Eliminating NVH

Sensors remove the guesswork from testing engines for noise, vibration and harshness.

Automakers rely on sensors to quickly, accurately and objectively measure various sensory inputs from engines. ***Photo courtesy General Motors Corp.***

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When consumers shell out $10,000 or more for a new car, they have little tolerance for unexpected engine noise and vibration. Trouble is, today's vehicle technology has made controlling noise, vibration and harshness (NVH) in engines more important than ever.

Advances in engine and powertrain technology, such as turbochargers, lightweight materials and complex intake systems, can make engines noisier.

At the same time, automakers have significantly reduced noise levels inside vehicles, through means such as placing dampening materials inside door panels and increasing the thickness of window glass. As a result, drivers expect a much quieter ride, not only in luxury vehicles, but in entry-level vehicles, as well.

To make matters worse, expanded warranty coverage leaves engine manufacturers exposed to claims for a longer time. Unexpected noise or vibration emanating from the engine, such as buzzes, squeaks or rattles, can adversely affect a customer's perception of the engine and the vehicle in general. The noise or vibration may not influence actual engine performance, but the customer may still perceive the engine to be somehow defective. Ultimately, the customer may make a warranty claim, and such claims are usually settled to maintain customer satisfaction. By some estimates, warranty claims cost automakers $22.6 billion annually.

With those kind of stakes, it's not surprising that automakers are going to great lengths to eliminate NVH in engines.

Objective vs. Subjective

Noise and vibration measurements have long been used as quality appraisal tools on the engine assembly line. The challenge for engine manufacturers has been to understand what level of NVH falls within consumer expectations, and then translate this subjective limit into an objective measurement for testing purposes.

Today's vehicle technology has made controlling NVH in engines more important than ever. *Photo courtesy DaimlerChrysler AG*

In the past, engine manufacturers relied on the experience of their production personnel to identify defective engines based on the sound they emitted during hot test. However, the subjective nature of such testing often meant that defective engines were shipped to the vehicle assembly plant—or worse, reached the customer. Subjective testing also hampered productivity, when good engines were misdiagnosed and sent for repair.

Today, automakers rely on sensors to quickly, accurately and objectively measure a variety of sensory inputs from engines. A modern NVH test system consists of sensors and a data processing system.

Both contact and noncontact sensors can be used for NVH testing. Which to use depends on cost constraints, the test environment and the defects to be detected.

Noncontact sensors, such as microphones or laser velocimeters, are not connected to the engine. Although they may have advantages in some applications, they are usually inadequate for the assembly line. For example, many microphones are not robust enough to function and survive in industrial environments, and they require frequent calibration. Background noise can also cause inconsistent results.

Contact sensors, such as piezoelectric accelerometers, are attached directly to the engine. They are robust and relatively immune to background noise. In addition, contact sensors are usually less expensive than noncontact sensors.

The data processing system takes the signal from the sensors and turns it into meaningful data. The noise or vibration signature of the engine can be extracted, and features from the signature can be analyzed.

Three processing techniques can be used to analyze these waveforms.

Time domain analysis is useful for detecting transient events. This technique is optimal when looking for defects that would cause knocks and clicks in a mechanism at a known time during the test cycle. An example of this scenario would be testing the function of the starter motor, which always happens at the same time during the test.

Unexpected noise or vibration emanating from the engine can adversely affect a customer's perception of the vehicle.

Frequency domain analysis is the most common tool used to detect and diagnose defects. It's used to assess signatures with a repetitive pattern. It's also used to detect the excitation of a natural frequency. Frequency domain analysis is a powerful tool for diagnosing defects, such as faulty fuel systems, defective ignition systems and missing bearings. These defects are generally associated with low-frequency excitations, and are relatively immune to changes in engine speed.

Order spectral analysis is used to find defects related to engine speed. This technique requires an extra sensor to detect the position of the crankshaft. Order spectral analysis solves the problem of accurately tracking repetitive, high-frequency signals from noisy camshafts and gear drives, which could be lost or misread by slight changes in running speed.

Signature Analysis

One advantage of NVH testing with sensors is that it can provide more than just simple pass-fail judgments. The waveforms produced by the data processing system can be used to optimize test parameters, diagnose the causes of defects, and improve the assembly process.

Specific signatures can be recorded in real time and classified as "normal" and "abnormal." Abnormal signatures can be defined based on engineering standards, results from road tests, or even subjective listening measurements by line personnel and engineers. By statistically analyzing a host of normal and abnormal signatures, the test system automatically sets acceptable threshold levels for NVH and transforms that data into test limits. In other words, the test system "learns" what experts consider to be acceptable or unacceptable NVH, and passes or fails engines accordingly.

Statistical analyses of NVH test data can help engineers optimize the assembly process. ***Photo courtesy Ford Motor Co.***

When an abnormal signature has been established, it can be linked with a specific defect, such as a missing bearing. When an engine fails, the system can then provide a diagnosis for the failure, so repairs can be done more quickly.

Statistical analyses of test data can also help engineers optimize the assembly process. For example, if Pareto analysis reveals that missing bearings are the most common defect detected during hot tests, engineers can devise a procedure for the bearing assembly station to ensure that all the bearings are in place before the engine is passed to the next station.

Identifying engine defects or process abnormalities at the earliest possible production stage can result in substantial savings. Test optimization can reduce test cycle time, reduce false rejects, maximize sensor life, and find defects that are unrelated to NVH, such as timing problems.

A comprehensive engine NVH testing system should include a method for archiving test results by engine serial number and storing the waveforms measured during testing. Storing waveforms gives manufacturers information they can act on. For example, specific engines can be isolated for recall without having to issue a costly and damaging general recall. Defects can be traced to individual stations, operators, shifts and components. This can help assemblers identify and resolve process and product problems before significant repair costs are incurred. Finally, manufacturers can quantitatively demonstrate to vehicle assembly plants that engines have been produced and tested according to specifications.

Keys to Success

The keys to successful NVH testing are process, people and practice! Implementing NVH testing for engines can be split into four phases:

- Test requirement planning. At this stage, responsibilities should be assigned, and cost and timing studies should be done. A thorough understanding of engine design and potential defects is essential.
- Feasibility and test verification. At this stage, engineers should determine which sensors and signature analysis routines are needed.
- Preproduction validation. In some cases, this phase can be done concurrently with the feasibility study. This phase will validate the measurement process and the classification system, allowing any issues to be resolved prior to implementation on the live line.
- Production testing: At this point, the system should provide accurate and consistent results. Remember to use the test results to facilitate continuous improvement! A

By storing data from NVH testing, assemblers can quantitatively demonstrate that engines have been produced and tested according to specifications. ***Photo courtesy DaimlerChrysler AG***

Sciemetric Instruments is the premier provider of defect detection, analysis and traceability solutions for engine manufacturers. Our solutions deliver the insight engine manufacturers require to improve quality, increase productivity and decrease costs across the entire production lifecycle.

Sciemetric has perfected the industrial application of electronic signature analysis technology — a powerful tool for detecting defects that were previously thought to be undetectable and for pinpointing the root causes of defects.

Customers who have implemented Sciemetric solutions to help them achieve their quality and productivity objectives include engine manufacturers such as Ford, General Motors, DaimlerChrysler, BMW, Cummins, John Deere, Caterpillar, Mazda, Hyundai, Holden, International and Saturn.

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