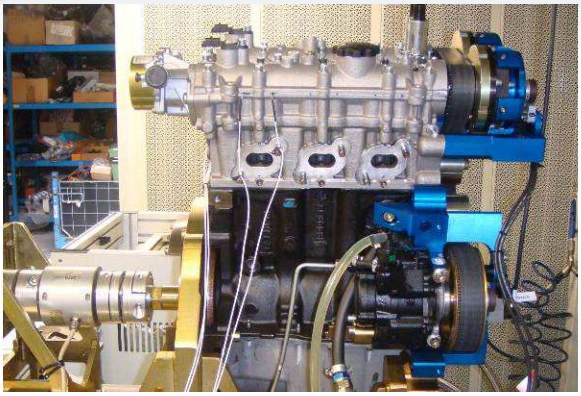
APPLICATION NOTE

Torsional vibrations measurements on engine timing

Camshaft torsional model validation - Advanced prototyping of car engine downsizing, *with E. Esterlingot Engine dept manager, Danielson Eng.*



Introduction

The **engine testing dept**., located close to the international racing circuit at *Magny-Cours* in the center of France, conducts **prototypes' manufacturing** (foundry, assembly) and **tests** (acceptance, durability, design validation). The dept test benches are **equipped with OROS systems for dynamic measurements** (vibrations, torsional, strain). The OR36 16 channels analyzer offers a **reliable** and **accurate front-end** plus narrow band, synchronous order analysis and torsional acquisitions for **real-time and post processing analyses.**

OR36 16 Channels

- **Made for the field**
- **Rugged**
- **Rough**
- **Reliable**
- **Portable**

NVGate Software

Modern and user-friendly software with specific modules:

- **Synchronous Order**
- **FFT**
- **Recorder**
- **Torsional inputs**

Since 30 years, **Danielson** group provides **engineering support** and **off-the-shelf solutions** for propulsion systems dedicated to standard application manufacturers. The 3 entities of the group (Engineering, Services and Aircraft systems) serve for the automotive, and the aeronautics/defense industries. Danielson Engineering is a CRO (Contract Research Organization) **engineering company** specialized in the **design, manufacture** and **development** of **engine prototypes** for validating new engine concepts for car and automotive equipment manufacturers.

http://www.danielson-eng.fr/en/danielson-engine-testing-98.html

Danielson Engineering clylider engine

Environment

The recent evolutions of the automotive industry and particularly the **propulsion innovations** push car manufacturers to develop lighter, cleaner and more economical models of their engines. In this tendency the company has been requested to support the **design validation** of the **downsizing** and **requalification** of an existing car engine.

The application accompanies the strong trend for downsizing car engines, going greener. It concerns the development of a **diesel engine** for the **automotive** industry.

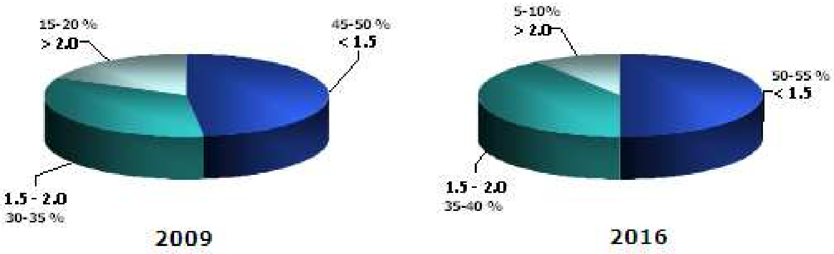


Fig1: Diesel Engines – Share of average Displacement ranges (in litres)

Validation of the camshafts torsional simulation model

This prototyped engine is a declination of a larger one. The load increase and the conjunction of the new rotational speeds with the natural frequencies of excited parts show the necessity to **adapt this part of the new engine**.
The timing (notched belt) of the prototype engine has been modeled with a FEM. This **simulation has produced typical torsional vibration signatures.** They are mainly leaded by the **belt and camshafts resonances**. At this step of the project, the digital model must be **validated with actual data** prior to be used for design evolutions. The final goal is the fine tuning of the valve timing and belt reliability.

Test stand and instrumentation

The engine test stand features a cylinder head with 2 camshafts with the entire timing including the fuel pump. The timing dynamic behavior is then correctly reproduced. The piston and intake/exhaust pipes are not present.
The crankshaft is driven by an electrical motor through a rubber belt and a torsional damper. This configuration protects the unit under test (UUT) from any torsional motion pollution being injected by the driving machine.

