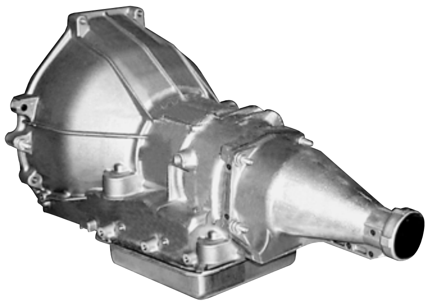
WHITEPAPER

KEYS TO SUCCESSFUL TRANSMISSION NVH TESTING



ABSTRACT

Many factors are driving the need for transmission manufacturers to implement more stringent noise, vibration and harshness (NVH) testing. Consumer tolerance for any perceived noise is minimal. The slightest objectionable transmission noise can lead to a costly warranty claim. Other factors such as longer warranty periods and increasing transmission complexity compound the NVH challenge for manufacturers. These manufacturers must earn customer satisfaction and minimize the risk of a large warranty exposure by implementing systems to drastically reduce NVH related transmission defects.

This document discusses some of the basics of transmission NVH testing in a production environment.

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KEYS TO SUCCESSFUL TRANSMISSION NVH TESTING

1. DEFINITION OF TRANSMISSION NVH TESTING

Noise, vibration and harshness (NVH) is one of the sensory inputs from a vehicle to the driver. Noise is audible, vibration can be felt, and harshness refers to the qualitative assessment of noise and vibration. Noise consists of any unwanted or unexpected sound. In assessing transmission quality, consumers expect smooth and silent shifting between gears.

2. DRIVING FACTORS FOR TRANSMISSION NVH TESTING

There are 4 major forces driving the demand for NVH testing of transmissions during manufacturing;

The capability of NVH Testing to find manufacturing or product defects.

NVH testing is a very effective way to catch manufacturing or product related defects such as: bearing damage, missing washers, or components with poor tolerance. These defects may not cause unwanted noise to the customer but could result in reduced transmission life or in-service failure, resulting in warranty charge-backs.

Increased complexity of transmission technology has lead to transmissions that have more sources of noise.

Advances in transmission and powertrain technology such as turbo-chargers, light weight materials and complex intake systems can all contribute to potentially noisier transmissions.

Decreased background noise levels in vehicle interiors amplify any transmission noise.

Over the past three decades, vehicle manufacturers have made significant progress in reducing the noise levels inside a vehicle through means such as introducing dampening materials inside chassis panels and increasing the thickness of window glass. These enhancements have resulted in drivers expecting a much quieter ride, not only in higher-end luxury vehicles but in the lower-end entry level as well.

Expanded warranty coverage leaves transmission manufacturers exposed to claims for a longer period of time

Any unexpected noise or vibration emanating from the transmission such as whine, rattle or knocks can have an adverse effect on the customer's perception of the transmission and the vehicle in general. The noise or vibration may not influence the short-term transmission performance but the customer may still perceive the transmission to be somehow defective. Ultimately the customer may make a warranty claim. In most cases these claims are settled in order to maintain customer satisfaction. These types of warranty claims contribute to the $22.6B in warranty costs that vehicle manufacturers[1] face on an annual basis.

Noise and vibration measurements have been used for a long time as a quality appraisal tool on the transmission production line. The challenge for transmission manufacturers is to understand the level and characteristics of noise that is within consumer tolerance and expectations then translate this subjective limit to an objective measurement for testing purposes. In the past, most transmission manufacturers have relied on the experience of their production personnel to identify defective transmissions based on the

[1] AMR Research. "Today's Vehicle Quality Improvements Lie Within Yesterday's Warranty Issues". February 12, 2004.

sound that they emit during functional or end-of-line testing. The speed, accuracy and objective nature of an instrument system is far more accurate, repeatable and reliable to even the most trained ear. Emerging NVH test systems are capable of the measurement, analysis, classification and diagnosis of complex sensory inputs from transmissions to provide accurate and real-time quality judgements.

3. WEAKNESSES OF TRADITIONAL NVH TESTING MECHANISMS

The subjective nature of using plant operators to test for NVH during production, in conjunction with the use of inappropriate test measurement techniques means that defective transmissions may pass to the vehicle operations plant or worse they may make it to the end customer and result in costly warranty claims. Ineffective testing techniques may also hamper productivity when good transmissions are misdiagnosed and sent for repairs.

Some test systems lack comprehensive classification systems and result in false accepts or false rejects of transmissions, impacting manufacturer quality or throughput. Other systems do not provide communicative diagnosis of the defect causing a failed transmission. This diagnosis capability is invaluable in facilitating defect repair management or in enabling root cause traceability and continuous process improvement initiatives.

Some test systems are not capable of capturing, processing and analyzing the extensive data required to detect some defects. For example, some faults may only be apparent at certain transmission speeds. To detect these defects the transmission test cycle must be conducted in a comprehensive way, using careful speed control and the capture of a large amount of data.

