Whitepaper

Applied Vibration Analysis for Acoustic Quality Assurance in Production

Application and benefits of vibration analysis for the acoustic quality control of drive train components in automotive manufacturing

Author: Dipl. Ing. Michael Ruthrof,
Managing Director of red-ant measurement technologies and services
Date: 02/10/2010

1 Introduction

Car buyers usually want a vehicle with as little disruptive noise as possible. Previously, the engine noise largely overshadowed all other sounds. With the increasing encapsulation of the engines other sounds now become apparent in the foreground. For example, transmissions with only slight deficiencies emit audible noise, which are considered particularly critical in assessing the overall noise level in the vehicle. An acoustic vibration quality assurance diagnosis of the engine and transmission production can prevent bad transmissions with acoustically perceptible faults, such as howling, whistling and knocking or motors with conspicuous acoustic problems from being installed in the vehicle and reach the end user.

2 Vibration Diagnosis in Manufacturing

Despite many early quality checks, during the production of engines and transmissions occasionally assembly errors and / or defective parts may be fitted. The sum of component tolerances can, when assembled, also lead to a particularly noisy engine or a howling transmission (in the following referred to as product).

The assembled product is extensively tested during the final functional testing. Usually a human inspector will subject the product to a subjective noise test.

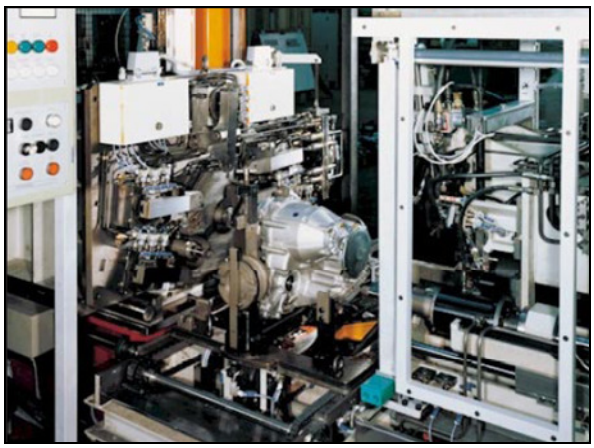

Figure 1: Test bed for acoustic quality control for automatic transmissions.

Vibration diagnostic measurement systems are usually used to increase process reliability and traceability of the noise testing. In this way the vibration diagnostics provide an acoustic quality assurance (AQS) for the products tested. Red-ant offers the highly specialized measuring system MIG16 AQS for this purpose.

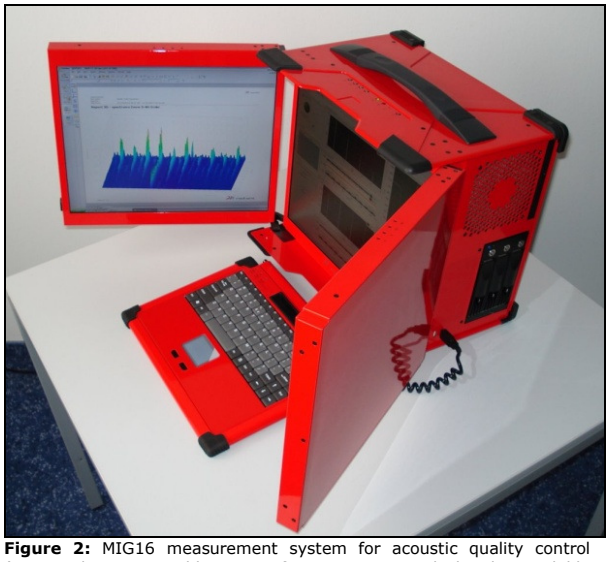

Figure 2: MIG16 measurement system for acoustic quality control (picture shows a portable version for measuring a vehicle, also available as a 19-inch junction box).

2.1 How does AQS work?

AQS measurement data from the products tested as well as the operating data of the test run are recorded. The main input signals are the vibrations at different points on the device under test (measured as units of acceleration) and rotational speed. In addition, torque, gear ratio and temperature may be recorded as well.

The following figure shows a possible scheme to measure these signals in an automated end-of-line test bed for a heavy duty vehicle manual gearbox with integrated axle and wheel head. An engine testing scenario will have a similar connection scheme.

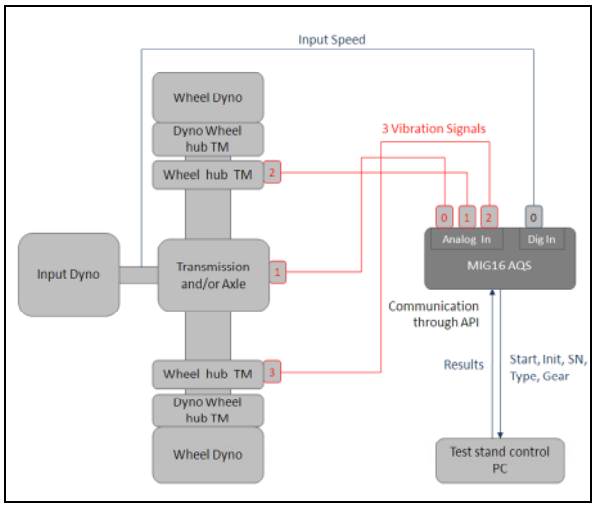

Figure 3: Wiring diagram of an AQS-measurement system on an end-of-line test bed for functional and noise testing of transmissions and axle drives.