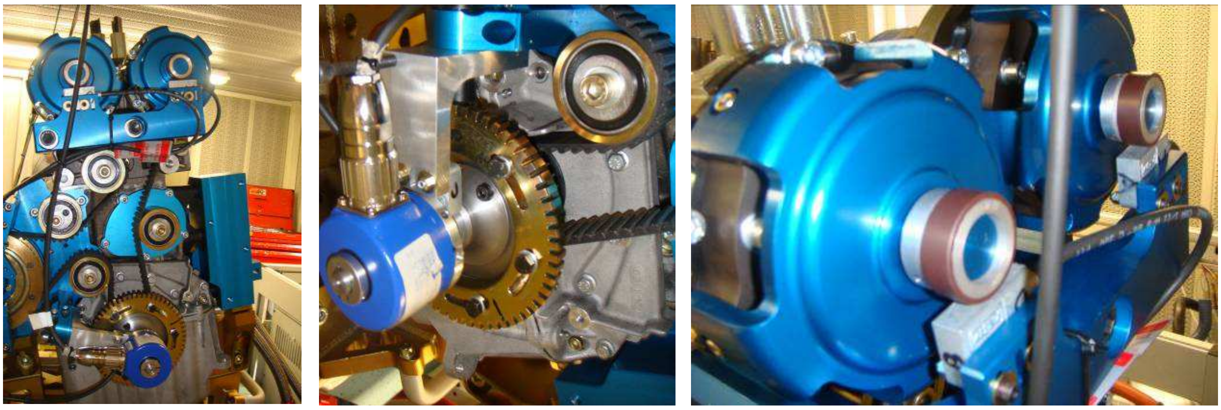


Fig2: - instrumentation of the distribution

The **instantaneous angular velocities** are measured with 2 detectors with **magnetic stripped rings** (50 points) on the camshaft and a **rotating encoder** (800 points) on the crankshaft.
The **valve actuation elements** are equipped with **strain gauges**. The strain signals show when the valve is pushed by the camshaft. It is used to measure the **exact time of the valve opening and closing** motions.

All these data are **acquired and analyzed with an OROS 3-Series OR36-16 channels analyzer**. The 3-Series analyzers have been chosen by Danielson Engineering for their **native qualities** of **robustness** and **real-time**. The **integrated torsional inputs** associated with the fast/accurate **synchronous order analysis** on DSPs are also keys features requested for engines measurements.
For this application, the following options of the OR36 analyzer are used:

- Parallel t**hroughput** recording
- **Narrow band** spectral analysis (FFT)
- **Synchronous order** analysis
- 6 **high speed torsi**onal inputs (6.4 MHz)
- **Virtual input** calculation
- **20 kHz** bandwidth

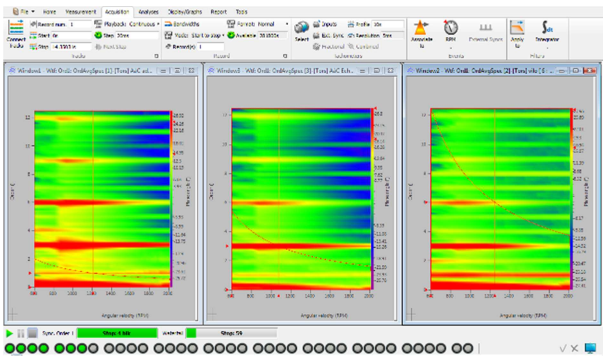


Fig3: - OROS NVGate software showing torsional order color spectrogram

A dual 21” screen configuration has been setup in order to **comfortably display the multiple data and results** provided by the real-time analysis. Several **3D waterfalls** were used to **monitor the torsional** behavior (Angular motion) of the camshafts and crankshaft during the trial.

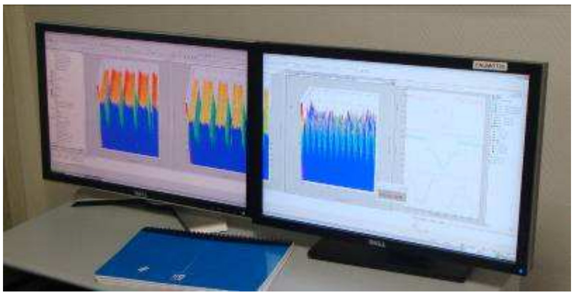


Fig4: - Dual screen configuration (real-time waterfalls)

The torsional channels are measured by delta-t method to get the instantaneous velocity and then both differentiated and integrated.
The **derivation gives angular acceleration** as a good marker of the **structural modes** of the camshafts. The **integration provides angular displacements** which are then subtracted to get the **belt length variation** between the 2 camshafts.

Measurements & results

The first run-up showed strong and noisy vibrations of the test engine which broke the tension roller. The next runs up where carefully monitored and conducted to avoid this situation.

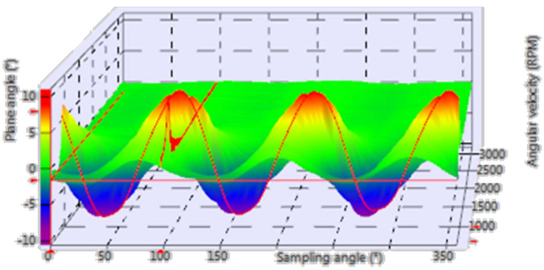


Fig5: - Intake camshaft angular deviation run up

First, the **waterfall of the camshaft angular deviation** is displayed. The signals are **re-sampled in the angular domain** (0 – 360°) in order to **compare each cycle** whatever the engine RPM.
A main resonance at order 3 is clearly visible. The deviation is about ±1.5° for the crankshaft where it is about ±6° for the camshafts.

