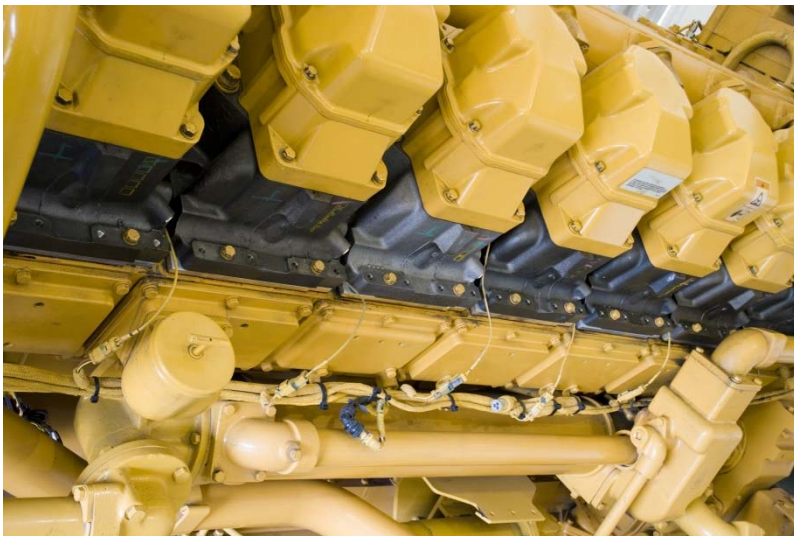


EngineDiag

The Reciprocating Machines Diagnostics Module

Introduction

Reciprocating machines are complex installations and generate specific vibration signatures. Dedicated tools associating the machine mechanical characteristics and high performance analysis capabilities are necessary to understand the dynamic behavior of these machines. With EngineDiag, OROS takes up the challenge to offer this tool integrating in one product its know-how as well as innovative methods for enhancing test efficiency. Pertinent decision criteria are available on the field skipping a long office work.



Industries

- > Energy & Process
- > Marine
- > Ground Transportation

Machines

- > Engines
- > Reciprocating Compressors
- > Piston Pumps

Applications

- > Design optimization
- > Field acceptance test
- > Troubleshooting & Diagnostics
- > Long term monitoring



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Description

The EngineDiag module is completely integrated in to NVGate, the OROS 3-Series analyzers software platform. It allows one to work in an environment dedicated to the reciprocating machine while taking advantage of all the NVGate capabilities.

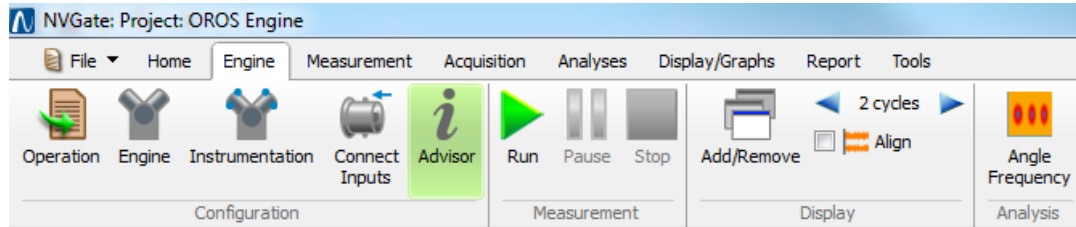


Fig2: Engine ribbon in the NVGate platform

Engine Model

The engine model corresponds to a type of machine. It relates the engine characteristics to the measurement. An engine model is defined by:

- > The mechanical settings
- > The timing diagram
- > The instrumentation
- > The type of analysis realized on the machine

Settings

Various engine models exist. They are classified depending on the following characteristics:

- > The power delivered
- > The nominal speed
- > The configuration: Inline or Vee
- > The cycle : 2-stroke or 4 stroke
- > The number of cylinders
- > The firing order

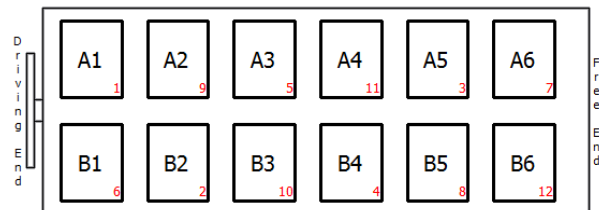


Fig3: Engine schematic representation with the cylinders and the firing order

All these main characteristics are necessary to understand the vibration signal acquired. For example, on reciprocating machines, it is useful to make the analysis on the machine cycle. This cycle is completely linked to the machine design. For a 2-stroke engine, the cycle corresponds to 1 crankshaft revolution (360°) and for a 4-stokes engine, it's equal to 2 crankshaft revolutions (720°).

