Monitoring reciprocating gas compressors with 4-20 mA LPS™ vibration sensors

Vibration monitoring introduction

Vibration monitoring is well established as a tool for diagnosing the mechanical health of rotating machines. Machinery analysts and technicians have been successfully using vibration monitoring of rotating machinery for many years. Pumps, fans, motors, gearboxes, rotary compressors and many other types of rotating equipment run better than ever thanks to advances in vibration analysis.

Many attempts have been made to automate the process through which vibration signals are analyzed to pinpoint a machine fault. Detailed diagnostic vibration analysis is often performed using portable spectrum analyzers that implement Fast Fourier Transform (FFT) mathematics on the vibration signal. In some instances, only a trained analyst can interpret the vibration data, effectively diagnose the problem(s) and make a final determination of the state of the equipment. Still, the success of vibration analysis tools has significantly reduced the cost of vibration monitoring and enabled monitoring of more plant assets.

Many industrial plants rely heavily on compressed air for their operation. Most applications of gas compression require a high compression ratio (suction to discharge pressure). Reciprocating compressors are ideal in high compression ratio applications. However, faults on reciprocating machines are difficult to characterize using vibration analysis software. Portable FFT analyzers fair poorly when applied to reciprocating equipment because they cannot account for the crank-angle position on the machine, which is important in analyzing the vibration of reciprocating machinery.

Consequently, reciprocating machines in plants are frequently ignored by vibration analysts and technicians simply because their primary analysis tool (the FFT analyzer) is not well suited to reciprocating equipment. Because specific problems cannot be easily identified, overall machine health is typically ignored as well. As a result, many companies spend more money on repairs and replacements than it would cost to monitor reciprocating machines.

Using 4-20 mA vibration data

Loop powered sensors are a low-cost alternative to traditional vibration monitoring and analysis. Loop powered sensors are vibration transducers that incorporate signal processing to produce a conditioned vibration signal relative to the overall vibration level of the machine. The lowest signal level is standardized at 4 mA to ensure that non-operating conditions (0 mA) are differentiated from low current levels. The top end of the scale is standardized at 20 mA to provide enough range to address almost any process.

The advantage of using 4-20 mA based vibration data is that there is no complex analysis to perform. The output represents the overall vibration of the machinery. The output does not contain sufficient information to determine a specific machine fault, but it can serve well as an indicator of general machine health. As with some rotating machinery, a trained analyst is required to interpret the vibration data, effectively diagnose the problem and make a final determination of the state of the equipment. The diagnosis can be made, and the fault repaired, before the maintenance costs multiply or the machine must be replaced.

Loop powered sensors can never be employed as a direct replacement for the dynamic vibration analysis. The 4-20 mA current loop is a low bandwidth system that can not support the transfer of the dynamic vibration data necessary to determine a specific fault. At a cost below $1000 per channel of vibration data, including the sensor, equipment, input channels and installation, many maintenance engineers use a 4-20 mA network as a cost effective way to monitor the machine's general condition.

Modern plant process control systems (PLC or DCS) can accept a 4-20 mA signal as input. The 4-20 mA loop signal is the de facto standard for plant process control signals and offers plants the ability to monitor vibration on a continuous basis. The existing PLC or DCS, already in place to control plant operations, will also control loop functions and provide data trend displays and long-term data archiving. The technical expertise to maintain these control systems exists in many plants already. In fact, most plants now depend on such systems for their operation. Adding 4-20 mA vibration data to these systems is simple and only requires the vibration probe and an available analog input channel.

Cross-head vibration monitoring

Inside the cross-head of a reciprocating gas compressor is the connection between the crankshaft drive and the piston shaft. This bushing and pin requires constant lubrication. Inadequate lubrication leads to excessive wear, resulting in a looseness of the bushing-to-pin connection. The looseness allows a metal-to-metal impact to develop in this connection. With 80,000 pounds of force, or more, being transmitted through the shaft, a small amount of looseness can quickly degrade the components through the impacting of the loose parts. It is important to be able to quickly and reliably detect this looseness.

Vibration monitoring with 4-20 mA data provides an economical way to detect looseness before the fault is exacerbated and repair costs increase. Figure 1 represents a hypothetical series of impacts that result from looseness in the bushing-to-pin connection. Wilcoxon's extensive line of 4-20 mA Loop Powered Sensors, the LPS™ series, have a unique design feature called "true peak" detection. True peak detection is exclusive to Wilcoxon Sensing Technologies, and presents an exceptional solution to monitoring reciprocating gas compressors.