Next, **a color-spectrogram of the camshaft torsional order** is used to determine the main orders. For this purpose, the NVGate interface allows **mixing order profiles with overall power**.
The max order function confirms that the main orders are 1st, 3rd, 6th and 9th. This corresponds to the FEM (Engine cycle + Order 3 and harmonics).
The selected order are then directly measured with the **synchronous order analysis plug-in**, providing **complex order profiles of the angular deviation** for each run-up.

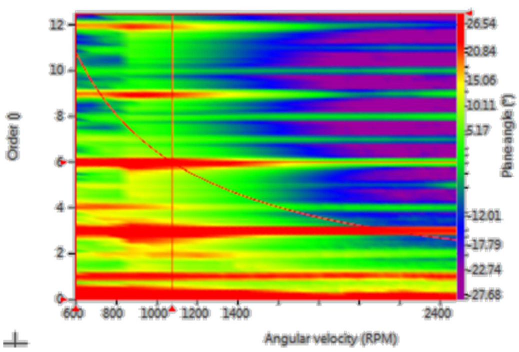


Fig6: – Max order Identification

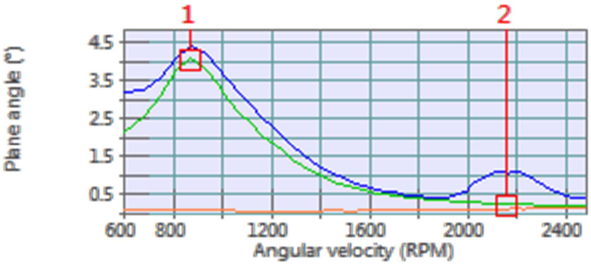


Fig7: - intake camshaft orders

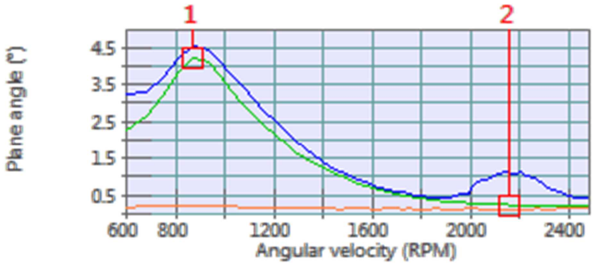


Fig8: - Exhaust camshaft orders

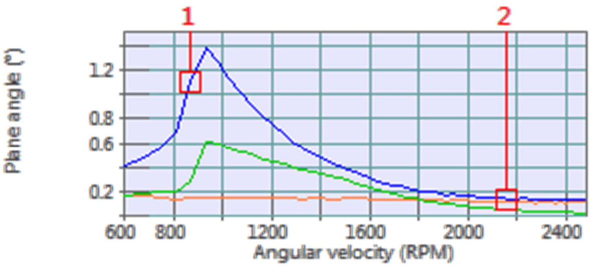


Fig9: - Camshaft difference orders

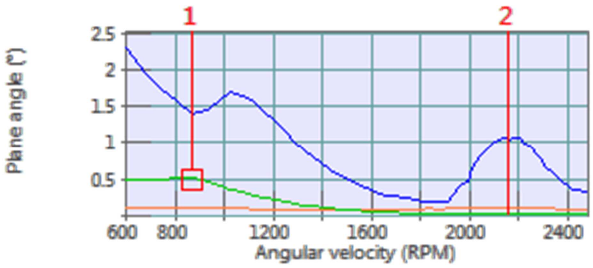


Fig10: - Crankshaft orders

Different parameters have been tested to validate the various simulations such as temperature and timing type (VVT, Phase shift pulley). All the **measurements** and analysis **results** are **saved in the NVGate project manager database**.

Conclusion

The collected result has **confirmed the validity** of the dynamic simulation. It also provided accurate data for **adjusting the model**.

The expertise of Danielson Eng. people associated with their flexible test stands equipped with real-time OROS analyzer made this model validation a success.

OROS, Leadership through Innovation

About Us
Now approaching 30-years in business, OROS' designs and manufacturing have been renowned for providing the best in noise and vibration analyzers as well as in specific application solutions.

Our Philosophy
Reliability and efficiency are our ambition everyday. We know you require the same for your measurement instruments: comprehensive solutions providing performance and assurance, designed to fit the challenges of your demanding world.

Our Emphasis
Continuously paying attention to your needs, OROS collaborates with a network of proven scientific affiliates to offer the latest of the technology, always based on innovation.

Worldwide Presence
OROS products are marketed in more than 35 countries, through our authorized network of representatives, offices and accredited maintenance centers.

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