Timing

The timing information corresponds to the machine kinematics. The cycle of each reciprocating machine is divided in to several phases. These phases are separated by kinematic events. The figure below shows the typical cycle of a 4-stroke diesel engine with the different phases:

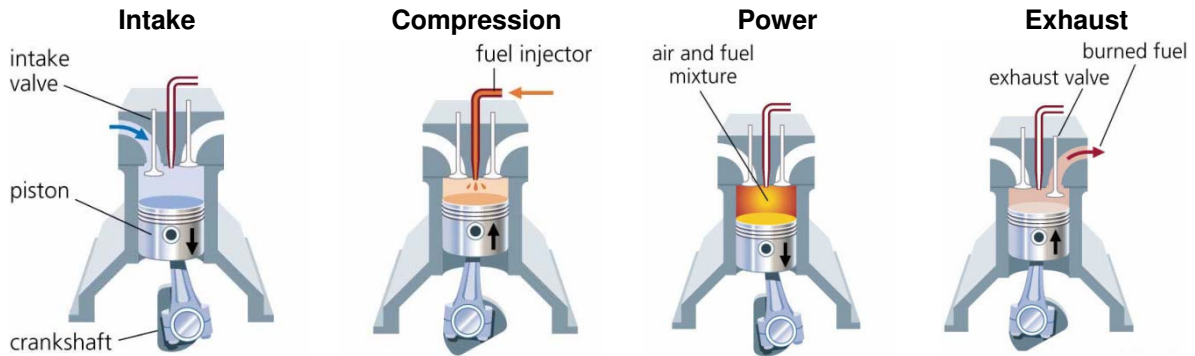


Fig4: Four-strokes engine cycle

The duration of each phase is defined by the valves opening and closing. The position of these events is given in angle relative to the Top Dead Center (TDC) where the piston is at top of the cylinder or Bottom Dead Center (BDC) where the piston is at the bottom of the cylinder.

This information is generally contained in the timing diagram provided by the engine manufacturer. EngineDiag supports the ability to enter the timing diagram information to be used in the analysis.

