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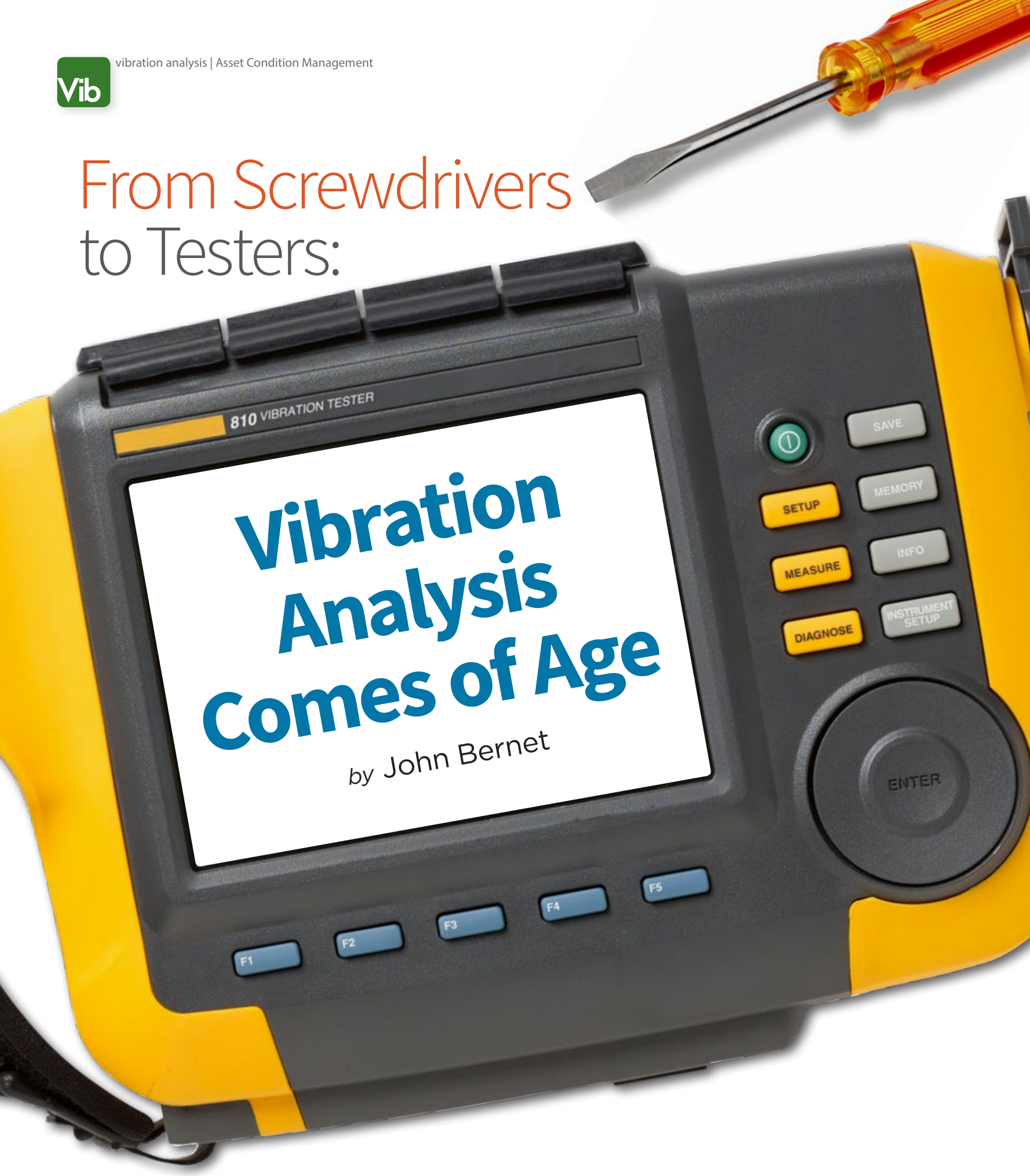

Vibration Analysis Comes of Age

by John Bernet

Figure 1: Understanding vibration analysis can change a run to failure system to a condition-based, proactive maintenance program

Most machines have rotating parts and those rotating parts vibrate. Measuring how and how much those parts vibrate can tell you a lot about the health of a machine. Whether it's the rumble of worn bearings or the shaking, shimmying, or thumping of loose, misaligned, or unbalanced parts, machines have a tale to tell those who are willing and able to listen.

The art and science of measuring and interpreting those telltale rumbles and shakes is called vibration analysis and it has been around for decades. Although historically the domain of specialists operating specific instruments for corporations and government agencies with mission critical equipment, vibration analysis is also employed by mechanics using a makeshift stethoscope or similar tool. Vibration analysis on rotating machinery has gained in popularity over more than four decades because thousands of faults can be identified without stopping the machine or tearing the machine down. Recent developments in vibration sensors, data acquisition and analysis technologies, however, are making vibration analysis cheaper, easier and more widely available.

