Brüel & Kjær Vibro

Application Note

Monitoring strategy – Gated vibration and rod position measurements for reciprocating compressors

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ABSTRACT

Gated vibration and rod position monitoring are some of the least intrusive monitoring installations of all monitoring techniques for detecting and diagnosing reciprocating compressor cylinder faults, and yet some of the most effective in terms of the number of potential failure modes that can be detected. Faults can be automatically detected early and do not require a specialist to analyze the results.

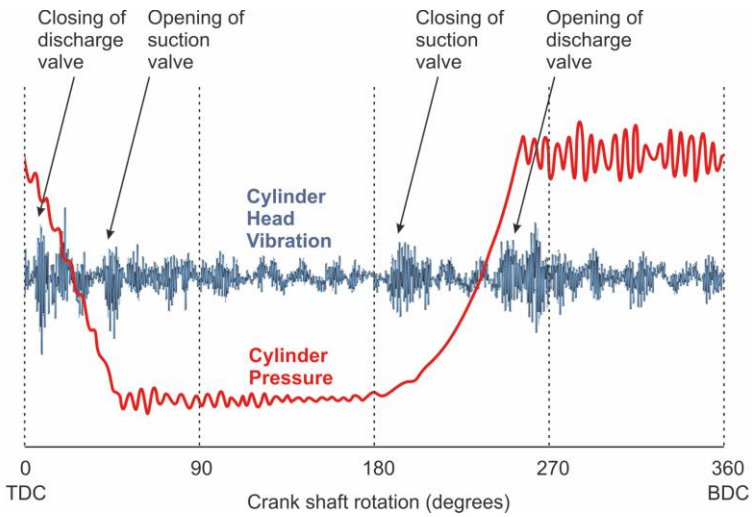

Figure 1. The cylinder head vibration time signal plotted against the cylinder pressure showing individual valve opening and closing events. Other vibration events not indicated here include pressure dynamics, pulsations within the cylinder and kinematics of the piston assembly movement.

Cylinder faults

Reciprocating compressors are very maintenance intensive in relation to turbo-machinery, and the cylinders account for most of the failures. These faults can be process related, such as liquid carryover, overpressure, excessive pulsations, insufficient rod reversal, or wear/damage related to the running components. If unchecked, faults can lead to component breakage, leaks or even complete machine failure.

There are a number of monitoring techniques available for detecting cylinder faults, but there is a big difference in terms of system cost, installation difficulty, kinds of faults that can be detected, how early the faults can be detected, and the amount of expertise required for diagnostics. Gated vibration monitoring and rod position are some of the best techniques from an overall perspective.

What is a gated measurement?

Gated vibration and rod position are extensions of the impact and rod drop vibration measurements that are traditionally done for cylinder monitoring. Gated vibration and rod position are monitoring techniques where vibration is measured with respect to crank angle instead of time or speed (see Figure 1). The measurement is based on dividing all the vibration data samples for one rotation of the crank into a number of segments (gates), such as 18 or more for condition monitoring (i.e. 20 degrees of crank rotation or less) or as few as 6 for protective monitoring (see Figure 2 and 3). Each of these

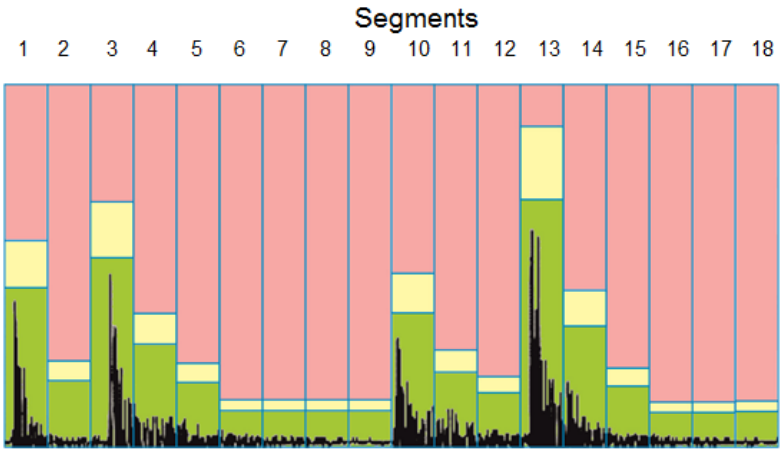

Figure 2. The individual events may be concentrated in a single segment or spread out over several. Each segment can be individual monitored to alarm limits (red is danger, yellow is alert and green is the reference). The segments shown above are equally spaced for one complete rotation of the crank. It is also possible to have segments with varying widths.

Fault detection monitoring strategy

Gated vibration and rod position are mostly used for condition monitoring applications but there are some customers who require a gated vibration solution for their protective monitoring application also (but typically not rod position). The type of faults detected and the monitoring configuration for the two monitoring strategies are different.