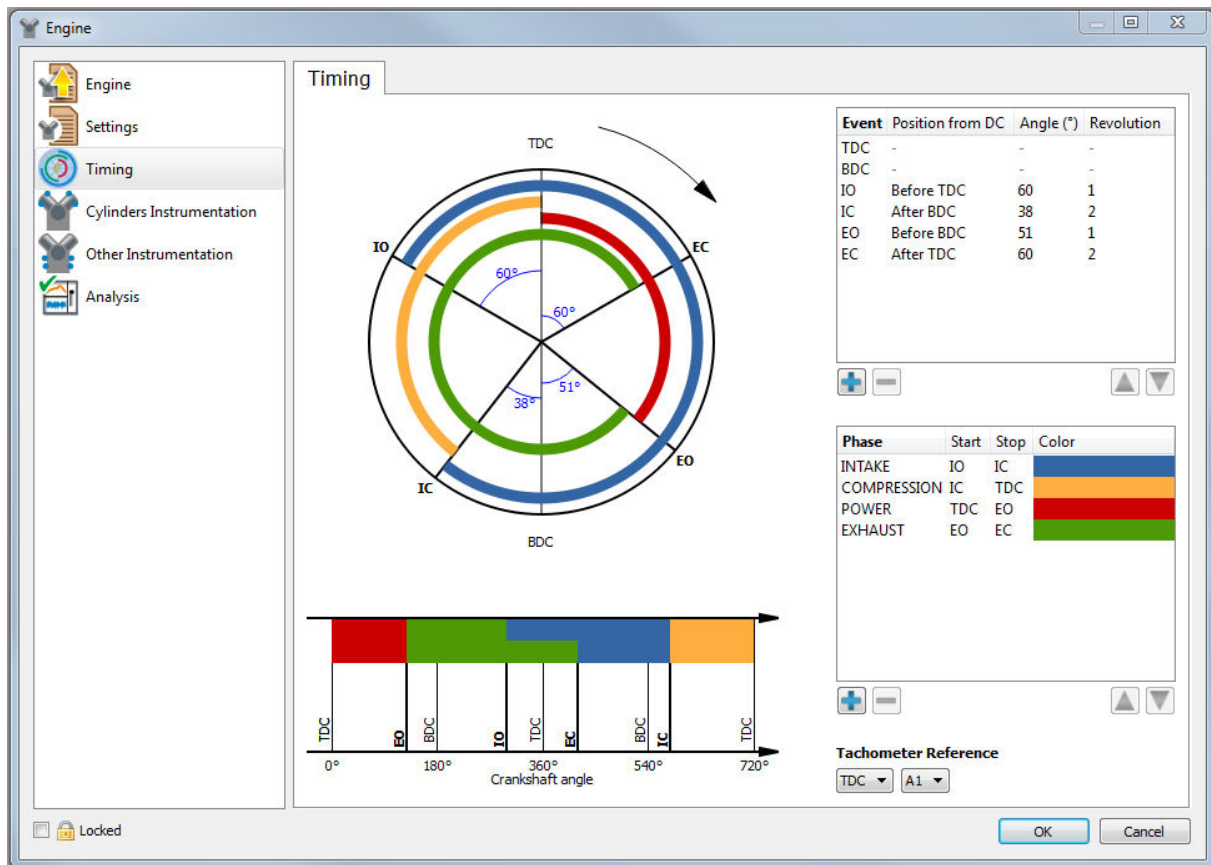


Fig5: Timing diagram and its linear representation (cycle overview) in EngineDiag

Instrumentation

One important consideration when dealing with vibration measurement for machinery health monitoring is the measurement reproducibility. Indeed, to be able to compare measurements acquired at different times, it is necessary to use exactly the same instrumentation: same transducers, same position on the machine.

To help the user on this point, EngineDiag proposes to define a typical instrumentation for each type of machine.

The instrumentation table shows:

- > All the transducers used whatever their type: accelerometers, pressure sensors, thermocouples, tachometers...
- > Their sensitivity
- > Their location (cylinders, bearings, absorbers...)

Analysis

Depending on the objective of the measurement, the type of analysis realized can be different. Recorder, FFT analysis, Synchronous Order Analysis are the main types of analysis used on reciprocating machines.

Advisor

From the Engine model, EngineDiag offers an Advisor to help to set up NVGate taking account all the characteristics of the machine and the objective of the measurement.

The advisor gives a status about the software configuration depending on the Engine model.

Using different colors, the advisor indicates the current status of the NVGate configuration.

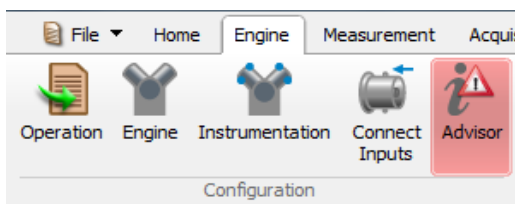


Fig6: EngineDiag ribbon with the advisor

	The measurement will not be done correctly. The configuration should be adjusted.
	Regarding the type of analysis selected, some settings are missing to obtain all the results.
	Regarding the type of analysis selected, the NVGate configuration is correct. The user can choose what results should be displayed and start the acquisition

In addition to give the status of the configuration, the advisor proposes the solutions to set up correctly the instrument.

