

## Measuring Displacement Using Accelerometers

Written by Renard Klubnik, Wilcoxon Research  
Saturday, 01 March 2008 15:58

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### **How competent is competent? More importantly, how much might it actually cost your operations if you were to entrust your pumps to the wrong shop?**

While it's the easiest vibration parameter to understand, it's also been the most rarely measured one. That's all about to change, with loop-powered displacement sensors now offering a simple, continuous way to get the job done.

#### **Clearing up misconceptions**

Regrettably, over time there has been a common misconception that measuring displacement using an accelerometer is not possible or leads to erroneous information. In reality, accelerometers have long been used to measure displacement. It is, however, important to understand that displacement measured with an accelerometer is not the same displacement measured with shaft riders or eddy current-style vibration transducers.

Eddy current probes are precisely thru-hole mounted into a mechanical casing and measure two very important shaft parameters.

- First, eddy current probes indicate the location of the shaft relative to the casing. This is crucial in sleeve bearing applications because it tells the operator where the centerline of the shaft is relative to the casing.
- Second, eddy current displacement measurements indicate the amount of 1x rotational vibration. From this measurement, it can be determined if the shaft vibration is within acceptable limits.

If an operator looks at the vibrational spectral content measured with a displacement probe, it is possible to see higher order harmonics of the shaft. These levels, though, are typically very small in amplitude due to the natural inclination of rotating machinery to dampen and attenuate vibration displacement levels at higher frequencies. Other uses of eddy current probes are to monitor shaft eccentricity or, in the case of probes positioned in the axial direction, to monitor case thermal expansion.

While all of these measurements are useful, they are not the same as a casing vibration measurement made with an accelerometer, then doubly integrated electronically to determine the level of machine displacement. Despite eddy current probes being widely used in sleeve bearing applications, a great majority of field machinery employs roller element bearings. Usually it is neither possible nor practical to mount an eddy current probe on this type of

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machine. Since the shaft is held tightly in place by a roller element bearing, an accelerometer mounted on the case will detect the force exerted on the bearing by the rotating mass.

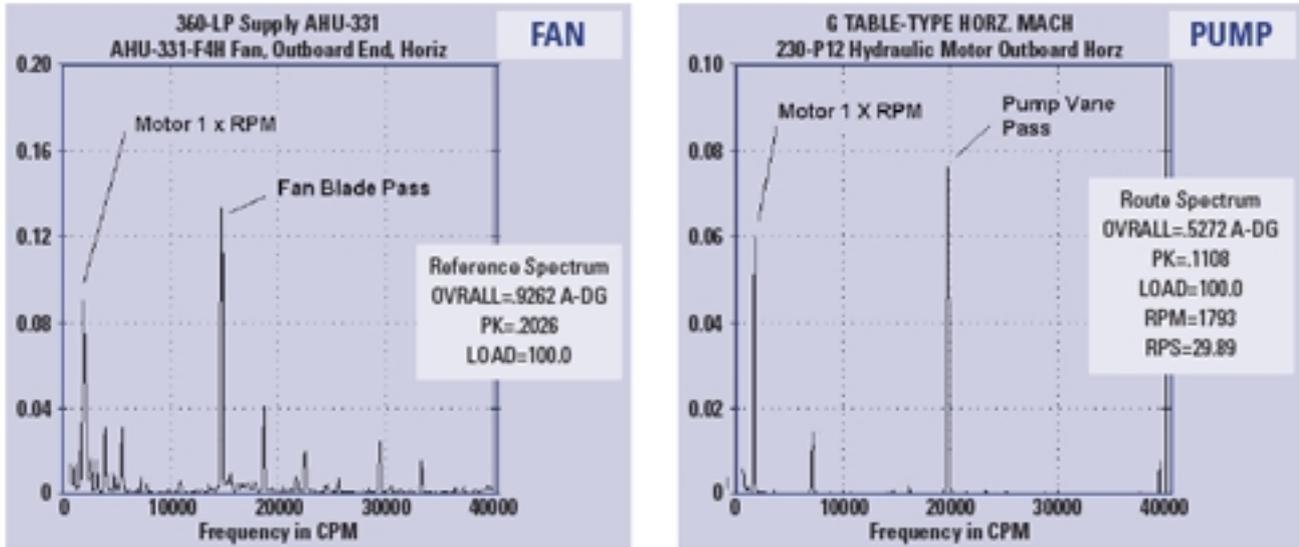


Fig. 1. Vibration readings of a fan and a pump in terms of velocity

### Deriving benefits

The benefits of using accelerometers to sense machine vibrations through casing measurements are well known. They have been in general practice for generations of equipment.

