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Improving measurement procedures for engine noise reduction with advanced microphones

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Per Rasmussen is Chief Technology Officer, co-owner and founder of GRAS Sound and Vibration A/S based in Denmark.

He holds a M.Sc. in Acoustics from the Technical University of Denmark.

He is an expert in design and application of advanced measurement microphones for a wide range of industries like automotive, aerospace and consumer electronics.

During his more than 35 years of experience with acoustic measurements, he has participated in the development of microphone solutions for sound intensity, acoustic holography, beamforming arrays, wind tunnel and turbulence measurements.

In connection with the development of the new 147AX 1/2" Rugged Automotive Surface Microphone for automotive NVH, GRAS has conducted a study in cooperation with Volvo Cars.

The main goal of the study was to improve the measurement procedure for Engine Noise Reduction to be able to better compare and evaluate different vehicle configurations across different platforms, independent of operator induced differences.

The transducer is specifically designed for easy and repeatable mounting inside the confined space of an engine compartment and was tested for localization accuracy. It can also be used in hot engine and track testing.

The acoustic environment inside a car is one of the primary comfort parameters. It is made up of a number of contributions from drive-train, auxiliary equipment, wind noise and tire noise, and all are influenced by the transfer from the source to the receiver. With the change from purely internal combustion engines to electrical or electrical assisted propulsion systems, a new set of noise sources are introduced in the engine compartment and this requires renewed focus on the transmission paths to the receivers inside the car cabin.

Typically, these mechanisms are studied by using a reverse transmission technique, placing a well-defined sound source in the receiver position inside the car and measure the resulting sound pressure levels in the engine compartment. Assuming reciprocity, these measurements can be used to estimate the attenuation of transmission from sound sources in the engine compartment to the receiver inside the car.

These measurements are time consuming and cumbersome as they involve the placement of up to 20 or more microphones inside the engine compartment. This has traditionally been performed using off-the-shelf measurement microphones. In order to optimize this procedure, GRAS has worked with Volvo Cars to develop a microphone optimized for this and similar applications.

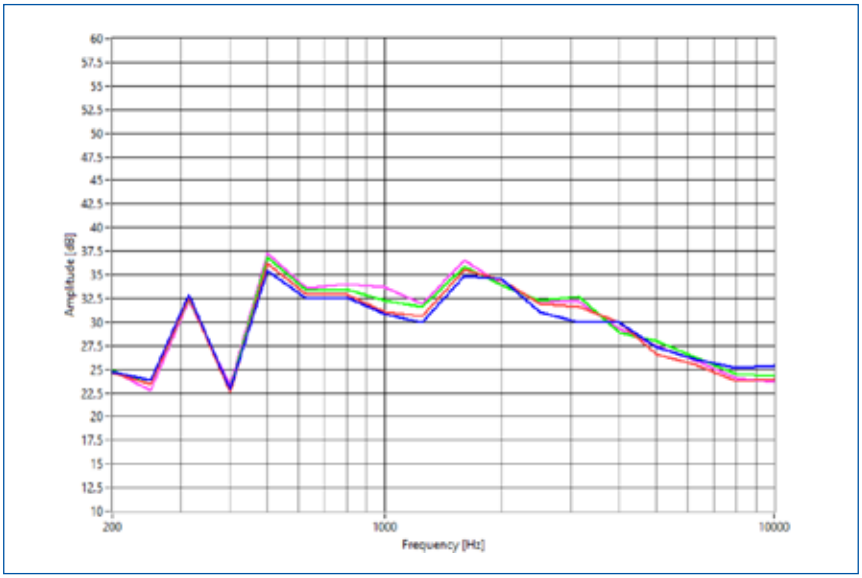
“... the major objectives with the new transducer is to obtain easy and repeatable transducer mounting for highly repeatable measurements, mechanical stability and easy calibration and channel identification.”

Some of the major objectives with the new transducer is to obtain easy and repeatable transducer mounting for highly repeatable measurements, mechanical stability in actual field use and easy calibration and channel identification.

Easy and repeatable mounting

The traditional measurement microphone is a cylindrical device optimized for free field conditions far away from sound sources and obstacles, with essentially no size restrictions. This is very different from a modern engine compartment where almost all available space is filled and it is difficult to find relevant places to mount the microphones. Often the microphones are mounted using ad-hoc mounting devices or taped to available structures. This introduces variations in the exact transducer position from test to test and from one operator to the next. This also makes it difficult to make comparisons across different versions, models and platforms as the layout in the engine compartment will change.

Analysis of the existing technique showed that even small differences in transducer positioning could alter the results substantially and therefore obscure the effects of optimization modifications or comparisons. This variability may be reduced by using large numbers of transducers and average the results of measurements, and thereby minimize the effect of dislocations of the individual transducer. This will however increase the setup time and also reduce the information from the individual position to an overall average.