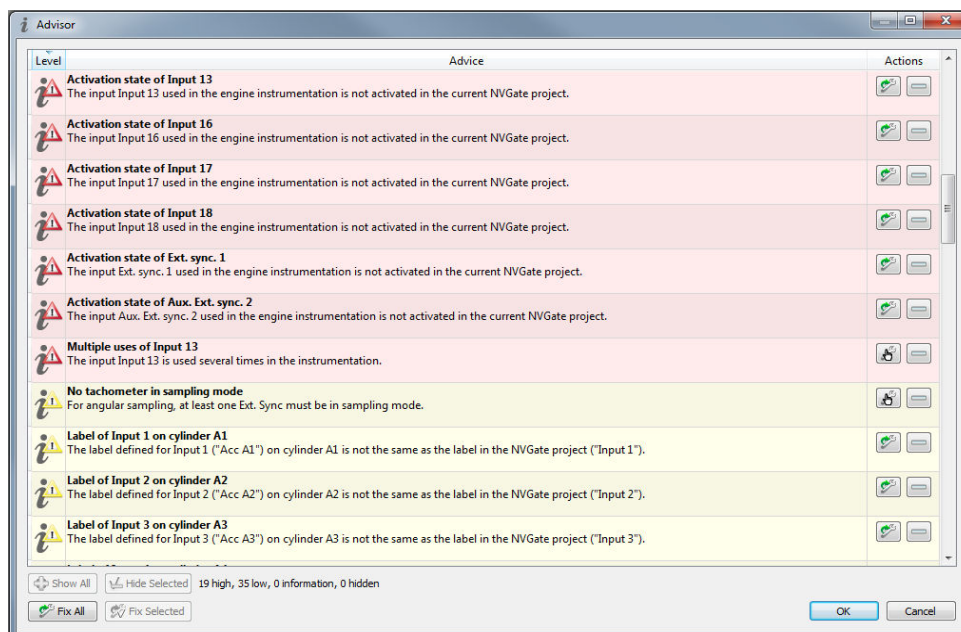




Fig7: The advisor window with several rules to follow

Among all the proposed solutions, the majority can be automatically applied by the advisor . When it's not possible to solve the configuration error automatically the advisor will indicate where and how to solve it manually . With the Advisor, it becomes easy to set up NVGate in minimal time without forgetting something critical for the measurement.

The Advisor displays the important rules to make a correct measurement. But the NVGate configuration remains available for your own settings. You can complete this first configuration to adapt it perfectly to your application.

Results

The specificity of the results proposed by EngineDiag is to integrate the machine kinematics. In each window the cycle overviews are displayed showing the different cycle phases.

Triggered blocks Engine

Based on the Synchronous order analysis, this result shows the time signal of the different cylinders. It has several specific characteristics:

- > The signal is displayed on one machine cycle. For example, 360° for a 2-strokes engine and 720° for a 4-stroke.
- > The inputs are automatically displayed in the firing order defined in the Engine model.
- > For each input, the cycle overview of the corresponding cylinder is also displayed.
- > With this function and the cursors linked between the signals and the cycle overviews, it becomes easy to identify the events observed on the signal.

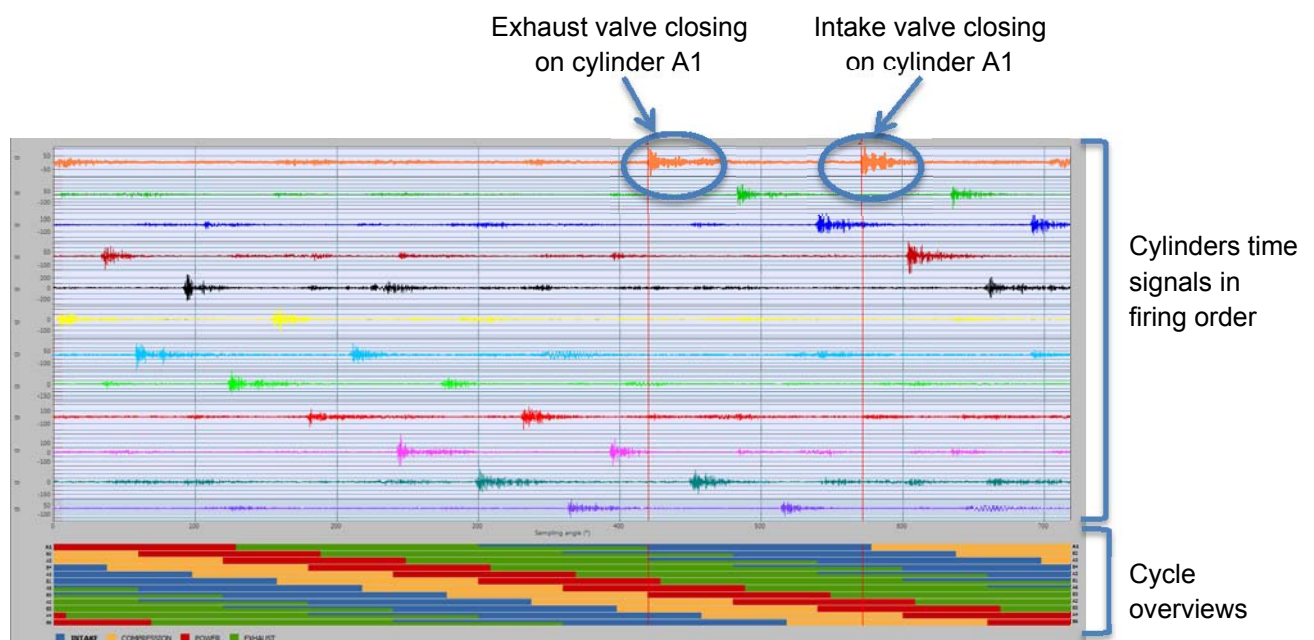


Fig8: Triggered blocks with the cycle overview of each cylinder

To still aid in the phenomena understanding and fault detection, it's possible to align these signals on a same kinematic event as shown in the graph below.