Condition monitoring – The gated vibration and rod position monitoring technique is intended to detect developing faults at an early

segments relates the vibration to specific positions of the crank. The root mean square of the vibration (or peak) is calculated into a single bandpass value for each segment that can be monitored to individual alarm limits and trended (see Figure 4). The intention with gated vibration and rod position is to isolate the vibration events into individual vibration segments so any changes that occur in these events can be attributed to a developing fault, such as malfunctioning valves, changing process conditions or worn, loose or damaged piston assembly components. Because the changes from one specific event are isolated from the other events, individual faults can be detected and trended earlier and diagnosed more accurately compared to a vibration signal that has been averaged for the entire crank rotation. Moreover, considering all operating conditions constant, the measurement signal variations are also constant during the course of a crank rotation.

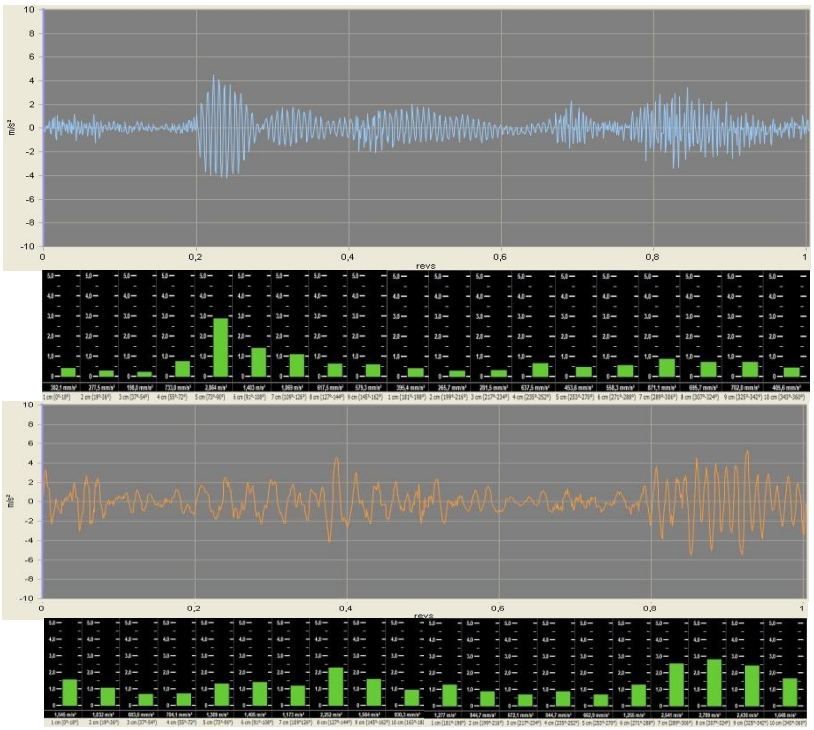

Figure 3. The vibration signal of the reciprocating compressor cylinder for one complete rotation of the crank. Top screen shows 20 RMS vibration bandpass segments at 18 degree crank position intervals for the cylinder head. Bottom screen shows the 20 segments for the crosshead vibration.

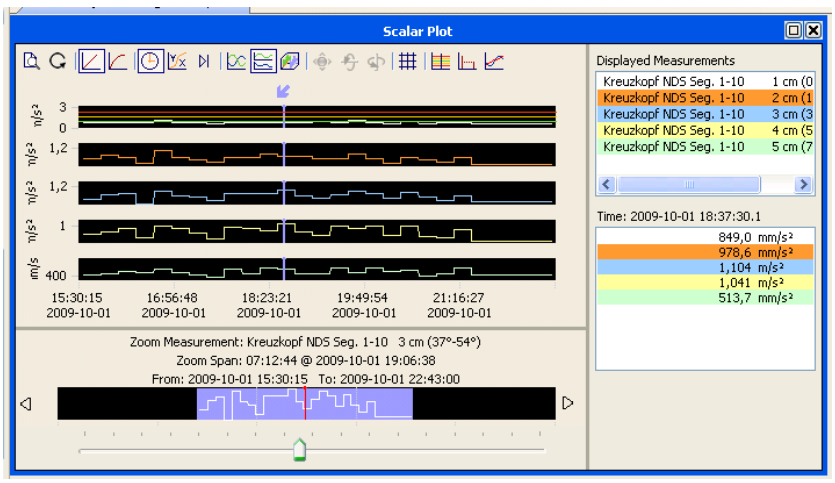

Figure 4. Gated vibration trend shown for the first 5 segments.

enough stage such that the compressor can still keep operating with minimal production loss. This enables maintenance to be cost-effectively planned ahead of time without stopping the machine. Condition monitoring focuses on maximizing machine uptime and minimizing maintenance costs. The types of faults that are typically condition monitored are those that have sufficient lead-time to failure and can be trended in a predictable manner.

The gated vibration condition monitoring function of Compass 6000™ can be easily retrofitted without adding hardware.

Protective monitoring – Protective monitoring is intended to shut down a machine if there is an imminent component failure that could in itself cause a catastrophic failure of the machine. Another important function of the protective monitoring system is to monitor failure modes of critical components which have little or no advance warning, and therefore cannot be monitored by a typical condition monitoring strategy. This could be liquid carryover, bolt/nut fracture, crosshead wrist pin seizing, loss of lubrication, etc.

