

Continuous Condition Monitoring with Vibration Transmitters and Plant PLCs

Written by Eric Saller, IMI Sensors, Division of PCB Piezotronics
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Because process monitoring systems are widely used in many plants, vibration channels can be added at a fraction of the cost of dedicated on-line condition monitoring systems.

Predictive maintenance techniques have proven to be effective strategies to reduce unexpected machinery failure. Vibration monitoring is by far the most widely used predictive maintenance technology due to the significant amount of machinery condition information provided.

Most plants that implement a vibration monitoring program begin with a portable data collector and a pre-determined route of data collection points. Vibration data is gathered and trended. Maintenance action then is determined based on machinery condition trends. Very often the new vibration information is reviewed and compared to trended data and no anomalies or exceptions are noted. Vibration data was just taken on healthy machines.

Plant size and the number of points of machines to be monitored can make implementing a vibration monitoring program a formidable task. Determining the machinery routes and the frequency of data collection also can be a difficult undertaking. These issues, as well as machinery with different rates of failure-that is, the time to machinery failure once excessive vibration is detected, direct many plant managers toward investigating continuous monitoring solutions with permanently installed instrumentation.

These investigations often reveal that existing continuous condition monitoring programs provide a tremendous amount of information for predicting machinery failure and diagnosing and analyzing root cause. This gives the plant engineering staff the most reliable and complete information available to help assess the health and condition of the plant's machinery.

If the only detail maintenance managers are interested in is determining if a machine is good or bad, these continuous condition monitoring programs may provide too much information and may be cost prohibitive. Also, many systems are not compatible with existing plant monitoring instrumentation and require implementation of proprietary equipment and significant duplication.

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Another approach may be for on-line condition monitoring systems to be implemented using existing factory process control equipment. This concept would monitor overall vibration levels using general-purpose accelerometers routed to vibration transmitters that convert the vibration signal into a 4-20 mA output compatible with plant process equipment. The programmable logic controller (PLC) then could send alarms to the vibration analyst when these levels become excessive. These alarms would alert the predictive maintenance team of the need for closer investigation with portable analysis and diagnostic equipment.

This approach may be much more cost effective. Since process monitoring systems are widely used in many factories, vibration channels can be added at a fraction of the cost of dedicated on-line condition monitoring systems. Other costs, such as installation and training, also are reduced since the monitoring network system already is installed and personnel are in place to manage the system.

Once the decision is made to implement a vibration monitoring program using existing process control instrumentation, the next task is to determine the equipment to be monitored and to define the machinery faults that need to be detected.

Answers to the first point are relative to the particular equipment: the cost of repair, rate of failure, and its importance to the production process. Answers to the second part require a basic understanding of the typical modes of failure of machinery and their respective vibration signatures.

Typical machinery faults

The first step in implementing any condition monitoring program is to know the equipment. Research the machinery to be monitored in order to be familiar with its operation and understand its potential failure modes.

There are many failure modes for machinery. The more complex a piece of equipment, the more complex the failure mode can be. Four basic failure modes most commonly found in standard equipment are imbalance, misalignment, bearing faults, and gear mesh failure. Each machinery fault has its own unique vibration signature that helps to identify the particular fault. Each fault has specific fault frequencies that help determine the mode of failure while the amplitude of the vibration helps to determine the severity of the problem.

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Imbalance and misalignment most often occur at low frequencies. Mechanical looseness and process loading also can produce faults at low frequencies. These machinery failures demonstrate high vibration at one, two, and three times running speed. These low frequencies are typically in the 2-1000 Hz range for equipment operating around 1800 rpm.

Since the mechanical defect is a result of a physically massive rotor or shaft, the amplitudes are relatively high. A good range for trending vibration is from 0-1 in./sec RMS.

Bearing faults occur at nonsynchronous multiples of machinery turning speed. Specific bearing fault frequencies are unique to the bearings and depend on the physical parameters of the bearings. Specific measurements such as the pitch and diameter of the bearing, the number of balls, and the turning speed are all needed to calculate the fault frequencies of bearing failures such as inner race and outer race defects as well as ball bearing defects. Bearing defect frequencies are available from most bearing manufacturers, but as a rule of thumb one can estimate the frequencies to be near 50 percent of the product of the number of balls in the bearing times the machinery turning speed.

Vibration amplitudes for these faults are very low as the mass of the moving parts is relatively small compared to the rotor or shaft mass. Bearing fault frequencies range from 200-5000 Hz with relatively low amplitudes. Trending acceleration data instead of velocity data is desired since velocity accentuates the lower frequency vibration and attenuates the higher frequency vibration while acceleration data gives stronger signals at higher frequencies and is better able to measure the lower amplitudes of bearing faults. A typical acceleration range for bearing fault detection may be 0-10 gs peak.

Gear mesh faults occur at even higher frequencies than bearing faults. Gear mesh frequencies are the product of the number of teeth times the shaft's turning speed. Depending on the particular machine, these gear mesh frequencies can range from 100 Hz to over 10,000 Hz. As mentioned previously, acceleration data is preferred over velocity data as the acceleration measurement emphasizes the higher frequency vibration and de-emphasizes and is less sensitive to the lower frequency mechanical defects and process loading conditions. A typical acceleration range for gear mesh

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fault detection may be 0-50 gs peak.

Selecting the proper transmitter

As discussed previously, it is imperative to know the machinery in order to effectively implement a condition monitoring program. Current machinery operating conditions, expected modes of failures, and potential machinery faults are all factors to consider when monitoring equipment.

Selecting the proper frequency band to trend over relative to the particular fault of interest is critical in order to actually detect the given machinery fault and eventually predict machinery failure. Determining the amplitude ranges within the given frequency band is also important so that alarms will provide an early warning when machinery condition has degraded.

Another critical concern for vibration monitoring equipment and alarms is that a time delay be available for each measurement point. A time delay would be used to avoid false alarms that could be set off as a result of transient vibration caused by local traffic, process changes, and even ancillary equipment. Also the time delay should be sufficient to avoid setting off alarms during machinery start up and coast down. During start up and coast down the equipment could move through mechanical resonances and high amplitude vibrations could be present. Transient time delays should be on the order of 5-10 seconds while time delays for machine start up and coast down should be greater (approaching 1 minute). It may be desirable to de-activate the vibration transmitters and their alarms during start up and coast down to avoid inadvertently setting off alarms.

A final selection criterion necessary for vibration monitoring instrumentation is that the raw vibration signal is made available for further diagnostics. The trended overall value within a given fault frequency band will be a good indication of the machine's condition relative to that general fault condition but it will not reveal specifically the details of the pending fault. For example, if an alarm is tripped in the lower frequency band where misalignment or imbalance may occur, in order to effectively make repairs prior to total machinery failure, the maintenance staff must understand what the exact fault is.

Many specific faults could occur in that broad low frequency band including mechanical looseness, oil whip, and oil whirl and even belt failures as well as the already mentioned

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misalignment and imbalance. Detailed diagnostics is required to pinpoint the exact failure mode. This is accomplished by inputting the raw vibration signal from the installed sensors into a portable diagnostic instrument for further analysis by a qualified vibration technician.

Machinery condition monitoring is an important facet in modern maintenance. Avoiding unscheduled downtime is critical to maintain corporate competitiveness. Low-cost on-line condition monitoring of rotating machinery using industrial accelerometers, vibration transmitters, and plant process equipment is an excellent method to gather information to help determine the overall health of a plant's machinery. **MT**

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