AUTOMOTIVE APPLICATION

Engine Noise Testing

ACOUSTIC SENSORS FOR PREMIUM NVH DATA

GRAS Sound & Vibration

Engine Noise Testing

A lot of noise originates from the engine itself of course, the gear box, the belt drive system, pumps, cooling fans, but also other components like the A/C compressor and the power steering motors. These systems contribute to the vehicle acoustic comfort and some parts of the noise provides important feedback to the driver while other parts are just annoying.

The noise from the engine bay can also affect the external noise (the pass-by noise), which is regulated by law. Vehicle interior measurements form the basis for verifying the vehicle performance, and the measurement procedures are developed to provide analysis results that correlate with the subjective impressions.

Measurements in the engine bay will provide detailed information about the noise to identify e.g. source location, source strength, frequency content, engine order content and time variation, and will explain the physical cause of the noise. This result will guide the engineers as to how to reduce unwanted noise.

Engine bay measurements in combination with interior or exterior measurements will provide information about the performance of acoustic packages and how well they work. These packages provide sound insulation or sound absorption.

The measurements will be done both on the OEMs 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 ENGINE NOISE TESTING

Measurements in the engine bay area include:

- 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 (ATF) measurements

Near-field measurements

The near-field measurements are best done at standardized positions distributed in the engine bay and close to where the noise sources are located. The measurement result can be used as a noise indicator and for comparison with other test vehicles. A single position selected from many microphone positions can be found to be a good indicator for the problematic noise during measurements at operating conditions. This result will then be used for verification of different engine calibrations for example.

Far-field measurements

Far-field measurements for sound power estimation are performed in a hemi-anechoic chamber equipped with a low-noise, vibration and harshness (NVH) chassis dynamometer. Engineering methods require few measurement microphones, three to four can be used, while precision methods require a minimum of 20 measurement microphones. The microphones are typically positioned in a hemisphere around the engine, and the sound power versus frequency is calculated.

Sound intensity measurements

Sound intensity measurements can be used for noise source location. This is mostly done in a NVH hemi-anechoic test chamber in combination with other NVH vehicle testing, but can be performed at other locations as well since the intensity technique is quite tolerant to the acoustic environment. This type of testing is mostly suitable for engine operating conditions at idle or at fixed engine rpm and gear in neutral. The result is a ranking of the different sources at different frequencies. Countermeasures with improved engine covers can easily be verified this way.

Microphone arrays for sound source location

Microphone arrays can also be used for noise source location in a hemi-anechoic chamber equipped with NVH chassis dynamometer. The array can be installed above the engine bay and allows for safe testing at driving conditions without any person outside the vehicle. Different techniques for analysis such as beamforming and acoustic holography are available and the result can be visualized in real-time.

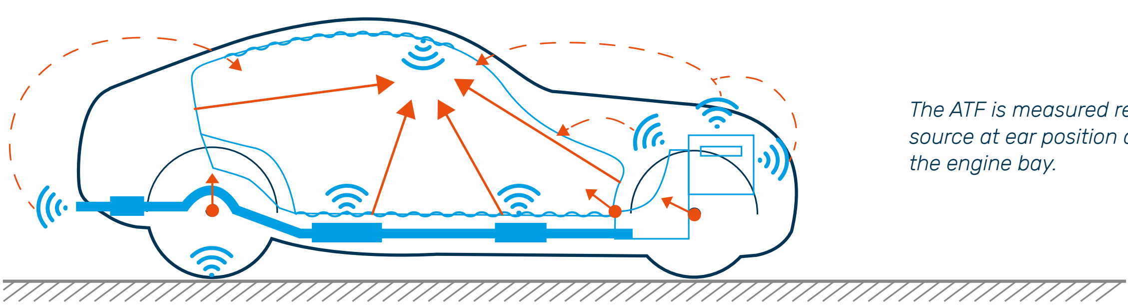
Acoustic transfer function measurements

The ATF testing is used to capture an average insertion loss, and the result will be used for:

- Verification of vehicle requirements
- Comparison to benchmarks
- To estimate noise levels in the vehicle interior from the sound power of the source
- Computer-aided engineering (CAE) correlation

These measurements need careful instrumentation since the result is determined as an average of several paths. The sound source is moved between several locations and the response is also measured at several positions in the engine bay. It is common to have up to 12 source locations and 36 response positions, so the final number of measurements can be several hundreds. The number of responses to measure is chosen as needed depending on test time and accuracy.

Since more and more electric vehicles are being introduced, the possibility to perform good measurements at higher frequencies is increasingly important. Electric motors with control system and gearboxes will produce tones at higher frequencies compared to the internal combustion engine.



