Polytec

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Technology benchmark

Comparing

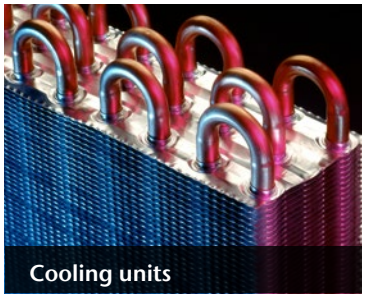
vibro-acoustic production testing methods

Vibro-acoustic quality control everywhere

Vibration analysis is a proven and recognized method to detect faults in an automated end-of-line testing. Assembly and component errors as well as other structure-borne noise phenomena can be detected quickly, reliably and reproducibly. Typical devices that benefit from vibro-acoustic quality control are:


Actuators

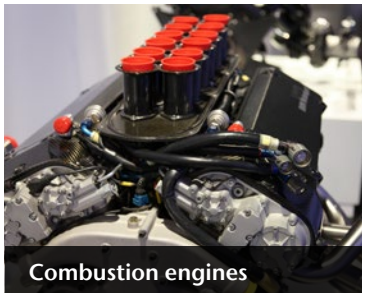

Pumps


Cooling units


Bearings


Machines


Gearboxes


Combustion engines


Electric motors


Fans

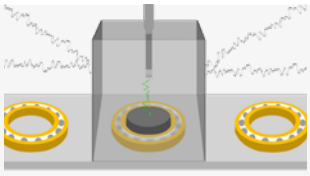
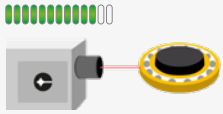
Comparing different technologies

In practice, three technologies have been established for vibro-acoustic quality testing. One is the use of **tactile accelerometers**. Since the sensor measures in contact, the connection (e.g. with screws, magnets, glue or stylus-based) to the measuring object is also an important influencing factor due to contact resonances.

Measuring microphones can detect acoustic vibrations from an entire object and usually require a chamber to isolate from external noise.

Finally, **laser Doppler vibrometers** as optical technology have well proven its worth. This method measures without contact even in hard-to-access areas or on uncooperative sample surfaces without preparation.

Laser triangulation is another optical measurement technique. However, due to its low displacement resolution for wide bandwith measurements, it will not be described further in this comparison.

Model			
	Accelerometer **tactile**	Microphone **acoustic**	Laser vibrometer **optical**
Measurands	Measures acceleration	Measures sound pressure	Measures velocity[1]
Form factor	Very small sensor	small sensor, but huge chamber (noise isolation).	Relatively small sensor
Working distance	Fix working distance	Close to DUT, but non-contact	Variable working distance and autofocus
Influence on device under test (DUT)	Lightweight devices are influenced (mass loading). Not suitable on hot or soft surfaces.	Ambient noise has effect. A noiseinsulation chamber with opening mechanism may be needed to move DUT in and out.	No influence, non-contact measurement
Signal quality monitoring / consistency check	No signal quality monitoring (no indication of incorrect connection, cable fault)	No signal quality monitoring	Signal quality monitoring by return signal level indicator
Miscellaneous	Positioning mechanics, actuation of the stylus and cables necessary	Space necessary for chamber	A nearly perpendicular reflective optical access is needed.
General applicability	Typically good but limited by type and mounting of the sensor	Typically good but may be influenced by ambient noise	Typically very good

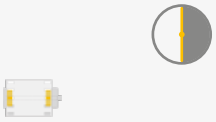
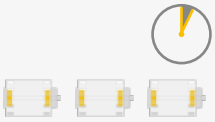
[1] *Comparison with a Polytec Industrial Vibration Sensor IVS-500-HR. Vibrometers with displacement and acceleration output are also available.*

The following chapters show strengths and limits of different production testing methods for vibro-acoustic quality control. The tables are intended as a guideline for selecting the best method for a particular application.

Different aspects such as time and effort, reliability and reproducibility, as well as questions regarding system integration, should help to make the right decision when considering the total cost of ownership.

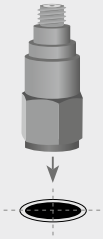
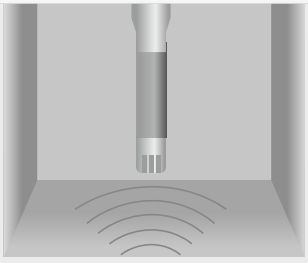
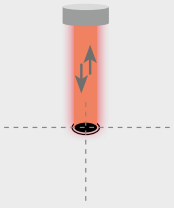
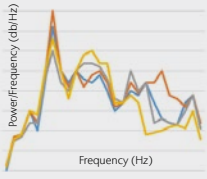
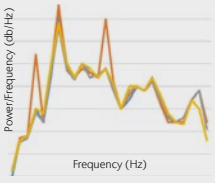
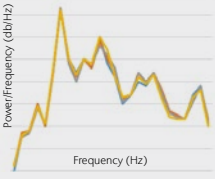
Time aspects

In manufacturing environments the clock is ticking. Minimizing the time for setup, measurement, and expected downtime all influence the overall throughput.