In principle, a protective gated vibration monitoring system uses fewer segments compared to a condition monitoring application, in order to avoid false trips due to varying process conditions. When an imminent failure is occurring, however, the vibration energy of these fewer segments for many faults is typically high enough to be seen also in a traditional impact vibration measurement that is averaged for the entire rotation. Therefore the need for a gated protective monitoring strategy as compared to a traditional vibration impact measurement depends on the specific application and customer requirements.

Brüel & Kjær Vibro offers a VC-6000® monitoring module with protective gated vibration monitoring capability.

Technique	Sensors type	Location	Faults that can be detected
Gated vibration	Accelerometer	Crosshead	Worn or damaged crosshead, valve, piston ring, piston bolt, seal, rod, rod bolts, liquid carryover
		Cylinder head	Same as above, but more sensitivity to valve and piston problems and liquid carryover (e.g. for a long cylinder, this sensor will be used together with a crosshead sensor)
Rod position	Displacement sensor (sometimes X-Y sensors)	Distance section	Rider ring wear, crosshead wear/excessive clearance, rod condition, loose piston bolt, loose rod bolts or worn seal

Table 1. Gated vibration and rod position monitoring techniques.

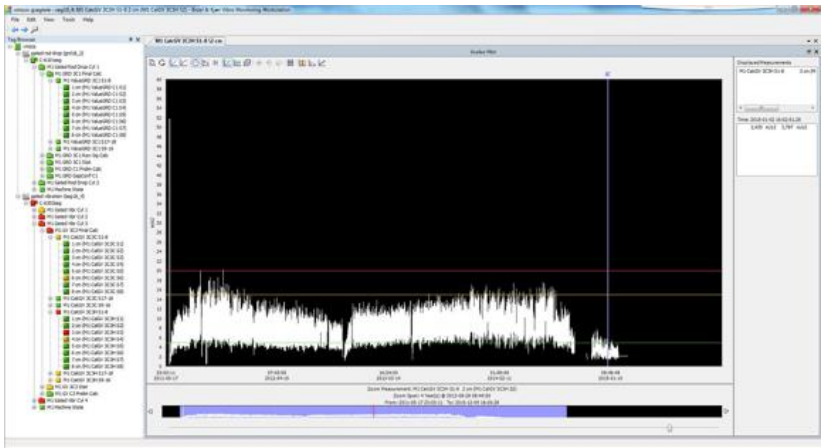

Figure 5. Long-term gated vibration signal from segment 2 of cylinder 3-HE of a 4-cylinder. The valve was replaced in October 2014.

- **CM Retrofit**: Easy extension to Compass 6000™ with no extra hardware needed. Uses the same sensors as for used for traditional monitoring applications
- **New Installation**: Sensors for gated vibration measurement are easier to install and less costly than that for other cylinder monitoring techniques.
- No specialist knowledge is needed to interpret the results
- Several years' experience on different types of compressors

Monitoring experience

Brüel & Kjær Vibro has several years of experience with gated vibration and rod position for different types of reciprocating compressors, including horizontal and vertical machines. A couple of examples of monitoring results is shown in Figure 5 and 6.

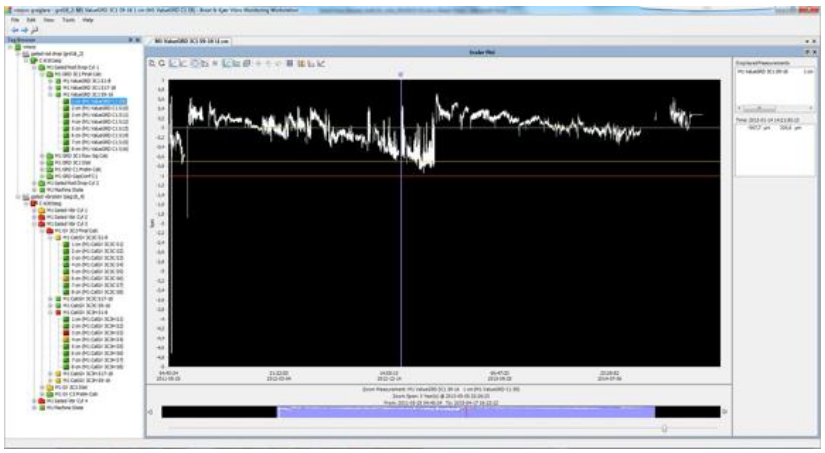

Figure 6. Long-term rod position signal from segment 9 of cylinder 1 of a 2-cylinder compressor.

Benefits and conclusions

Gated vibration and rod position are ideal monitoring solutions for detecting cylinder defects at an early stage of development, especially on compressors where it is not feasible to install valve temperature sensors or dynamic cylinder pressure sensors. The gated vibration technique can be used on its own, or preferably together with the other cylinder fault detection methods.

Some of the benefits of gated vibration and rod position are:

- More accuracy with greater lead-time for detecting, diagnosing and trending developing faults
- More versatile for detecting a wide range of faults, such as valve leaks, damaged or worn piston rings, seal, piston bolt, rod, crosshead, crank bolts, wear rings and liquid ingestion

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