The ATF is measured reciprocally with a noise source at ear position and the response in the engine bay.

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CHALLENGES COMMON TO ENGINE NOISE TESTING

A lot of vehicle design concept selections are critical for successful reduction of unwanted airborne noise from the engine bay.

Firstly, it is essential to minimize the leakage in the firewall and to optimize the acoustic insulation package. Secondly, you should make sure that the actual noise sources are as silent as possible, maybe with the help of acoustic insulation covers.

To quantify all this in a measurable and comparable way, it is important to be very structured during the testing so that requirements for systems and components can be derived from the vehicle level targets.

All test conditions must be identical. The microphone positions and microphone type must be specified. The driving conditions, engine load and environmental conditions must be standardized.

The measurement data is used for noise analysis in the frequency and order domain, and will show noise levels and sound quality as well as how good the airborne sound insulation from the engine bay to the vehicle interior is.

Instrumentation of the vehicle should be fast, exact and easy to perform since the testing time is short. Also, access to prototype vehicles is usually limited. The microphone performance should, therefore, be of highest standard, and the possibilities for repeatable mounting of the microphones in the standardized positions should not be underestimated.

The selection of microphone type is of less importance for the low frequencies like engine orders. But to be able to capture higher frequencies arriving from any direction, a pressure or random-incidence microphone is the recommended choice. Both types behave very similar in this application.

Space is limited and environmental conditions harsh with exposure to extreme heat, dust and humidity. The transducers are often moved to different positions and, therefore, must withstand strong vibration and shock. Because it is hard to position the microphone in the exact same spot, the results for the same vehicle will vary too much for trustful comparison, even though the sound insulation measurements are based on multiple averages of the ATFs.

If the installation of microphones can be done very precisely, this makes it possible to do some of the measurements based on fewer positions whenever timing is an issue.

The microphone mounting should also work on the test track to allow for operating test, and calibration verification should be easy to perform.

SELECTING THE RIGHT MICROPHONE

The recommended microphone inside the vehicle is a ½" free-field or random-incidence microphone as defined by company standards.

The response microphones are often located where it can be hard to install a microphone in a good and repeatable way, so this is also a critical parameter when selecting the right microphone. It is recommended to use pressure or random type microphones for transfer path analysis (TPA) measurements when frequencies above 3-4 kHz are of importance.

Acoustic transfer function measurements
The 147AX Pressure Rugged Microphone has been specially designed to achieve repeatable measurements in positions that are hard to reach with other types of microphones. This makes it a perfect choice to place in the response positions for TPA measurements in the engine bay of a car. Its small and rugged design allows for microphone mounting in places that were otherwise impossible. Furthermore, the magnetic base of the 147AX enables easy positioning on any metal surface and the included mounting disc will ensure the exact same microphone position for future measurements.

Since the 147AX operates in the -40 to 125 °C (-40 to 257 °F) temperature range and is designed to be water and dust proof (IP67), it will survive even the most challenging engine bay environments.

For vehicle interior measurements, the 146AE ½" CCP Free-field Microphone Set is the perfect choise. When a random-incidence microphone is needed you can add the RA0357 Random-incidence Corrector to the 146AE.

The possibility of easy verification of calibration will minimize test time and enable repeatable measurement results. The 42AG Mulifunction Sound Calibrator can be used for daily sensitivity verification with both the 147AX and the 146AE with the included adapters.

RECOMMENDED MICROPHONES AND CALIBRATORS

Acoustic Transfer Function Measurements		
Engine bay	**147AX**	CCP Pressure Rugged Microphone
Inside car	**146AE**	½" CCP Free-field Microphone Set
	RA0357	Random-incidence Corrector for 146AE
	RA0504	GoPro Adapter
Calibration	**42AG**	Multifunction Sound Calibrator, Class 1

Troubleshooting

For noise source identification, use intensity microphones or array microphones configured according to the relevant equipment needs.

When troubleshooting, measuring or locating sound sources using techniques like beamforming, near-field acoustic holography (NAH) or acoustic cameras, array microphones are a viable option. This could include the 40PH and the 40PL CCP Free-field Array Microphones, which 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. The 42AG calibrator can be used for calibration of array microphones as well.

RECOMMENDED MICROPHONES AND CALIBRATORS

Troubleshooting		
Test cell	**40PH**	CCP Free-field Array Microphone
	40PL	CCP Free-field Array Microphone, High Pressure
	PR0002	Array Module
	50GI-RP	CCP Rugged Intensity Probe
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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