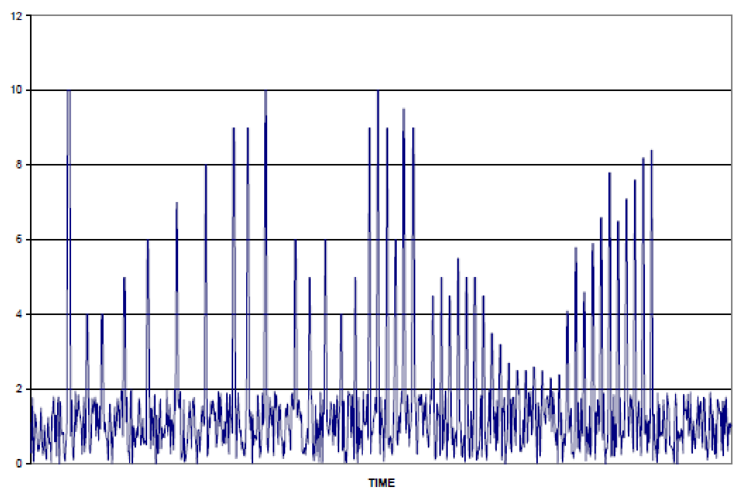

Figure 1: Impacts at varying amplitudes and repetition rates.

The 4-20 mA signal output by true peak vibration monitoring is proportional to the actual peak level. With true peak detection the output will track the level of the peak time signature and output the proportional 4-20 mA signal. The Wilcoxon true peak sensor captures the peak, holds that level, and then ramps down slowly. Illustrated in figure 2 on page 3 is the operation of the true peak detection with varying amplitude and frequencies of impact signals. The left-hand axis illustrates the 4-20 mA loop current. With true peak detection, the output loop current will "jump" up quickly upon detecting an impact signal. The loop current will then begin to "ramp" down unless another impact event occurs that exceeds the ramp-down signal level.

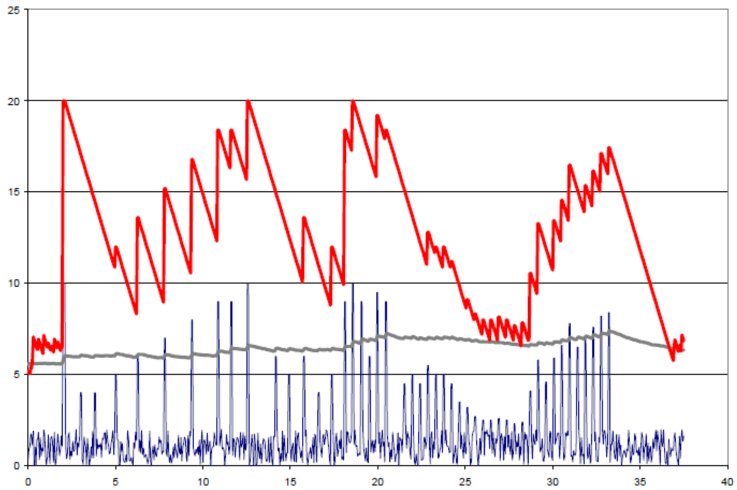

Figure 2: Illustration of “true peak” output (upper) versus vibration signal (lower). The gray (middle) line illustrates the r.m.s. output from a 4-20 mA sensor or transmitter.

The middle line in figure 2 represents the output of a traditional loop powered sensor, which utilizes root-mean squared (r.m.s.) detection. These sensors do not always identify a problem because the impacts do not affect the overall level of the signal output. It would be difficult to know that an impact problem exists if a reciprocating gas compressor were to be monitored by such sensors. On the other hand, the true peak detection method offered by Wilcoxon provides immediate notification of transient impacts. (While true peak detection is most appropriate for monitoring reciprocating gas compressors, Wilcoxon LPS™ sensors offer true peak, peak or r.m.s. detection to meet the requirements of many applications.)

Looseness in the cross-head bushing and pin can be detected by mounting the sensor on either the cross-head section or the distance piece in the vertical direction on the top of the case. The PC420ATP-20 is the best LPS™ Series sensor to use for monitoring looseness because of the high acceleration pulsations produced by impacting. A full scale of 20g is recommended because looseness will produce fairly high g-level impacts.

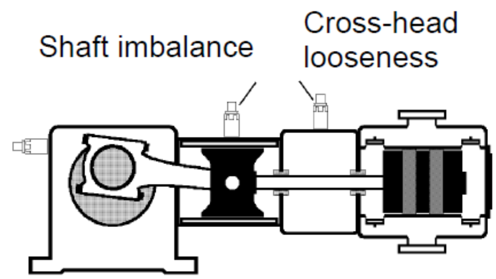

Figure 3: Mounting locations for sensors

Frame vibration monitoring

Wilcoxon’s 4-20 mA LPS™ Series should also be used to monitor vibration on the compressor frame. Except for bearing wear, the most common failure mode of these large frame devices is imbalance. The typical speed for most drivers is less than 1800 RPM. The imbalance frequency occurs at the rotational (1X) speed.

