MEMS Sensor Technology Enables Manufacturing to Improve Predictive Maintenance

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IDEA IN BRIEF

Manufacturers can use vibration sensors to monitor machinery, anticipate part failure, and thereby avoid costly damage and lost productivity.

Reactive, avoidable equipment repairs are a leading contributor to lost productivity in industrial manufacturing operations. Parts with an average selling price of just a few dollars can cost manufacturers many times that in repairs and unrealized revenue once they fail. In a worst-case scenario, undetected faults can cascade through the system, causing widespread damage and triggering major and expensive production outages. Historically, manufacturers have relied on preventive measures to keep their production floors up and running.

While an improvement over after-the-fact repairs, preventive maintenance typically requires costly service contracts and ultimately is limited in its ability to ensure continuous equipment uptime. Consider the rotor bearings that turn the blades of a 200 foot wind turbine. Emergency repairs and spot maintenance are expensive—and, in this case, may even be dangerous as technicians are required to work at high elevation. Moreover, if the turbine is tied into the power grid of a local municipality, unscheduled downtime can result in lost energy production and possibly disrupt electrical service.

A new industrial sensing technology is helping manufacturers optimize their equipment by using a form of predictive maintenance that anticipates part failures. While many forms of industrial sensing exist, vibration sensing is perhaps the most effective and efficient. According to a study by Lindsay Engineering, a provider of predictive maintenance products and services based in Camarillo, CA, vibration sensing delivers three times the return on investment of steps such as regularly changing gear or motor oil (see Figure 1).

BENEFITS OF VIBRATION ANALYSIS

Vibration analysis is commonly used in rotating machinery to detect loose or worn bearings, equipment misalignment, or low fluid levels that may cause a change in vibration. Typically, this vibration occurs at frequencies between 6 kHz and 10 kHz. Other data is also available at higher frequencies but is typically very difficult to measure due to the magnitude of the response and requires expensive technologies such as ultrasound. By measuring that frequency range and monitoring changes in the response, manufacturers can schedule maintenance or bring down equipment when it is most convenient and before the part is damaged to the point where it can cause even more costly secondary system failures.

Additionally, various statistical formulas, such as mean time to failure (MTTF) and mean time between failures (MTBF), can be used to forecast the life of the system. Using those formulas, along with raw data from the system, allows customers to focus directly on the potential problem. For example, using MTTF, you find that a certain bearing has a high degree of failure. You can use a vibration sensor to carefully monitor that particular machine and bearing to make sure that the failure does not happen.

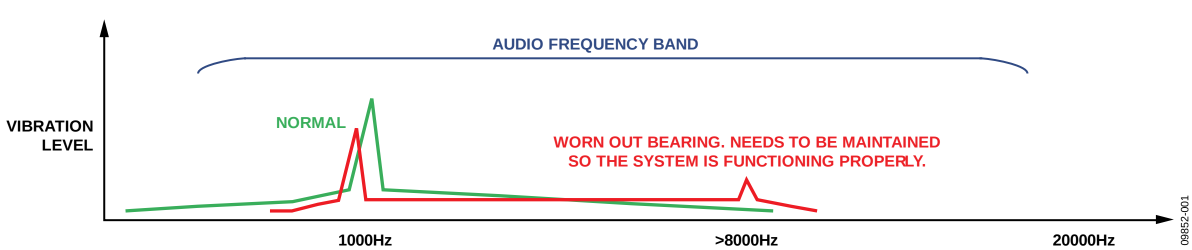

Figure 1. Vibration in Rotating Machinery Typically Occurs at Frequencies from 6 KHz to 10 KHz

The two most common means of implementing industrial vibration sensing are to retrofit existing equipment with sensor systems or contract with a third party service that conducts regularly scheduled equipment tests. The latter option can be expensive, and periodic checks are less effective than mounting sensors directly on the equipment. The system mount approach affords manufacturers continuous monitoring but has also had historical limitations.

The majority of today's vibration sensors typically operate below 5 kHz of bandwidth, which is significantly lower than the frequency at which most equipment failures can be detected. Additionally, conventional sensors are most often based on high-voltage piezoelectric technology that requires a bulky metal-can package, and the devices demand frequent calibration and are not easily manufactured in large volumes. Additionally, they are typically at a low level of integration and require significant external conditioning and processing to extract useful data.

