Electronic Design

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Improve Rotary-Machine Uptime with Real-Time Monitoring

Sponsored by Digi-Key and Analog Devices Inc.: Preventive maintenance that implements condition-based monitoring and accelerometers can significantly enhance rotary-machine functionality and your overall Industry 4.0 operation.

What's in it for you? That is, how can the increasingly hallowed movement called Industry 4.0 help you? If you've been following the development and adoption of Industry 4.0, you already know that the goals are to improve productivity, flexibility, and safety in your factory. Further goals are expected to bring things like edge-to-cloud computing, more powerful analytics, and methods to adapt systems for mass customization. It's pretty heady stuff. Within all of those offerings, though, are some real practical solutions.

One inevitable occurrence in factories and plants everywhere is machine failure. When a machine vital to the process goes down, productivity goes down or completely stops. It can lead to the loss of hundreds of thousands, even millions, of dollars daily. This situation is so critical that considerable work has gone into finding ways to predict the occurrence of such an event.

Predicting and diagnosing a machine's health before it becomes problematic requires insights that can only come from having accurate and reliable data about the machine operation. Today, condition-based monitoring (CbM) technologies can significantly improve uptime, productivity, and quality. That ability depends on being able to monitor the machine in special ways during normal operation. Then the monitoring equipment can capture that data over time and subsequently analyze it to attempt to predict not only the failure, but also when it's likely to happen.

Predictive Maintenance

It sounds like magic, but you can determine when a specific machine is likely to fail. By monitoring the machine, collecting vibration and shock data, it's possible to predict within a specific time range when a breakdown could potentially occur and how it will fail. The follow-up consists of shutting down the machine before it fails and making adjustments, replacing the motor or otherwise fixing the problem. Given all of the vibration data, you can often zero in on what the problem is and fix it. The relevant data can then become a part of a database for every machine in the facility.

One sensor that's emerging as an invaluable monitoring device for rotary machines is the accelerometer. Analog Devices offers a range of new products that address this application, helping manufacturers achieve some of the goals of the Industry 4.0 movement.

The Solution is a Sensor

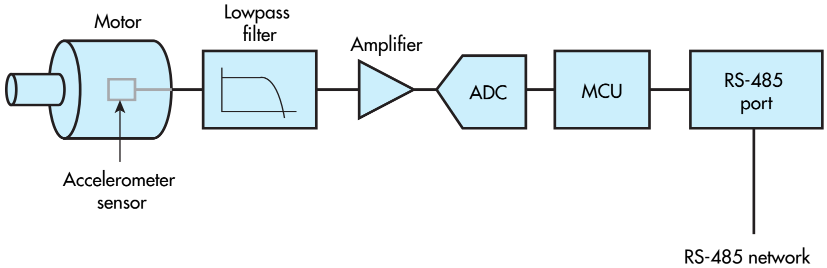
The way to detect machines needing attention or replacement is to monitor its operation over a period of time. Look for repeated shock and unwanted vibrations. These measures give clues as to how a machine gets used or abused.

An accelerometer is a sensor that measures acceleration. There are different types of accelerometers, but we're interested in the one that measures proper acceleration. Remember from one of your college physics courses that acceleration is the rate of change of velocity. An example is meters per second per second (m/s/s or m/s^2) or miles per hour per hour. The accelerator tells you how fast something is increasing or decreasing in speed. Such information is useful in various ways.

Some types of accelerometers factor in surrounding forces plus the earth's gravitation pull. Called coordinate acceleration, this measures objects within a coordinate system with different positions and orientations. These accelerometers are used for inertial navigation systems for missiles, spacecraft, and aircraft.

The accelerometers of interest here are those that will determine the orientation of a smartphone or tablet screen and adjust it to always be upright. Such an accelerometer should be used to monitor rotating machines for vibration.

Accelerometers break down into several classes—all of them, though, are electromechanical devices that convert acceleration into a signal that can be interpreted in various ways. One popular type is the piezoelectric accelerometer. It's made up of a piezo crystal that produces a voltage across one of its axes when pressure is applied. An alternative sensor is one that uses a piezoresistive crystal; when subjected to pressure, it changes the resistance of the crystal.