At the beginning of the measurement the type and serial number of the test specimen as well as the launch of the individual test steps (e.g. 1st gear thrust, 1st gear brake etc.) are transmitted from the test bed computer to the AQS-measuring system via an interface.

The signals are then recorded by the AQS-measuring system and digitized. So-called NVH indicators are calculated from the digitized signals in real time and compared with limit values. If an indicator exceeds a threshold in the course of the examination, then the device under test is marked as failed. If the NVH indicators remain within the limits, then the device under test is passed. In conclusion, the test results of the AQS-measuring system are passed via the interface to the test bed computer and any other computers as well (e.g. control room).

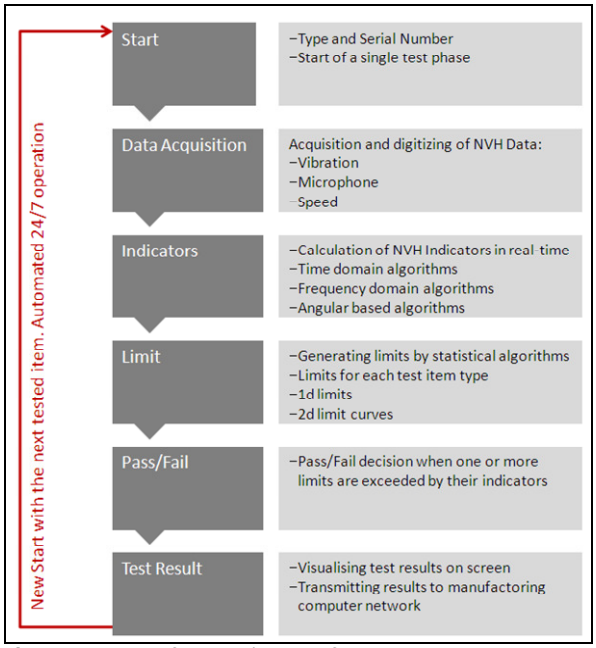

Figure 4: Course of events diagram of an AQS-measurement system on an end-of-line test bed for functional and noise testing of engines, transmissions and axle drives

An important point is the setting of limits for the NVH indicators. The system learns the limits for different operating points (torque, rotational speed) usually automated by way of passed and failed samples.

In addition, there is the possibility to automatically learn by way of statistically identified limit values without sample inspection during production. Here, a simple statistical method which has been well-proven: A certain number of products in current production are selected, from which the parameters, mean, variance and standard deviation are calculated. From these static values the pass sample is defined with which the rest of the production is compared.

2.2 What does AQS deliver?

The following four points are provided by an AQS-measuring system:

- Detection and marking of noisy items
- Error determination
- Documentation of the delivery condition of the device under test
- Safeguarding personnel and the test stand from tested items with severely defective parts

Detection of noisy items

Noisy items under test are caused mostly by errors in assembly or by fitting defective components such as gears or bearings. Less often, an assembly with components which have borderline tolerance values leads to a noisy transmission or engine. With gear mesh, one distinguishes between tonal noise (howling, whistling), periodically recurring noise (knocking, rattle) and aperiodic noise (shifting, rattle).

Error determination

An AQS-measuring system can capture the above-mentioned errors and document them objectively. By analyzing the data using modern vibration diagnostic techniques such as digital angle synchronous order analysis and 3D structure-borne sound detection, the cause of the noise can also be diagnosed. The following figure shows the extensive data of a manual gearbox with integrated axle, from which the error is determined.

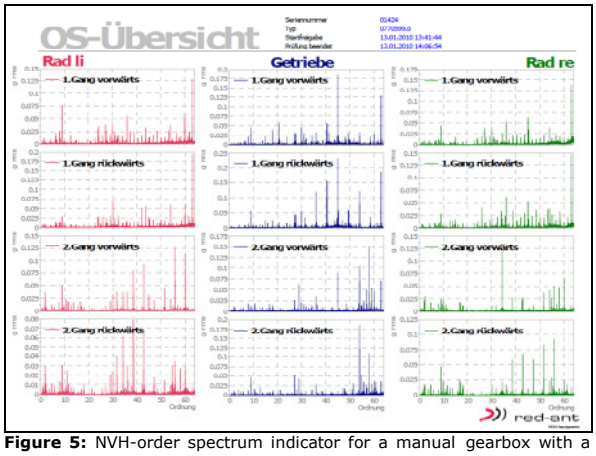

Figure 5: NVH-order spectrum indicator for a manual gearbox with a flange attached axle.

