattle noise is another issue. The actual design of the gears like shape, material and tolerances is critical, and transmission error is the most important design criteria.

EXAMPLE

A vehicle verification test on a NVH chassis dynamometer typically includes two to four microphones at ear level inside the vehicle distributed between the driver's and passenger seats. The wheel rpm is used to track the gear orders and can be registered with an optical or inductive sensor or from anti-lock braking system (ABS) sensors. The Controller Area Network (CAN bus) bus also provides powertrain performance data to further increase the knowledge.

Computer model validation

A lot of the design decisions and verifications are done before any prototype part or vehicle is manufactured. The body and chassis design thus has a big impact on the vehicle NVH powertrain performance and needs to be verified at an early stage. Measurements from existing cars or systems are used to correlate the simulations. Mule vehicles (existing cars modified with new concepts) are also used.

General measurements include modal analysis and transfer function measurements, noise transfer function (NTF) and acoustic transfer function (ATF). Impact hammer, shakers and volume velocity sources are used for excitation. Furthermore, the standardized vehicle verification tests are used for computer-aided engineering (CAE) model verification.

**) For more information on other NVH powertrain testing applications, please refer to other automotive application literature from GRAS.*

CHALLENGES COMMON TO POWERTRAIN NVH TESTING

Challenges R&D typically deals with when working on powertrain NVH include:

- Concept selection for engine installation, engine content, layout and insulation
- Exhaust system installation and optimization
- Transmission design
- Concepts for auxiliary components
- Predictions of noise radiation
- Compromising between NVH and other important attributes like performance, fuel consumption and emission

TOMORROW'S CHALLENGES WITHIN POWERTRAIN NVH

- Accurate NVH modelling methods and early tests in engine test cells to predict vehicle noise and sound quality is extremely important. Some test data used in NVH driving simulators may also need to be binaural recordings.
- Environment-friendly, small engines with low noise levels for steady state driving, but powerful temporary sound at acceleration as well as new propulsion concepts, belong to a successful future.

Requirements for powertrain NVH testing
Regardless of the specific test, several factors 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 powertrain testing must be robust and, if they are used close to the engine, able to handle heat, dust and humidity. A small size is important for easy positioning in the engine bay.

Free-field or random-incidence microphones are most often used, and the choice depends on test procedures.

Powertrain test
GRAS provides a wide variety of standardized measurement microphones that can be used in the many different stages of powertrain testing.

The 147AX CCP Rugged Pressure Microphone can be used for engine bay measurements during powertrain tests, where a low profile microphone capable of handling high temperatures is needed. Its magnetic MagMount™ system can be used to mount the microphones in very small or challenging spaces where no other microphones can be placed.

The 146AE ½" CCP Free-field Microphone Set will be the best choice to test the powertrain under different load conditions both for far-field measurements in dynamometer, road or drivetrain test rig and for interior measurements. The 146AE is a robust microphone that will be able to withstand dusty and humid environments, very high and low temperatures, and possible shocks and drops.

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).

The 146AE can be mounted using the AL0006 Microphone Tripod in combination with the RA0093 ½" 5-click Microphone Holder or the AL0008 ½" Microphone Holder. 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 power-on LED indicator in both the 146AE and the 147AX will help the test engineers to swiftly check the status and readiness for data collection of all microphones. 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 146AE and 147AX using the included adapters.

RECOMMENDED MICROPHONES AND CALIBRATORS

Powertrain Test		
	146AE	½" CCP Free-field Microphone Set
	147AX	CCP Rugged Pressure Microphone
	AL0005	Swivel Head
	AL0006	Microphone Tripod
	AL0008	½" Microphone Holder, POM
	RA0093	½" 5-click Microphone Holder, Stainless Steel
	RA0357	Random-incidence Corrector for 146AE
Calibration	**42AG**	Multifunction Sound Calibrator, Class 1

Sound intensity and sound source location
Array microphones like the 40PH and the 40PL CCP Free-field Array Microphones are cost-effective, free-field acoustic sensors designed to be mounted on large or small array modules like the PR0002 Array Module for the analysis of sound fields. These types of microphones can be used in powertrain testing for measuring and locating sound sources using techniques like beamforming, near-field acoustic holography (NAH) and acoustic cameras. The 42AG can be used for calibration of array microphones too.

A sound intensity probe like the 50GI-RP CCP Rugged Intensity Probe can also be used for sound intensity measurements and source location, especially useful when testing in noisy environments and for areas difficult to access with microphone arrays. The 51AB Phase Calibrator according to IEC 61043 is used for level and phase calibration of the intensity probes.

RECOMMENDED MICROPHONES AND CALIBRATORS

Sound Intensity and Sound Source Location		
	40PH	CCP Free-field Array Microphone
	40PL	CCP Free-field Array Microphone, High Pressure
	50GI-RP	CCP Rugged Intensity Probe
	PR0002	Array Module
Calibration	**42AG**	Multifunction Sound Calibrator, Class 1
	51AB	Phase Calibrator according to IEC 61043

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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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