Basing Vibration Tests on Realistic Specifications Helps Valeo Deliver Reliability and Performance at Right Cost

Solution requirements:
- Quickly generate synthesized test signals to drive fatigue test systems.
- Convert time history data acquired into realistic vibration specifications that provide a much closer match to the loads experienced in real vehicles.

Valeo
The key to success for automotive suppliers is to design components that meet reliability targets, keep warranty costs low, while at the same time achieve low production costs. Traditionally, automotive components are tested using generic specifications based on historical damage profiles with little connection to the vehicle that the component will be used on. The result is that the component may be overdesigned for some types of vibrations while remaining vulnerable to others.

Valeo has pioneered a new approach that transforms road load data acquired from the vehicle on which the components will be used into a test signal that realistically represents the fatigue loads seen by the component during its life on the actual vehicle. Valeo worked with HBM-nCode to implement this approach in nCode GlyphWorks test data analysis software and uses this software to quickly generate synthesized test signals to drive fatigue test systems. The result is that the component is designed to meet the specific requirements of the vehicle, resulting in a reduction both in manufacturing and warranty costs.

Valeo is one of Europe’s largest car parts suppliers, providing components for nearly all global car manufacturers. Valeo is organized into four business groups: Comfort and Driving Assistance Systems group (interior controls, security systems); Powertrain Systems (engine and electrical systems, transmissions); Thermal Systems (climate control, compressors, engine cooling); and Visibility Systems (lighting systems, wiper systems). Valeo Service also distributes products to the automotive aftermarket. Valeo has about 120 production sites in 27 countries and more than two-thirds of its sales come from Europe.

Reliability at the right cost
Designing products that deliver the right performance and reliability at the right cost is critical to success in the automotive components business. “Today, expected vehicle lifetimes are typically in the area of 16 years and 300,000 kilometers,” said David Delaux, Group Reliability Director for Valeo. “Automotive component suppliers must ensure that their products can achieve these targets. Of course, it’s not possible to actually test components over the full lifetime of the vehicle. So components are usually evaluated using generic specifications provided by vehicle manufacturers. These are typically either random power spectrum density or harmonic swept sine signals. They are applied for different exposure durations, typically 30 to 100 hours per axis.”

“But in reality different vehicles place very different loads on their components,” Delaux continued. “For generic specifications to cover many different types of vehicles requires that they incorporate large safety factors but even then they do not necessarily cover the complete range of damage seen in particular vehicles. Historically we have seen failures and failure modes in the actual components on the road that were not seen in testing with generic specifications. We’ve also seen failures in testing that were not seen in the real vehicles. Furthermore, designing to generic specifications makes it necessary to overdesign components which adds considerably to their cost.”
Converting time histories to realistic specifications

Valeo has been working for about a decade to develop methods to convert time history data acquired into realistic vibration specifications that provide a much closer match to the loads experienced in real vehicles. These time histories are generally captured by customers on a test track using accelerometers, strain gauges, pressure sensors, etc., and in some cases acquired by Valeo itself. The French military with its GAM-EG-13 standard, the American military with its MIL-STD-817 and the French scientific society, the Association pour le développement des Sciences et Techniques de l’Environnement (ASTE), have all developed fairly consistent methods of converting time history signals into vibration specifications for driving fatigue test equipment. Delaux said: “I would like to warmly thank Christian Lalane, Henri Grzeskowiak, Bruno Colin, Bernard Colomies, Jacques Vanuxem, Lambert Pierrat and Armand Delanghe, who have built these strong methodologies.” The challenge for the automotive supplier that attempts to pursue this approach is accepting large volumes of time history signals from test tracks around the world and developing an efficient and accurate method of converting them to fatigue test specifications.

“I started working with HBM-nCode about a decade ago because the company surpassed any other in developing software to convert time history data to synthesized vibration specifications,” Delaux said. “HBM-nCode is unique in the amount of testing knowledge possessed by its people, including both its developers and its technical support staff. We have worked closely with HBM-nCode to implement the latest methods for generating a damage equivalent synthesized power spectrum density in its GlyphWorks test data analysis software. During this process we have developed a strong working relationship with HBM-nCode.”

Figure 1: Spiked data before (top) and after (bottom) correction

Figure 2: GlyphWorks is used to detect and correct peaks, deviation, loss of signal, saturations, etc. Close-up of corrected data – blue is original, red is corrected

The first step in this process is to input the time history data into GlyphWorks using the time series input glyph. The anomaly detection algorithms within GlyphWorks are used to detect outliers. A measurement specialist reviews the anomalies and corrects spikes while keeping an eye out for other defects, such as saturation, that might require the data to be discarded.