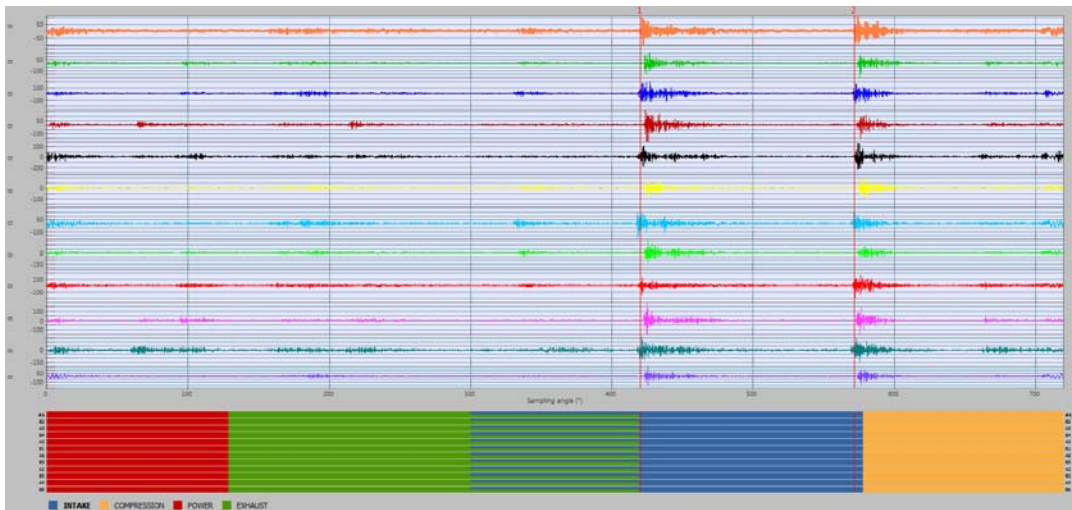


Fig9: Triggered blocks aligned on the same kinematic event

Overall level

The overall level gives good information about the health of a machine. But for reciprocating machines, this result must be calculated in a specific way and synchronized with the cycle of the machine.

The overall level calculated by EngineDiag is the overall level of the machine cycle averaged along the measurement. To go further and identify the fault more in details, overall levels of the different kinematic phases (intake, compression,...) can be extracted. This extraction is made easily by selecting the phase on the cycle overview displayed in the window.

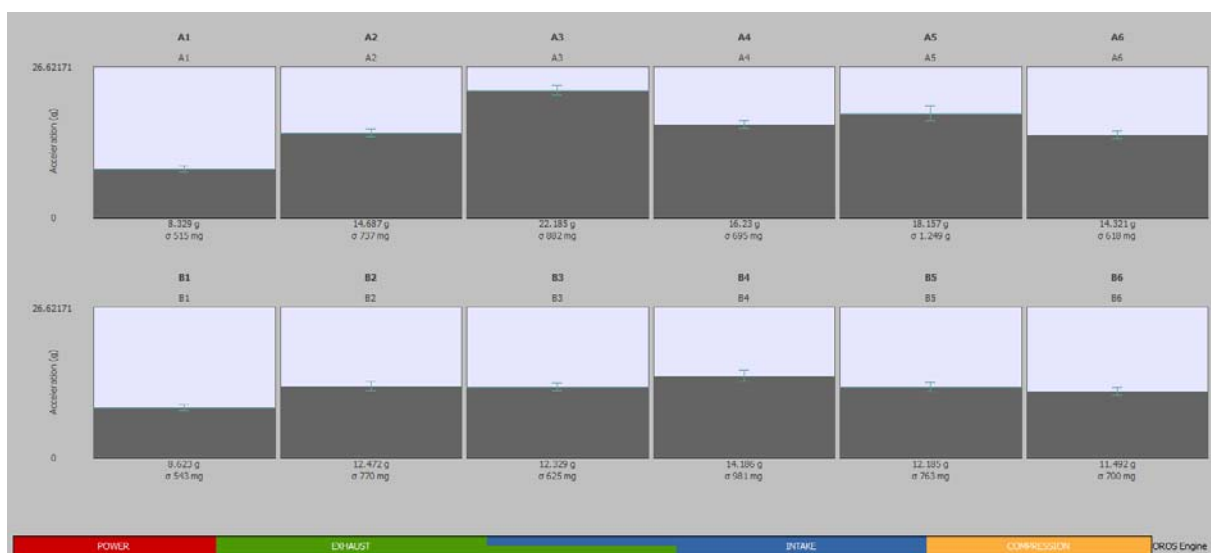


Fig10: Cylinders RMS value averaged by cycle on a measurement

To follow the evolution of a machine, the overall level of several measurements acquired at different times may be compared in the same window as shown in Figure 10.

