WHY IS TORSIONAL VIBRATION A BETTER TECHNOLOGY?

The information one can obtain from lateral-vibration readings concerning the condition of a machine is well known. But by gathering torsional vibration a lot can be learned about a machine from this data too.

The FFT spectrum analysis of the rectilinear vibration of a reciprocating machine shows all the harmonics of running speed. Thus, a peak in the data at e.g. twice running speed might not indicate misalignment, as it is for a rotating machine. Torsional vibration is well suited to reciprocating equipment, because it concerns itself only with the rotational motion that results from reciprocating pistons. The same applies for all non-reciprocating machines too. Thus, only the nonuniformity of the speed of rotation of the crankshaft or shaft (its angular acceleration and deceleration) is considered in order to detect any anomalies in the driving motions.

Sidebands appear in lateral-vibration spectra as the result of an amplitude or phase modulation of the basic motion of the components being tested. When measuring lateral motion resulting from a rotating forcing mechanism it is a secondary effect. Measuring the modulation of the rotation directly, via torsional vibration measurements, these small rotations are the primary effect. Small changes in the angular acceleration of the shaft are more prominent in the spectra and the physic of the cause is likely more obvious than searching the sideband signature characteristics for meaning.

Torsional vibration analysis is one of a few non-intrusive condition monitoring techniques that could be applied for early detection of fault developments in an engine or any other rotating machine before it goes into a functional failure. This method needs only a non-intrusive speed sensor (magnetic or optical) signal to assess in detail the mechanical behavior of an engine and diagnose injection, compression, or valve state defaults, and bearings/moving parts damages. The method is able to point out the exact cylinder which is in defect using additional order tracking speed sensor (TDC or camshaft). The technique is more suitable and efficient for mass industry deployments than other non-intrusive methods such as vibration and acoustic emissions. A combination of instantaneous angular speed analysis based on Hilbert transform associated with order analysis and statistical moments is used by alphaSYSTEM and give detailed and robust diagnosis.

alphaSYSTEM operates by analyzing the instantaneous speed variations of the axle caused by torsional vibrations. This pickup method is more sensitive than using accelerometers for several reasons:

	Lateral Vibration	**Torsional Vibration**
Definition:	Vibration is the movement or mechanical oscillation about an equilibrium position of a machine or component.	Torsional vibration represents changes in the relative angular displacement between two points on a rotating shaft.
Sensor:	There are three general types of sensors commonly used to measure vibration in rotating machinery. • Accelerometers (mostly used) • Displacement or proximity probes • Velocity probes	Various measurement techniques are available for torsional vibration. Sensors are • Magnetic speed sensor (MPU) • Hall effect speed sensor • Optical sensor

Sensor location:	The measurements should be made at different points on the machine. The best locations are at the component to be analyzed, e.g. bearing locations of each component. It is not always possible to collect data on points where it seems to be good due to obstructions. Thus, the accelerometer can be installed at poor mounting locations without really knowing it.	The measurement only needs to be done at one point on the machine, at a rotating shaft. Sensor has to be installed close to the device to be analyzed. The location where a speed sensor is installed is always well known regarding good or bad location.
Needed information:	For accelerometers at least one measurement in the horizontal, vertical, and axial direction should be collected as a minimum.	Raw speed signal requires at least 60 pulses per revolution for around 20 seconds – depending on rotational speed of shaft.
Transmission path:	An accelerometer requires a solid transmission path (good mechanical path) from the component that could fail, e.g. bearing, to the sensor in order to not lose important information. The vibration should only travel along solid material with no gaps or joints. The shortest path between the source and accelerometer has to be chosen which is sometimes not possible. It is often impossible to collect data from one or more axis at the measurement location, e.g. for motors because the motor has a fan cover on the free-end or outboard end. An axle measurement cannot be made there because there is not a solid transmission path from motor bearing to sensor.	Speed sensor must be installed very close to the component that could fail, e.g. bearing, to gain a very solid transmission path. In this case the transmission path from source to sensor is very solid because of the shaft. For motors the speed sensor must be installed at the free end to get a good mechanical transmission path, which is along the shaft.
Vibrations:	There is a reason, apart from mechanical fault in the machine, why the vibration pattern could change. There are many places on a machine that vibrate. They may rattle, resonate, and do not represent forces of the component that could fail, e.g. bearing. When the accelerometer is attached to the machine, the vibration from inside the machine causes the sensor to vibrate, which is pick-up by the electronics inside. If the accelerometer is not mounted correctly, the senor will vibrate in a way unrelated to the machine, and the vibration data will be useless.	Vibrations of the machine have almost no impact on the torsional vibration and thus on the speed signal. Should the vibration of the machine be too high, this is shown in a separate indicator and does not affect the results of the analysis. Therefore, the torsional vibration only represents forces of the component that could fail.

Sensor mounting:	To mount the accelerometer correctly the sensor must directly contact the machine surface. The stronger and stiffer the connection, the more likely getting a measurement with an acceptable frequency response. The surface must be smooth and flat and must be free of paint chips, rust or grit, otherwise the frequency response will be compromised. E.g. this means that one should not attached a sensor directly to a painted surface. If the surface of the machine is dirty or if the sensor is not placed in the same position each time or if different accelerometers are used, the vibration pattern will be different. So the data collection person's job is very important.	Speed sensors are often used in industrial applications because they are robust and have low sensitivity to ambient dust. Setups for this are often very practical as well, since existing gear sets on the machine can be used as target, e.g. gear-teeth on flywheels of transmissions. As a result, magnetic pickups are very popular for measuring torsional vibration because they are easy to set up, they work very well with existing gear teeth, have no direct contact to the target due to an air gap of approx. 1 mm or more, and are very robust. Even a change of the speed sensor is not as critical as for accelerometers.
Repeatability:	To get a perfect repeatability the measurements must be taken the same way EVERY time! This means the accelerometer must be mounted correctly every time and it has to be mounted in the same way every time. No matter who collects the data, it must be done the same way. In other words, there must be a clear documented procedure for testing each machine that anyone can follow. Note: Changes in vibration pattern are important and these changes should not be caused by variations in how the data is collected.	To get a perfect repeatability the measurements must be taken at the same place every time. But the mounting is not as critical as for accelerometers due to the air gap between target and sensor. Note: Changes in torsional vibration caused by variations in how data is collected is negligible.
Evaluation of results:	The results of an analysis have to be compared manually with the ISO 10816-3 Vibration Severity Chart.	The results of an analysis of alphaSYSTEM inform directly which component or components of a machine (reciprocating or non-reciprocating) are in good operating condition or start to fail soon and is based on latest scientific knowledge.
Summary:	The measurement of lateral vibrations is an **indirect** measurement of the forces of the component that could fail. Broadband device affected by all general vibrations in its environment.	The measurement of torsional vibrations is a **direct** measurement of the forces of the component that could fail. Like FM radio, analysis tuned to the frequency of the speed sensor signal, unaffected by broadband vibrations at other frequencies.