	Accelerometer **tactile**	Microphone **acoustic**	Laser vibrometer **optical**
Setup time for different products being tested	 Mechanical setup and alignment is needed.	 Typically, a standardized setup and enclosure is used for each product in the line.	 Just focus to adjust for different working distances as long as line of sight to the area to test is maintained.
Reference check	Manual or automated with shaker	Manual or automated with reference sound source	Not required because the system is calibrated every few years.
Throughput/ cycle time influenced by measuring duration	 Additional time for sensor actuation and settling necessary	 Opening / closing and loading of acoustic chamber delays the measurement	 Very fast inspection, measures immediately
Downtime	 Mechanical wear degrades sensor performance. Regular service for validation and adjustment of contact force. Normally this is done daily.	 Microphones require frequent calibration verifications. Normally this is done daily.	 Recommended service of the laser unit after a few years

Reliability and reproducibility

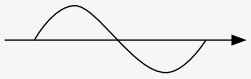
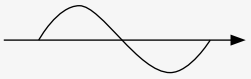
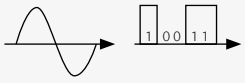
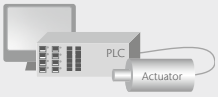
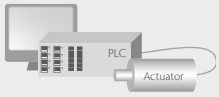
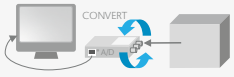
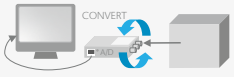
End-of-line tests metrology needs to fit to the particular application requirements. This section highlights the influence of the test method on the end results. The best reproducibility will be dependent on the application.

	Accelerometer **tactile**	Microphone **acoustic**	Laser vibrometer **optical**
Frequency range	 ■ Up to 1 - 8 kHz[2] due to mechanical setup	 ■ <100 Hz to 20 kHz[3] ■ High frequency versions available	 ■ 0 Hz to 100 kHz[4] ■ High frequency versions available (24 MHz)
Measuring spot	 Approx. some mm². Flat surface with some surface area required; limitations with application on hot or soft materials.	 System measures sound and sometimes will require a chamber for isolation of ambient noises.	 Approx. 50 - 100 µm diameter required (depends on working distance and focus). Can measure through access holes.
Measuring zone	Measures vibrations at specific points with mechanical access.	Measures only overall noise on an entire object.	Measures vibrations at specific points with optical acccess.
Reproducibility (FFT or time analysis is usually used for the evaluation)	 **Limited.** Depends on sensor contact point (surface properties, dirt, wear) and contacting force. Sensor mounting can cause discrepancies.	 **Good.** May be influenced by ambient noise.	 **Very good.** High dynamic range available.

[2] *Frequencies limited by coupling resonances. 8 kHz claimed by specific stylus models.*
[3] *Frequencies lower 20 to 100 Hz are troublesome depending on cabin size.*
[4] *Comparison with a Polytec Industrial Vibration Sensor IVS-500 HR. Much higher frequencies are available with other types of vibrometers, but not common for the purpose considered here.*

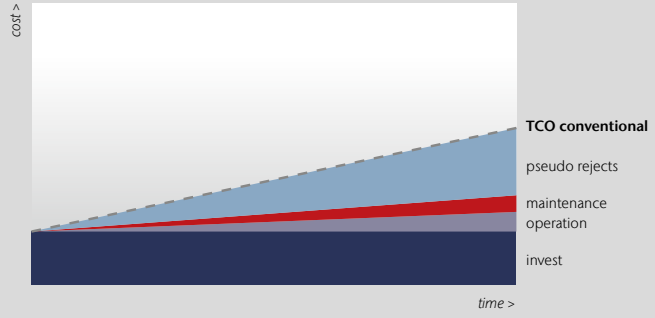
System integration

In order to analyze the signal, a data acquisition system must be implemented to acquire and condition the data. Once collected, the data can be analyzed and results shared back with the process control system.

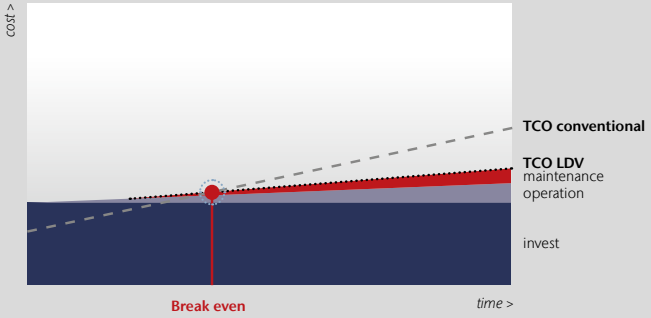
	Accelerometer **tactile**	Microphone **acoustic**	Laser vibrometer **optical**
Typical interfacing output	 Analog	 Analog	 Analog or digital
Sensitivity (measurement range)	 Fixed acceleration sensitivity (every sensor has only one range)	 Fixed microphone sensitivity (every sensor has only one range)	 Adjustable sensitivity and dynamic range. Allows one vibrometer model to be used for different appli-cations.
Signal validation	 Not available. Additional hardware and effort necessary. (pressure force can vary without noticing)	 Not available. Additional hardware and effort necessary.	 Integrated signal level indicator (voltage/digital signal). Allows for automatic validation of each measure-ment.
PLC (SPS) connection	 Required to move mechanics	 Required to move target in and out	Not required
DAQ (analog) **measurement data**	 A/D Data acquisition converter required	 A/D Data acquisition converter required	 No A/D converter required, whendigital output (e.g. Ethernet) used