The older measurements are taken as reference and the software detects if the level increase (in red) or not (in green).

This real-time display gives a first indication about the health of the machine during the measurement.

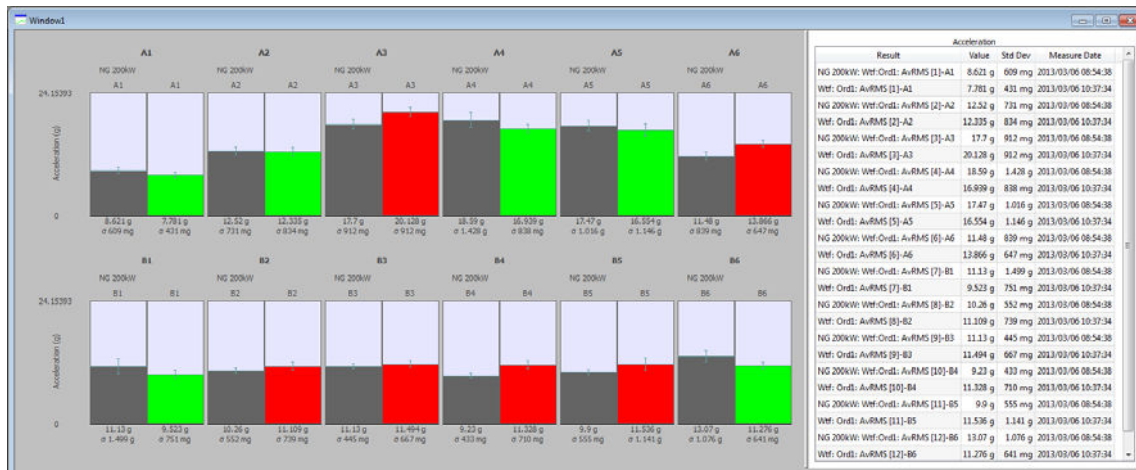


Fig11: Averaged RMS values comparison

This type of machine operates over several years. During this life time, a vibration history may be created and indicators can be trended over the long term. To observe the overall level evolution on a long period, profiles along date are more appropriate than the previous representation.

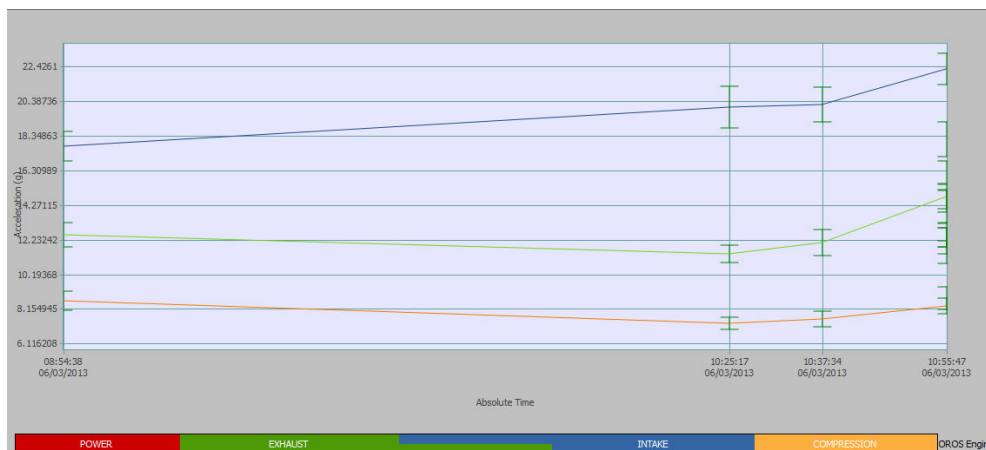


Fig12: Profile of RMS values in absolute time

Angle frequency analysis

Angle-Frequency analysis is interesting when working on reciprocating machines. It allows one to identify specific events.

The method implemented in the software is based on the Wigner-Ville algorithm.

This method is particularly adapted for short transient signal where the STFT is not sufficient. Another advantage is the good resolution, both in angle and frequency, that can be obtained.

The principle is to represent the energy density on a colorspectrogram using the Wigner-Ville distribution $W(\theta, f)$. The relevance of the results of such analysis depends on settings including angle and frequency resolution.