The effects of positioning variations are in the order of several dBs.

Measurements of localization sensitivity revealed that changes in microphone placement of as little as a few centimeters could change the measurement results by several dBs. As this level often coincides with the levels of interest for proposed optimization changes this needs to be improved.

“Measurements of localization sensitivity revealed that changes in microphone placement of as little as a few centimeters could change the measurement results by several dB’s.”

To make the mounting of the microphones less time consuming and improve the localization accuracy a new microphone form factor was introduced. This microphone is designed to be mounted on the structure instead of hanging in the space between structures.

The new rugged automotive surface microphone comes with a mounting disc which can easily be mounted on well-defined and representative positions with for example double sided tape, and the microphone element attaches magnetically to this mounting base. This means that the microphone can be mounted and removed within seconds even in hard to reach positions.

> "... the microphone can be mounted and removed within seconds even in hard to reach positions."

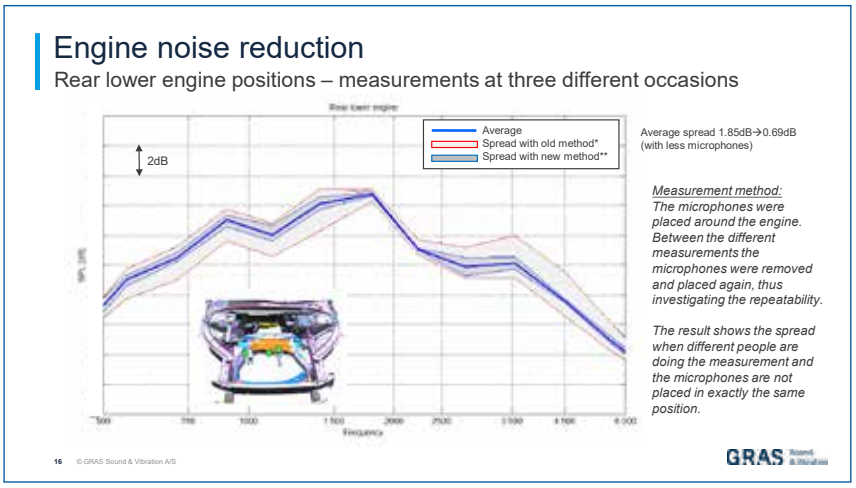
The new rugged automotive surface microphone with its mounting disc.

> "The "rigging" of the test car can be done once and for all (...) by placing the mounting base in precise (...) places."

The "rigging" of the test car can be done once and for all by placing the mounting base in precise (and even hard to reach) places. The mounting of the microphones can be done quickly and precise in the measurement area/dyno.

The new measurement positions were selected to be easily identifiable and representing important positions for important major acoustic noise components in the engine compartment.

As can be seen below, the improved positioning directly leads to much mproved repeatability between measurements.



Repeatability is significantly improved compared to previous methods with standard free-field microphones.

> "Repeatability is significantly improved compared to previous methods with standard free-field microphones."

> The new transducer has (...) been designed with the rough automotive NVH testing environment in mind.

Microphone stability

Traditional measurement microphones were originally primarily designed to be used in well-controlled laboratory-like environments, and should be handled with care. This is different from the day-to-day operational environment of automotive development and quality assurance measurements.

The new transducer has therefore been designed with the rough automotive NVH testing environment in mind. As part of the design verification, the microphone has been subjected to comprehensive HALT testing, including drops onto a solid steel surface simulating accidentally dropping the microphone, and "tumbler" tests simulating vibrations and suddenly changing g-forces.

The microphone including the cable is designed for high temperatures up to 125ºC. Additionally, it has been made water and dust proof so that the microphone may be used in harsh environments.

> ... the microphone is equipped with an LED which makes it easy to verify that the microphone is properly connected and ready for use.

Channel identification

One of the major complications with multi-channel measurements is the channel identification and calibration. To facilitate this the microphone is equipped with an LED which makes it easy to verify that the microphone is properly connected and ready for use.

Additionally, it is equipped with TEDS (Transducer Embedded Data Sheet) which can be activated by reversing the supply voltage. In this state the transducer will transmit the full calibration data to the attached signal analyzer for channel identification.

Reading the TEDS will turn on the LED and this will allow the position of the specific transducer to be verified.

Conclusion

Having tested the new automotive surface microphone for several months, Volvo Cars concludes that this microphone makes it possible to obtain better measurements and improved repeatability compared to previous methods. Also, it is now possible to use the same test configuration for indoor testing and outdoors on proving grounds and public roads.

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