Reliability and cost-efficiency in production testing

Once quality metrics are determined, the optimal measuring solution can be selected. The following technological comparison of different metrological approaches shall show ways of pass-fail analysis, production testing or end-of-line (EOL) testing methods, quality control and in-line quality inspections in production environments.

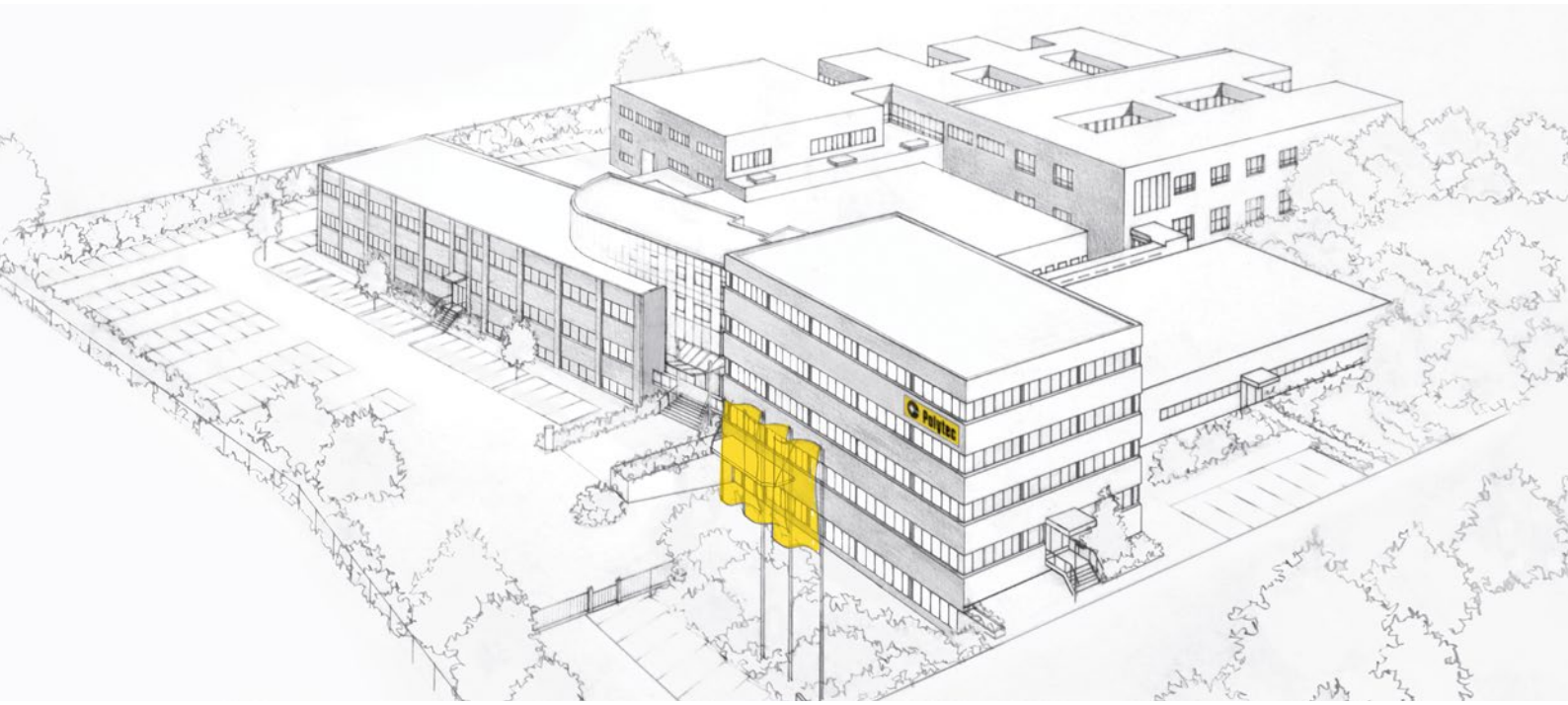


1 TCO for conventional testing methods



2 TCO when using laser Doppler vibrometers (LDV)

Comparing four typical measurement technologies highlights the best technique for finding the faults. If more than one method is applicable, then the total cost of ownership (TCO) can influence the decision. Figure 1 shows that for a conventional process that is susceptible to pseudo rejects and wear maintenance of the sensor, the TCO over time can be higher than for the laser Doppler vibrometry (figure 2), due to its technical advantages like short cycle time and very good reproducibility.



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