Another common weakness of traditional transmission NVH testing is that the same systems used for testing in the laboratory during the transmission design stage are being used in the production environment. These systems are not robust or built for high-volume operation and result in continuous failures when deployed in manufacturing environments. Laboratory type systems are also built for engineers and do not have the ease of use required for production plant operators. When selecting a transmission NVH system for high-volume transmission production, it is imperative for the system to be robust, production floor ready and easy to use.

4. NVH TESTING TECHNIQUES

NVH test systems consist of sensors, a measurement system, a classification system and the result – a pass or fail judgement.

Sensors

There are two types of sensors – contact and non-contact. Sensor selection depends on cost constraints, the environment where testing will be done and the specific defects that need to be detected.

Typical *non-contact* sensors such as a microphone or laser velocimeter are not connected to the product under test. Although they may have advantages for certain applications, they may not be adequate in some production environments. For example, a microphone is not industrially robust and requires frequent calibration. Background noise can also cause inconsistencies in results.

A *contact* sensor such as a piezoelectric accelerometer is attached to the transmission, and has certain advantages such as its level of robustness and its relative immunity from background noise. Contact sensors also tend to be less expensive than non-contact sensors.

Measurement System

The measurement system takes the signal from the sensors and manipulates it into meaningful data. The noise or vibration signature of the transmission can be extracted, and features from the signature can be analyzed. The signature may be processed from time domain to frequency domain by use of a Fast Fourier Transform (FFT). Additional useful information and measurement accuracy is gained if the time domain data is converted to angle domain data by using a shaft angle position sensor (such as an encoder), providing an order based spectral analysis.

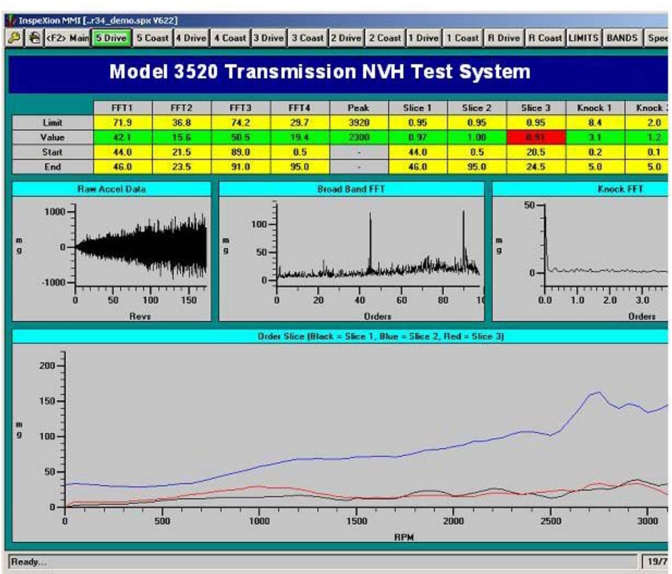
Various processing techniques should be used:

- ***Time or angle Domain Analysis*** is particularly useful for transient event detection. Time domain analysis is optimal when looking for defects that would cause knocks and clicks on a mechanism at a known time or position during the test cycle. An example of this scenario would be a gear nick that causes an impact at a predictable and repeatable gear position.

- ***Frequency Domain Analysis*** is the most common tool used to detect and diagnose defects. The FFT analysis is used for analysis of signatures with a repetitive pattern, and can also be used to detect the excitation of a natural frequency. Frequency domain analysis is a powerful tool for the diagnosis of transmission defects such as gear whine and bearing defects. These defects are generally associated with predictable noise frequencies and subsequent harmonics.

- ***Order Analysis*** is a variation of frequency domain analysis. This technique helps to resolve the problem of accurate tracking of frequency content such as gear whine that could be lost or misread by slight changes in running speed. The "order tracked" or "order normalised" signature may be used for other analysis associated with high frequency excitations dependant upon the transmission configuration.

The following diagram is an example of transmission test waveforms where classification can be used to diagnose the source of the defect.



Classification
The above processing techniques lead to measured noise characteristics that are logically attributable to specific transmission features and quality. Most defects can be identified by analyzing specific features on a result waveform. When optimal processing techniques are applied to each relevant transmission feature, an excitation map can be defined to identify and classify defects.

The classification system then determines if a test signature falls into the "normal" or "abnormal" result category. Normal ("Pass") or abnormal ("Fail") criteria can be established using engineering standards and specifications, results from road tests or even by converting subjective jury listening assessments into an objective/scientific measurement. Optimally, this evaluation is made during production in virtual real-time. If the signature is determined to be abnormal, the system should provide the engineer with a diagnosis of the defect that caused the "abnormal" assessment. This classification data will reduce the required repair time for the failed part.