Typically, accelerometers internally generate an output voltage proportional to g's, with 100mV/g being the common reference value. After the accelerometer output signal is received by the measurement instrumentation, the acceleration signal is converted to either velocity or displacement. Depending on the preferred measurement parameter chosen by the plant reliability engineer, the velocity and displacement characteristics are trended against time to indicate when the machine condition has changed enough to warrant special attention or preventive maintenance. While this method is effective, it requires a high degree of instrumentation to accomplish the desired goal of averting machine failure.

The measurement instrumentation involved is usually a spectrum analyzer that collects, conditions, manipulates and displays the data. This raw accelerometer data then is frequently transferred to a software database package that offers significant additional analytical capabilities and record keeping. Considerable resources can go in to the measurement instrument, training personnel in its proper use, interpretation of the data and ongoing software updates. Nevertheless, this approach has been successfully implemented in thousands of plants over the last several decades and has saved industry countless dollars in unscheduled downtime and costly repairs on large, critical machinery.

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On the other hand, there remains a large amount of unmonitored plant machinery that could benefit from vibration analysis. Unfortunately, the costs associated with using highly trained staff to collect hundreds—perhaps thousands—of data points makes such widespread analysis impractical, especially when the increased demand on personnel to “accomplish more with less” is taken into account.

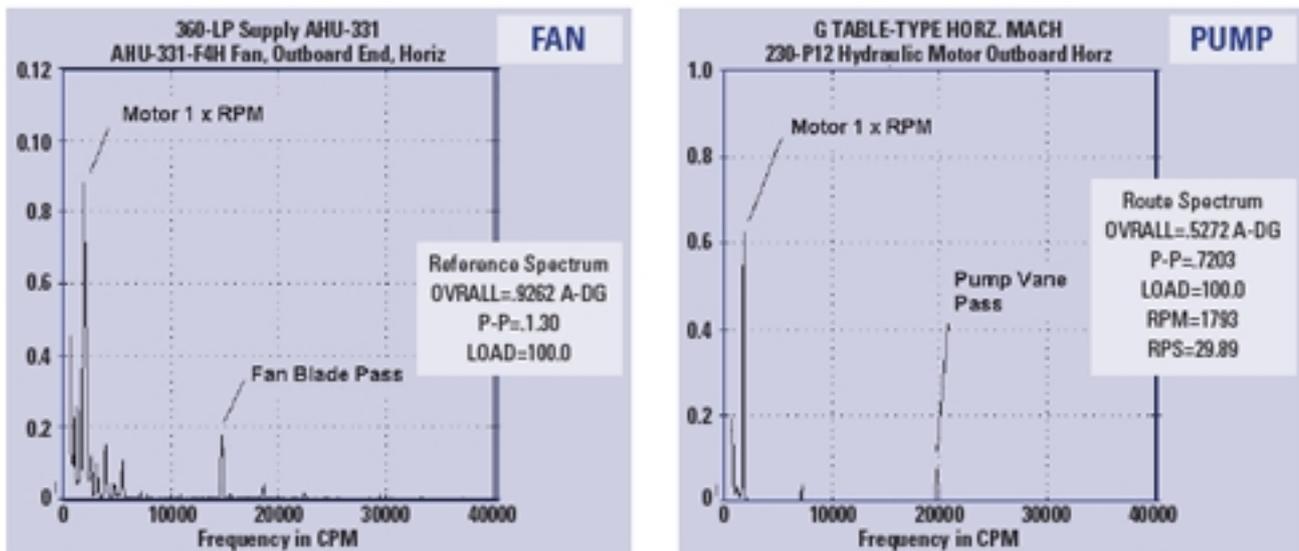


Fig. 2. Vibration readings of a fan and a pump in terms of displacement

### Loop powered vibration sensors

In recent years, there has been increasing interest in loop powered vibration sensors, which are powered from 24 volt supplies and output a 4-20 mA signal. The advantages of using 4-20 mA vibration sensors are simplicity and cost-effective continuous monitoring. They take the same accelerometer-based vibration signal discussed above, internally process that signal using one of several detection schemes (rms, peak, peak-to-peak, or true peak) and convert it into a 4-20 mA signal that is proportional to either acceleration or velocity. This signal is then routed to a much more common piece of process equipment, such as a PLC or plantwide DCS system.

So, instead of spending tens of thousands of dollars on sophisticated instrumentation, a plant can invest about \$300 per data point and obtain continuous real time data on any piece of equipment. That means a facility can now monitor many more pieces of equipment— more cost-effectively than in the past. Considering the investment in capital equipment, this can be a very small price to pay for continuous operating information on a critical pump or fan stationed remotely in the plant. Even a higher priced analytical system does not offer 24/7 protection, and it usually requires human interpretation.