From this representation, additional results are extracted to make the analysis easier. They correspond to the integration of the energy densities on the engine cycle and on a selected frequency range. They are defined as follows:

- > Energy spectrum $S(f) = \int S(\theta, f) d\theta$
- > Instantaneous power $P(\theta) = \int S(\theta, f) df$

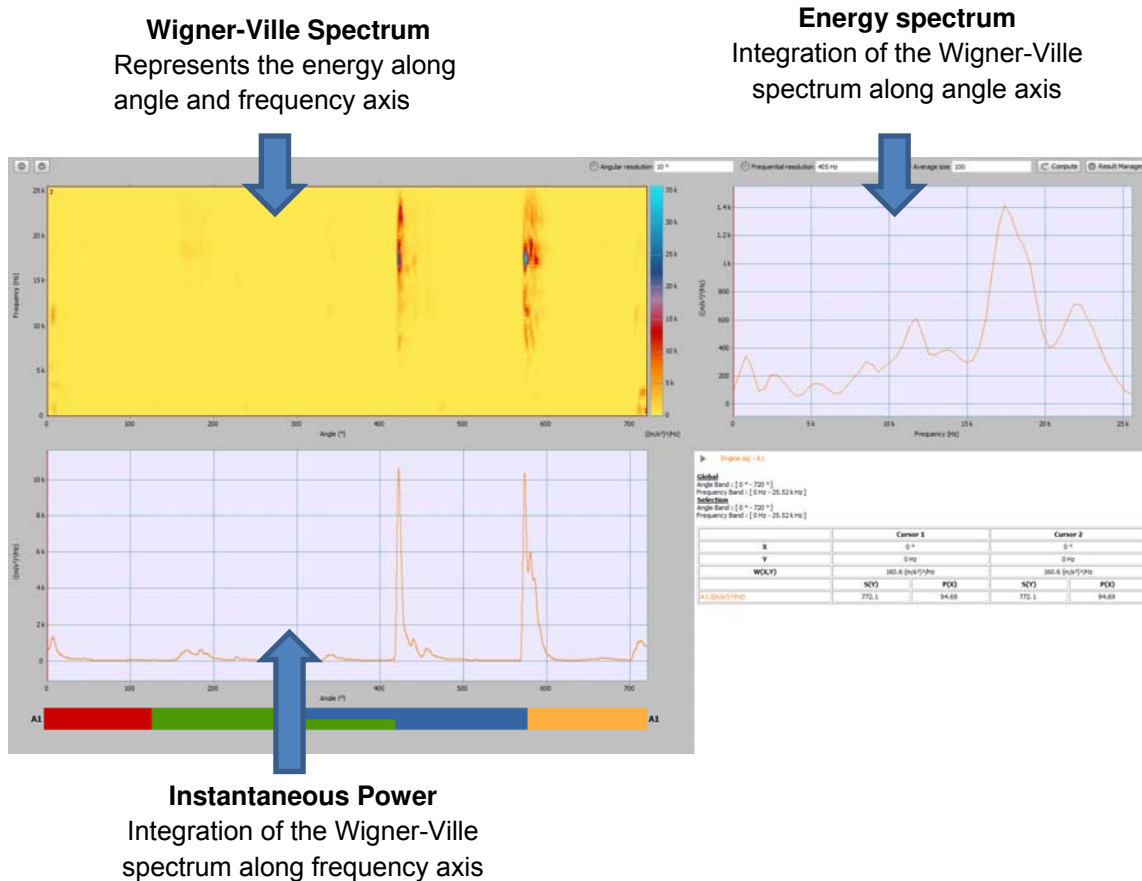


Fig13: Angle frequency representation: Wigner-Ville spectrum / Energy spectrum / Instantaneous power

The advantage of this display is to provide all the results in one window with intuitive tools for the analysis:

- > Extraction from the colorspectrogram
- > Linked cursors between all the results as well as the cycle overview.
- > The sidebar Infotrace displaying all the information (range, resolution, cursors values)
- > Possibility to compare several tracks from one signal or from different signals.

A Powerful and Flexible Range for your Needs

EngineDiag runs on or analyzes results from all 3-Series analyzers providing flexible choices of the hardware platform size.

- > OR38: 8, 16, 24, 32 channels
- > OR36: 4, 8, 12, 16 channels
- > Mobi Pack: 4, 8, 12, 16 channels
- > OR35 : 4, 6, 8 channels
- > OR34 : 2, 4 channels



Software modules such as **torsion**, **structural dynamics (ODS and modal)** and **acoustics** may be provided with the exact, same hardware platform. The user can carry, with the same instrument platform, the complete toolbox to work effectively on these machines.