Advanced transmission NVH test systems should have the ability to statistically 'learn' acceptable threshold levels by capturing the knowledge of an expert panel and transforming this knowledge into scientific test limits. In other words, the test system should be able to 'learn' what experts consider to represent good or bad transmission NVH and pass or fail transmissions accordingly.

Result
The pass/fail result should be passed to a birth history system for storage and further analysis or to a repair area to facilitate efficient repairs. Results can be saved as simple Pass/Fail indicators including information to aid repair.

5. OPTIMISING TEST SYSTEM SETTINGS

Armed with valuable understanding of the manufacturing process and comprehensive test results, manufacturers will be equipped with the insight they need to optimize their transmission NVH test system. The understanding of defect root cause may lead to upstream testing to isolate defects as early in production as possible. For example, if Pareto analysis reveals that damaged gears are the most common defect detected by transmission NVH testing at final test, then a process change can be introduced upstream to eliminate the defect from occurring and a new test can be implemented to catch the problem before it reaches end of line testing. Identifying transmission defects or process abnormalities at the earliest possible production stage can result in substantial savings (please see Sciemetric's "In-Process Test Blueprint of Transmission Manufacturing" for more details).

Test optimisation can:

- Reduce test cycle time
- Reduce false rejects
- Reduce test process failures
- Maximise sensor life expectancy
- Exploit advanced processing techniques for other non-NVH defects

An effective transmission NVH test system should come with an integrated SPC (Statistical Process Control) module to allow optimisation of the test system by statistically updating of the classification system. There will be natural changes to the test parameters during a production run, and these may be tracked and monitored using statistical analysis. This mechanism may be used to facilitate a continuous improvement process.

6. EMERGING NVH TECHNOLOGY

Recent advances in waveform analysis allow both time and frequency domain data to be displayed and analysed in an efficient manner. This is useful for detecting defects such as chafing components. Creation of proprietary algorithms for specific defect mapping is possible given the range of engineering software available to the NVH engineer. Complex mathematical manipulation of waveforms can provide engineers with enhanced insight into process and quality weaknesses.

The decreasing cost of sensors such as laser velocimeters is encouraging the use of non-contact sensor arrays for transmission NVH measurement. Non-contact sensors have the advantage of providing versatility as they can be suitable for both production and laboratory use. Engineers can use a laboratory measurement sensor in a production environment, saving time in the feasibility and pilot phase of deploying a transmission NVH solution.

7. PRODUCT QUALITY MANAGEMENT

A comprehensive transmission NVH testing solution should include a system to archive test results. Results should be archived by serial number and include the actual test result waveforms. Storing complete waveforms equips the manufacturer with actionable information. For example, if required, specific transmissions could be isolated for recall without having to issue a costly and damaging general or batch recall. Defects and deficiencies can also be traced to the level of individual stations, operators, shifts, and sub-components. This capability facilitates rapid identification and resolution of process and product problems before significant costs for repair and rework are incurred. Finally, storing complete waveforms allows the transmission manufacturer to quantitatively demonstrate to vehicle operations plants their commitment to the quality process, ensuring that transmissions have been manufactured and tested according to specifications.

8. KEYS TO SUCCESSFUL NVH TESTING

The keys to successful NVH testing are process, people and practise! The process of testing transmissions for their noise, vibration and harshness can be split into phases;

- ***Test requirement planning, including costs, timing and responsibilities:*** The planning phase should include cost and timing studies, with good prior knowledge of the transmission design, and potential defects. Reference to the transmission manufacturing failure mode cause and effect analysis will facilitate the planning of measurement verification.

- ***Feasibility and test experiment verification:*** The feasibility study should make careful study of critical test aspects such as sensor selection and utilization, signal processing and analysis routines.

- ***Pre-production line validation:*** The pilot phase and the feasibility study may, in certain applications be made 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:*** Should provide accurate and consistent test results and facilitate continuous process and quality improvement.

9. BENEFITS OF ACCURATE TRANSMISSION NVH TESTING

Effective transmission NVH testing will allow manufacturers to:

- Reduce costs by detecting NVH issues during production where repairs are less complex and less costly than when discovered by vehicle operations, dealers or end customers.
- Minimize the impact of quality spills by isolating units with specific NVH problems.
- Improve their production process using root cause understanding.
- Improve the sound quality of their transmissions.
- Improve customer satisfaction and industry reputation.

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For more information on how you can catch more transmission NVH defects and improve your transmission quality call 1-877-931-9200 in North America *(see our Web site for international contact information)* or email inquiries@sciemetric.com.

About Sciemetric® Instruments

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Sciemetric customers are leading manufacturing companies in the automotive sector. Customers who have implemented Sciemetric solutions to help them achieve their quality and productivity objectives include Fortune 500 manufacturers such as Ford, General Motors, DaimlerChrysler, BMW, Delphi, Visteon, Behr, Cummins, John Deere, Caterpillar, Mazda and Saturn.

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