Figure 3: Stationary test values including signal, probability density, running mean and running standard deviation

Global statistics are then computed on each channel such as max, min, mean, standard deviation, RMS, skewness and kurtosis. These stationary test values are used to quickly assess whether the signal is centered around its mean and its peakiness. Statistical analysis is performed to determine whether the mean and standard deviation values remain constant over the sampling period. These analysis help the measurement expert determine whether to use a deterministic or probabilistic approach to calculate the fatigue damage spectrum.
Evaluating frequency ranges

10 to 200 Hz: Mechanical shock and vibration, dominated by maximum pressure in cylinder during cycle

200 to ~2 kHz: Combustion noise: due to variations of pressure in cylinder during cycle: dP/dt

Above ~2 kHz: Acoustic noise: due to cylinder’s cavity modes + noise from other sources like turbo whistling, belt friction, etc.

A Fast Fourier transform is then performed on the time history data with GlyphWorks to help determine what frequency range to excite in the vibration test. Based on the frequencies that are seen, the measurement expert can determine their source. In some cases the measurement expert may decide to limit the frequencies that are included in the damage spectrum. A displacement of a constant amplitude acceleration decreases with the square of the frequency. Sometimes high frequencies can be eliminated because strain is proportional to displacement and high frequencies generate little displacement.

Calculating the fatigue damage spectrum

Figure 5 shows an example of a fatigue damage spectrum calculation using GlyphWorks. The deterministic approach was used in this example because of the non-stationary nature of the signals. The fatigue parameters used are typical for metals: Basquin slope \( b = 8 \) and dynamic amplification factor: \( Q = 10 \). The same parameters are used for derivation of the synthesized spectra. The objective is to find a power spectral density or swept sine whose fatigue damage spectrum is equivalent to the fatigue damage spectrum generated from the time history. This is accomplished in GlyphWorks using an iterative approach that involves adapting the power spectral density until its fatigue damage spectrum overlays with the target fatigue damage spectrum within a certain margin. In the example, the synthesized equivalent power spectral densities are calculated to have an equivalent damage in an exposure duration of 30 hours per axis.

A statistical safety factor is added to account for variations in applied loading and the fatigue strength of the component. An additional safety factor is used to account for the limited number of durability tests that will be performed and for the reliability targets of the carmakers. The total safety factor is a product of these two numbers.

The realistic specification that was created in the example above was compared to generic specification provided by the automotive manufacturer as shown in Figure 6. The overlay shows that the synthesized specification exceeds the generic specification at frequencies under 200 Hz, typically where the engine orders are important contributors to vibrations. On the other hand, the synthesized specification has a lower magnitude than the existing profile in the high frequencies. In this example use of the generic specification may lead to overdesign at high frequencies and underdesign in the low frequency range.

Valeo has used these methods in the design and validation of over 400 engine cooling products. The company typically begins by using fatigue analysis software to evaluate the PSD specification against the current design. If the simulation shows the current design cannot stand up to the realistic spectra then the design is iterated until engineers are confident that it will pass the test.

The realistic specifications produced by the new method have proven to be considerably more accurate than generic specifications.
For example, in one case an automotive OEM asked Valeo to use a generic swept sine test on a plastic component. Valeo measured the time history data and also computed the damage based on a realistic profile. Designs were created to meet both specifications. The design based on the realistic specification saved 100,000 Euros in tooling cost, 0.60 Euros per part in manufacturing costs and also provided a weight savings of 10%.

"Much higher but more difficult to measure savings are achieved through our ability to more accurately design products to meet real world conditions using reliable specifications," Delaux said. "Parts designed with generic specifications sometimes are unable to stand up to loads generated by specific vehicle configurations. Designing parts to reliable specifications can generate huge reductions in warranty costs by ensuring that the part is able to meet the requirements of the application."

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-David Delaux, Group Reliability Director for Valeo

About us

nCode products are provided by HBM, a world-wide technology and market leader, offering products and services across the entire measurement spectrum, from virtual to physical. Since 1982, nCode is the leading brand for durability and data analysis solutions. Its technologies help customers understand product performance, accelerate product development and improve design. The power and ease of use of HBM technologies is a direct result of its world-class development process, expertise and in-depth experience of a broad range of industries. nCode product development is ISO9001 certified. Product support is available through HBM-nCode offices in Europe, North America and Asia.

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