Choosing OROS products and add-on services (training, renting and coaching), allows you to continuously optimize your tests on reciprocating machines.

On-Site Measurements & Applied Trainings

Experts from OROS come on-site for applied trainings. They will help you using your OROS system. They provide assistance in your measurement. They are also able to recommend optimization in your measurement process depending on your application and field constraints.

Applied training : Measurement on reciprocating machines with EngineDiag

Objective

Understand the behavior and the main characteristics of the reciprocating machines. From this, discover how to measure and identify the main phenomena that can appear.

With EngineDiag, learn how to associate the machines mechanical properties to the vibration measurements to obtain relevant results from your test.



Public

Technician or engineer with knowledge in vibration analysis dealing with reciprocating machines.

Program

- > Reciprocating machines characteristics
- > Integration of the machines characteristics in the software
- > Synchronous Order Analysis, the principle and features
- > Dedicated results provided by EngineDiag
- > Test setup
- > Analysis from real measurement
- > Report

Who should attend

- > Technician or engineer with knowledge in vibration analysis dealing with reciprocating machines

Duration 1 day

On-site measurements

- > Assistance in your measurement.
- > Expertise in diagnostics

Specifications

Configuration

Features	Description
Machine settings	Delivered power, nominal speed, configuration: Inline or Vee, the cycle : 2-stroke or 4 stroke, number of cylinders, firing order
Timing diagram	Kinematic events and phases
Instrumentation	Tables associating input, input label, connected transducer on and sensitivity
Advisor	List of rules depending on the Engine Model to set up NVGate automatically or manually

Analysis & Results

Recorder

Features	Description
Results	Raw signal
Dynamic channels throughput	Selectable recording sampling frequency (Up to 102.4 Ks/s). Independent from the measurement analysis settings.
Ext sync throughput	Records ext. sync at over sampled resolution (6.4 MHz).
Mode	Start to stop manual or triggered start and stop - Start to time fixed duration - Time to stop fixed duration before stop trigger, up to 2 GB rolling buffer on disk
Recording support	On Hard Disk, On PC
Post analysis player	Tracks update: Sensitivities, Units, Labels, Selectable playback speed

Synchronous analysis

Features	Description
Bandwidths / Resolution	DC to 40 kHz - 101 to 25601 lines – 1-1/32 order
Window	Uniform, exponential, force/exponential, hanning, hamming, flattop
Averaging	Linear, exponential, peal hold
Tachometer	Integrated high speed digital inputs with different modes : Trigger, Tachometer & angular sampling
Time results	Triggered block engine – Triggered block on one or several machine cycles with cycle overview display
Aligned Time results	Triggered block engine aligned on a same kinematic event
Overall results	RMS values calculated on the machine cycle and on the different phases of the cycle

Angle-Frequency analysis

Features	Description
Result	Wigner-Ville spectrum
Extracted results	Energy spectrum (angle integration) & Instantaneous power (frequency integration)

Asynchronous analysis

Features	Description
Bandwidths / Resolution	DC to 40 kHz - 101 to 25600 lines
Time results	Triggered block, weighted block
Frequency results	auto-spectrum, cross-spectrum , FRF H1, FRF H2, coherence, Power Spectral Density, Half Power Spectral Density

Ordering Information

EngineDiag license

Reference	Description
ORNVS-ENGD	EngineDiag module for OR36, ORMP, OR38
ORNVS-ENGD-8	EngineDiag module for OR34, OR35

Example of instrument configurations

Reference	Description
OR36-ENGD-16	OR36-16 Ch. EngineDiag pack
ORMP-ENGD-16	Mobi-Pack-16 Ch. EngineDiag pack
OR38-ENGD-32	OR38-32 Ch. EngineDiag pack

Note: all the EngineDiag packs include the Recorder plug-in, the FFT plug-in, the Order plug-in and the ASAMP option.

Training

Reference	Description
ORSC-TR	Measurement on reciprocating machines – EngineDiag setup and training
ORSC-PREST	On site assistance for measurement and coaching, Noise and vibration measurement and diagnostic

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.

Want to know more?

OROS headquarters	OROS Inc	OROS French Sales Office	OROS GmbH	OROS China
Tel: +33.811.70.62.36	Tel: +1.888.200.0ROS +1.703.478.3204	Tel: +33.169.91.43.00	Tel: +49.261.133.96.50	Tel: +86.10.59892134
Mail: info@oros.com	Mail: info@orosinc.com	Mail: info@orosfrance.fr	Mail: info@oros-deutschland.com	Mail: info@oroschina.com
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