From these data, a repair directive for the downstream repair station will be automatically issued.

Documentation of the condition of the item

The advantage of an objective acoustic noise test is that the state of the device under test has been documented when it left the plant. Should the end customer have complaints at a later time, a re-examination will detect any differences and determine their causes (transportation, improper filling of lubricants etc.).

Objective noise testing prevents the delivery and further work on noisy products. Thus, decommissioning costs can be saved, which usually have to be borne by the supplier of the product.

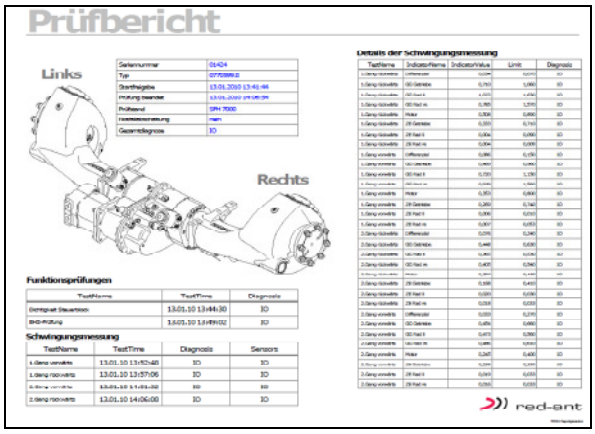

Figure 6: Audit report of the product with serial number, type, date, drawing, functional test results, results of vibration measurement in short form (left side) as well as all detailed NVH indicators (table on the right side).

Safeguarding personnel and the test stand from tested items with severely defective parts

The final functional testing of engines and transmissions generally requires the proximity of staff to the device under test. At the same time high kinetically bound energy is present (high speeds and torques). If the assembly of the product is not appropriate, so that the device under test is damaged or destroyed, this can lead to property damage and personal damage on the test bed.

A special feature of the red-ant measuring system MIG16 AQS is that the entire test will be monitored in real time. Should damage occur during testing, the measurement system triggers an emergency shutdown of the test bed before the component is destroyed. The following figure shows the course of an AQS-examination from the perspective of the emergency shutdown operation.

Figure 7: Emergency shutdown after permanent body sound monitoring during the AQS examination of a manual gearbox with a flanged axle. Upper graph: Rotational speed profile during the entire measurement, 1st gear driving, 1st gear braking, 2nd gear driving and 2nd gear braking. Lower three graphs: black line: NVH indicators of different measuring points (top to bottom: left wheel head, manual transmission, right wheel head), red lines: Limit values.

2.3 What does AQS cost?

The capital investment in an AQS measurement system is usually 30,000 to 80,000 Euros, depending on the complexity of the testing and the devices under test as well as the number of channels and sensors. In relation to the cost of a test bed a rather low price because it is only about two to five percent of the total expenditure.

In general, the investment in an AQS-measuring system pays for itself within two to three years by reducing the decommissioning costs and fewer warranty costs due to the premature failure of the product.

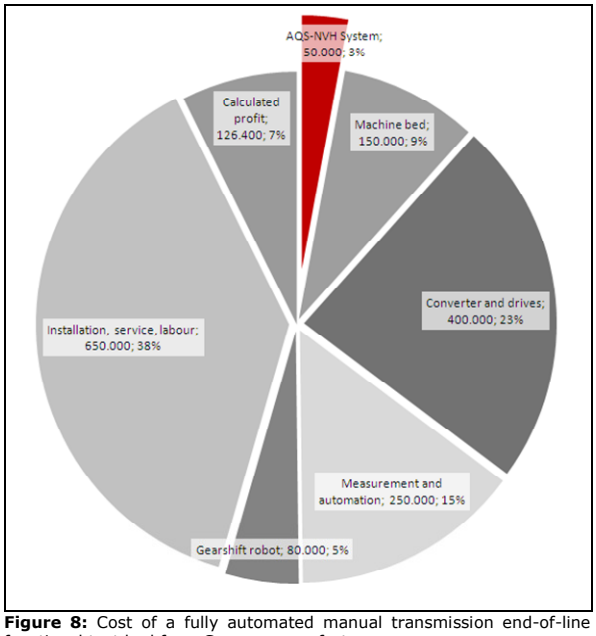

Figure 8: Cost of a fully automated manual transmission end-of-line functional test bed for a German manufacturer

3 Summary

The report shows that a positive effect of the use of vibration measurement diagnostic systems for quality assurance in production both in economic terms and with a view to optimizing production processes and the safety of personnel can be achieved.

The descriptions of the application and the performance of the AQS-measurement systems allow one to infer that its high precision and resulting product improvement can be accrued.

The concluding economic analysis shows the relatively low cost in relation to other related expenditures.