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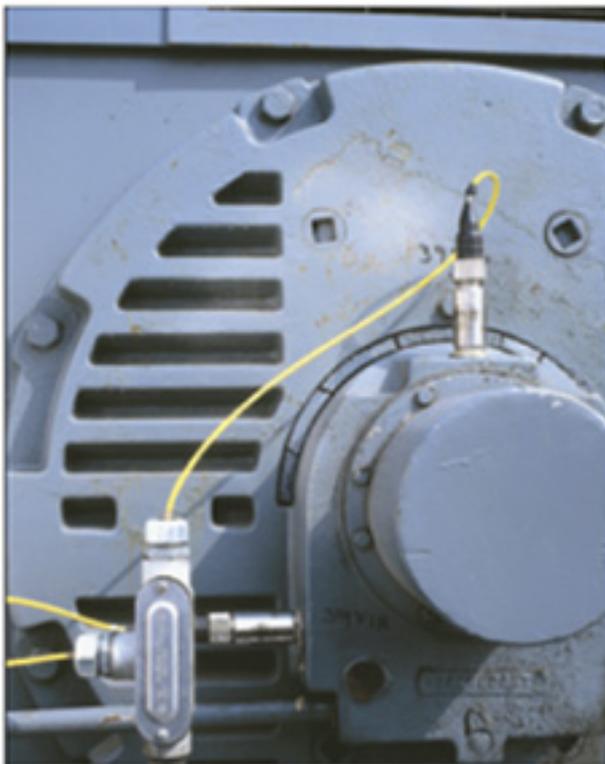
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### Today's technology

While all of the loop powered vibration sensors up to this time based the 4-20 mA output signal on acceleration or velocity, measuring displacement with a 4-20 mA sensor is now an option. With no cabling and no instrumentation before it is converted to displacement, the cleanest signal is possible (where cleanest is defined as the least amount of electrical, thermal and cable noise before conversion). As previously mentioned, in traditional walk-around vibration systems, it is standard practice to convert the accelerometer signal to displacement after the signal reaches the measurement instrumentation. The result often seen in this data has been characterized as 'ski slope,' where low-frequency signals are lost in the integration process.

When an accelerometer is mounted on the machinery, the processing is performed right at the point of data collection. As a result, it is possible to control the entire measurement and integration process to a much greater degree than was possible before. The acceleration signal coming from the sensing crystal is first conditioned, that is, made readable by subsequent measurement amplifiers. Once amplified to an acceptable level, the signal is passed through a double integrator, which is similar in design to a low pass filter. This AC signal, representative of the machine displacement, is fed into the averaging circuit, converted to the required DC value and passed out of the sensor as a 4-20 mA signal. Now, data screens for process control machinery can be calibrated in mils displacement in the same manner that vibration velocity signals have been recorded with previous generation sensors.



With an accelerometer mounted directly on a piece of machinery, processing of data is performed right at the point of its collection.

### Expanded opportunities

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Through simplicity and the low cost of continuous monitoring, direct reading, accelerometer-based 4-20 mA displacement sensors expand the opportunity to use vibration monitoring within a plant. Fans, for example, offer a significant benefit from this technological improvement. When an accelerometer is sensitive to velocity, the overall vibration level can be dominated by blade pass frequency. Vibration readings of a fan and a pump in terms of velocity are shown in Fig. 1.

By utilizing a sensor based on displacement, the high blade pass frequency (relative to 1x vibration) is attenuated in the signal resulting in a monitoring system that is focused on the rotational (balance) component of the system. The vibration readings of a fan and a pump in terms of displacement are shown in Fig. 2.

Loop powered 4-20 mA displacement sensors also can improve pump monitoring, because the pump vane pass frequency can dominate a spectrum. Velocity sensors may be blind to changes in rotational speed vibration—thus, velocity may not be the ideal measurement parameter. Conversely, 4-20 mA sensors mounted on fan pillow blocks or pump housings can output directly to process control points, providing operators with never-before-seen information on their machines.

While measuring displacement is useful in many instances, most reliability engineers and maintenance managers realize that a single measurement focused on a single parameter (acceleration, velocity or displacement) is only a small part of a comprehensive predictive maintenance program. The choice of available sensors for measuring vibration is constantly changing. Advances in technology enable us to increase the measurement range of sensors; the bandwidth, both low-end and high; and ability to resolve low level signals in the presence of high signals like imbalance. The recent acceptance of loop powered 4-20 mA vibration sensors continues to expand the capability of predictive maintenance and real-time monitoring. Displacement-based accelerometers are the latest addition to the arsenal of vibration measurement tools and provide an easy to understand measurement with the capability to unmask hidden problems. **MT**

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