MEMS APPROACH

Micro electro mechanical system (MEMS) based vibration sensors are becoming an important alternative to conventional sensing approaches, as the demand for earlier and less costly predictive maintenance alternatives increases. Most importantly, any alternative solution must operate at a higher and wider frequency range, which is essential for earlier detection. For example, Analog Devices offers a portfolio of wide bandwidth MEMS sensors (ADXL001, ADIS16220, ADIS16223, and ADIS16227) that have a bandwidth of 22 kHz resonance and high sample rates, making them ideal for machine-health applications. They allow a system operator to identify failing equipment long before costly damage is sustained.

The intricacies of vibration monitoring, particularly capturing accurate representations of the vibration profile and then correctly interpreting the data are highly complex disciplines. For many wishing to implement vibration monitoring, the optimum solution lies far beyond the transducer element. Much of the complexity lies in the data analysis where a typical time-based analysis of the equipment produces a complex waveform combining multiple error sources and providing little discernible information prior to FFT analysis.

Most piezo based sensor solutions rely on external computation and analysis of the FFT. This approach eliminates the possibility of real time notification and greatly increases the design burden on the equipment developer. Specialized MEMS sensors like the Analog Devices ADIS16227 vibration monitor address this complexity and feature embedded frequency domain processing, a 512 point real value FFT, and on-board storage providing the ability to identify and classify individual sources of vibration, monitor their changes over time, and react to programmable threshold levels.

This device also includes configurable spectral alarm bands and windowing options that allow analysis of the full frequency spectrum with the configuration of six bands, Alarm1 (warning threshold), and Alarm2 (fault threshold) for earlier and more accurate detection of problems.

To ensure accurate data capture, there is a strong desire to implement embedded and autonomous sensing. At the right level of integration (that is, sensor analysis, storage, and alarm capability), the sensor system can be embedded much closer to the potential error sources, allowing more accurate representation of the machine vibration and a significant reduction in interface complexity such as cabling, off-site analysis, and scheduling of data captures. Devices like the ADIS16227 are complete data conversion and sensor processing solutions, which provide access to the processed wide-bandwidth sensor data through a serial peripheral interface (SPI). These devices provide continuous monitoring for, and interrupt-driven notification of, user-programmed alarm thresholds, as well as the ability to schedule (user-programmed) periodic wake and record operation where power is a concern.

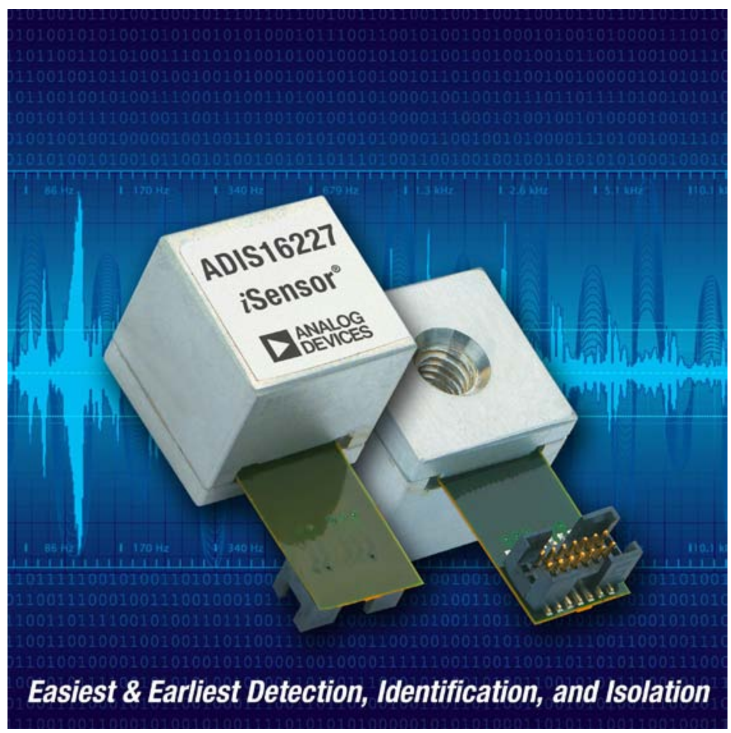

Figure 2. MEMS Sensors Such as the Analog Devices ADIS16227 Sensor Can Sense Component Failures at Frequencies of Up to 22 kHz, Thus Providing Early Warning of Equipment Malfunctions

RESOURCES

For more information, visit www.analog.com.

Products Mentioned in This Article

Product	Description
ADXL001	High Performance Wide Bandwidth *i*MEMS® Accelerometer
ADIS16220	Programmable Digital Vibration Sensor
ADIS16223	Digital TriAxial Vibration Sensor
ADIS16227	Digital TriAxial Vibration Sensor with FFT Analysis and Storage

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