Imbalance in the drive shaft of the driver or compressor would be detectable with the sensor mounted in the horizontal axis at opposite ends and 90º opposing sides of the crankcase. Imbalance is better monitored using velocity, since, at typical running speeds, only very low accelerations are present. ISO 10816, *Mechanical vibration -- Evaluation of machine vibration measurements on non-rotating parts*, is a guideline that advises typically acceptable vibration levels related to imbalance. Figure 4 shows these levels.

LPS™ velocity transducers monitor vibration caused by imbalance energy to detect this highly damaging machinery fault. ISO10816 recommends that peak vibration levels exceeding 0.63 inches-per-second (11.2 mm/sec. r.m.s.) be considered unacceptable for

<table>
<tr><th>Vibration velocity in/sec peak (mm/sec r.m.s.)</th><th>Class I</th><th>Class II</th><th>Class III</th><th>Class IV</th></tr>
<tr><td>2.5 (45)</td><td rowspan="6">D</td><td rowspan="5">D</td><td rowspan="4">D</td><td rowspan="3">D</td></tr>
<tr><td>1.6 (28)</td></tr>
<tr><td>1.0 (18)</td></tr>
<tr><td>0.63 (11.2)</td><td rowspan="2">C</td></tr>
<tr><td>0.4 (7.1)</td><td rowspan="2">C</td></tr>
<tr><td>0.25 (4.5)</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>0.16 (2.8)</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>0.1 (1.8)</td><td rowspan="2">B</td><td rowspan="5">A</td></tr>
<tr><td>0.063 (1.12)</td><td rowspan="2">B</td><td rowspan="4">A</td></tr>
<tr><td>0.04 (0.71)</td><td rowspan="3">A</td></tr>
<tr><td>0.025 (0.45)</td><td rowspan="2">A</td></tr>
<tr><td>0.016 (0.112)</td></tr>
</table>

Figure 4: ISO10816 vibration recommendations.

heavy, high-horsepower drive systems (Class III equipment, over 100 HP, as shown in figure 4). The PC420VP-10 has a full scale of 1.0 inches-per-second (i.p.s.), peak velocity, making it ideal for monitoring frame vibration on a reciprocating gas compressor.

Cooling fan vibration monitoring

Many reciprocating gas compressors also have inter-stage cooling systems. Fin-fan cooling devices are critical in multiple stage compressors and should be monitored for imbalance. Air is forced over cooling fins to remove the heat generated during the compression process. The fan speed is based upon several factors and can vary between 300 to 1800 RPM.

Imbalance on the fan shaft is properly monitored by placing the sensor perpendicular to the shaft of the fan. Velocity monitoring provides the best measure of the imbalance condition. Most fin-fan coolers and cooling tower motors use relatively low horsepower drives (Class II, under 100 HP as shown in figure 4), so their recommended vibration limit would be around 0.4 i.p.s., peak velocity. A PC420VP-05 would provide a useful range for trending the vibration of these motors.

Recommended sensor summary

All sensors in Wilcoxon's LPS™ Series are hermetically sealed. Hermetic sealing can suffice for installations in Class I, Division 2 areas as the sensors have no open electrical contact and are not incendive devices. For installation in Class I, Division 1 areas, the LPS™ Series has Intrinsically Safe and Explosion Proof sensors rated for hazardous areas. Integral cable options are available for harsh environments.

Location monitored	Class I, Division 2, or Unclassified area	Class I, Division 1
Cross-head or Extension piece	PC420ATP-20	PC420ATP-20-IS or PC420ATP-20-EX
Frame imbalance	PC420VP-10	PC420VP-10-IS or PC420VP-10-EX
Cooler or tower fan	PC420VP-05	PC420VP-05-IS or PC420VP-05-EX

In all cases, the appropriate full scale value of the sensor should be carefully chosen based upon the known existing vibration level of the device being monitored. Please consult your engine analyst or your Wilcoxon representative for sensor type and full scale selection. Manufacturer-supplied information may also indicate typical vibration levels of a healthy machine.

In addition to full scale and hazardous area options, Wilcoxon's extensive LPS™ Series lets you select between monitoring acceleration or velocity, and among peak, r.m.s., and our exclusive true peak detection. Side exit versions of virtually all LPS™ are available, and can be used in areas with low overhead clearance. All sensor settings are established during manufacturing are not field changeable.