Shown are the main components of a data-acquisition system used in the implementation of condition based-monitoring.

The other major category of accelerometer leverages microelectromechanical-systems (MEMS) components. Some accelerometers use a variable capacitor sensing mechanism.

MEMS accelerometers are very effective and come in a variety of forms with one-, two-, or three-axis measurement capability. These inexpensive devices produce a low analog output; therefore, amplification and analog-to-digital conversion (ADC) are required to make them useful.

Finally, the accelerometer may be an ac or dc type. The ac outputs come mainly from piezoelectric sensors and aren't always needed. MEMS sensors are preferred for a dc response. The most popular sensor is the capacitive MEMS type.

Key specifications when selecting a MEMS accelerometer include low noise and wide bandwidth. Among the specs for Analog Devices' ADXL1001/ADXL1002 sensors are:

- Output: Analog
- Axis: X only
- Acceleration range: ±100 g or ± 50 g
- Sensitivity: 20, 40 mV/g
- Bandwidth: 21 kHz
- Noise: µg/√Hz
- Supply voltage: 3.3 to 5.5 V
- Package: LFCSP (5 x 5 mm)

Enable Real-Time Monitoring of Industrial Assets

The most common problems with rotating machines like motors, turbines, pumps, fans, robots and others are misaligned shafts, incorrect mounting position, poor lubrication to bearings, and others. These problems manifest themselves as vibration and extreme anxiety. Some of them are minor, but others are more violent. By recording the vibration with an accelerometer, the sensor provides data that can eventually predict the exact nature of the problem as well as when it might occur.

The CbM method requires building a data-acquisition system (DAQ). The *figure* shows a generic data-capture system. Accelerometers are used for sensors on the machines to be monitored; both analog and digital sensors are available. Most digital sensors have an SPI serial interface output. Analog sensors need amplification and perhaps other signal conditioning like filtering followed by an ADC. The data converter can be a simple successive-approximation-register (SAR) type or a more precise sigma-delta converter, depending on your application.

Some systems will also incorporate a microcontroller in which data is initially stored locally and some preprocessing can occur before being passed on to a remote server/processor. A desirable feature of this embedded controller is software that can perform a fast Fourier transform (FFT) on the captured data. Frequency spectrum analysis by way of FFT is one of the primary analysis steps in machine monitoring.

Many CbM data-acquisition systems use a wired data-transfer network rather than wireless. To ensure integrity of the data collected, the sensors are set up to place their SPI data on an RS-485 network. The RS-485 network uses unshielded twisted pair in a balanced configuration to minimize noise over long connection distances. Data rates are typically low, but the RS-485 can handle rates to about 50 Mb/s over short distances (<100 meters). Cable lengths extending to about 1000 meters are possible with much lower data rates.

Products to Build an Accelerometer-Based DAQ

Analog Devices has a line of products like accelerometers to support predictive-maintenance routines. Examples are the ADXL1001/ADXL1002 low-noise and wide-frequency accelerometers and related products.

The accelerometers come as a simple chip for designing into products or as complete ready-to-use modules for a new or replacement machine. These modules are ready to connect to the network. Also available are evaluation boards that can be used in your own designs.

A Word About ADCs

To digitize the accelerometer output, you need an ADC. Since the accelerometer output is low frequency in nature, a fancy high-speed converter isn't required. It can be a simple

SAR type or whatever may be inside an accompanying microcontroller. While conversion speed isn't an issue, the real need is high precision. That means a greater number of bits of resolution, at least 16 bits, and better still, 18 or 24 bits. Readily available is Analog Devices' AD7768/AD7768-4 simultaneous sampling ADCs.

The AD7768-1 is a low-power, high-performance, Σ-Δ ADC with a Σ-Δ modulator and digital filter for precision conversion of both ac and dc signals. Resolution is 24 bits. It also offers eight selectable input channels. Conversion rate is 256 ksamples/s per channel.

Summing Up

If you have not yet implemented the Industry 4.0 program in your facility, give it some consideration. One of the fastest and easiest first steps to joining Industry 4.0 is preventive maintenance using condition-based monitoring and Analog Devices accelerometers.