Vibration analysis is a critical component of a condition-based maintenance system. An alternative to the run to failure strategy, condition-based maintenance measures machine health, which doesn't require tearing a machine down to find out its condition. When a machine condition fault comes up, a repair is scheduled when it's needed, not before and not too late.

HOW IT WORKS

Through analyses of patterns and amplitudes of vibration peaks at specific frequencies, rules and algorithms have been developed to diagnose problems with machines. This is accomplished by securely attaching a sensor, typically an accelerometer, to the bearings of a machine and measuring the vibration frequencies that transmit from the rotating shaft through the bearings into the outside metal surface of the machine and then into the sensor.

Among the most important mechanical faults that vibration analysis can reveal are:

1. **IMBALANCE** – A "heavy spot" in a rotating component that causes vibration when the unbalanced weight rotates around the machine's axis, creating a centrifugal force that causes advanced wear in bearings and seals and wasted energy.

2. **MISALIGNMENT** – High forces that result when machine shafts are out of line. For example, misalignment forces on the shafts, a motor and pump will cause advanced wear to the bearings and seals, resulting in wasted energy.

3. **WEAR** – As components, such as bearings, drive belts, or gears, become worn, they may cause vibration. When a roller bearing race becomes pitted, for instance, the bearing rollers will cause a vibration each time they travel over the damaged area. A gear tooth that is heavily chipped or worn, or a drive belt that is breaking down, also can produce vibration.

4. **LOOSENESS** – Vibration that might otherwise go unnoticed may become obvious and destructive if the component that is vibrating has loose bearings or is loosely attached to its mounts. Such looseness may or may not be caused by the underlying vibration.

VIBRATION TOOLS TO THE RESCUE

For the past 30 years, there have been only two tools for vibration analysis: the high-end, very sophisticated vibration analyzer and the vibration pen (or maybe the screwdriver to the ear to sense vibrations!). Recently, two new categories of vibration test tools have gained popularity to help the mainstream technician fill the void between complex vibration analyzers and simplistic pens. These new vibration tools are the vibration tester and the vibration meter. As shown, each tool has its own strengths and detects different vibration problems.

VIBRATION ANALYZER

PROS/CONS

- Essential for complex, production-critical machines
- Requires experienced operator with high knowledge level
- Produces large quantities of complex data, requiring analysis
- Large investment up-front and ongoing fees

Vibration analyzers conduct a sophisticated analysis of machine condition. They analyze vibration spectra (vibration amplitude versus frequency), create a baseline for the tested equipment and trend the results over time. This sophisticated analysis not only provides information about whether there is a problem, it also helps users understand the root cause and time to failure. However, this traditional type of vibration troubleshooting requires a significant amount of training and a strong understanding of the spectra and equipment's history.

WHEN TO USE:

- For big, complex machines with many variables, such as paper machines, multi-axis machines, turbines, etc.;
- For troubleshooting using real-time analysis, bump testing, cross channel phase and resonance testing for faults other than the four common faults previously described.

VIBRATION TESTER

PROS/CONS

- Well suited for vast majority of machinery in plant
- Fully automated machine conditioned answers without manual analysis
- Minimal up-front costs, resources and training
- Easy to use

Vibration testing provides automated diagnosis of the most common faults on most rotating machines, such as specific fault, fault severity and repair recommendation. The tester starts as a four-channel vibration data collector, but then many features and functions are modified to make it easy to use by a technician with minimal training and experience. Experienced vibration analysts may feel that they need these functions, but a large team of vibration experts working over 30 years have proven that complex and advanced troubleshooting techniques are not needed to diagnose the most common faults in most rotating machines. Put another way, you don't see a surgeon if you have a cold or the flu, you see your general practice doctor. With the vibration tester, let it help you find the most common faults and leave the advanced troubleshooting to the analyzer.

WHEN TO USE:

- For most machines with few variables, such as motors, pumps, fans, compressors, blowers, belts and gears;
- For diagnosing common machine faults (90 percent): imbalance, misalignment, bearings and looseness;
- For technicians that have many other tasks that need to get done and have no time to analyze complex graphs.

VIBRATION METER

PROS/CONS

- Multiple readings from single tool: overall vibration, bearing impact, infrared (IR) temperature, bearing health, machine health screening

When you move up to a vibration meter, you have the capability to measure overall vibration, as well as a database of real machine values to provide the user with an answer. Some vibration screening devices have a combination vibration and force sensor tip that compensates for user variance (force or angle), yielding accurate, repeatable readings. These meters also may have a four-level severity scale and an onboard processor that provides both bearing condition and overall machine health using easy to understand text alerts. In most instances, these devices can measure a wide range of frequencies (10 to 1,000 Hz and 4,000 to 20,000 Hz) in a couple of seconds and cover most machine and component types. Most are equipped with a straightforward user interface that minimizes user inputs to RPM range and equipment type. These types of meters give frontline maintenance personnel and operators a screening tool to determine which equipment is healthy and which needs further testing.

WHEN TO USE:

- To check hundreds of expendable machines and to perform a daily quick check of critical machines in-between testing by the analyst;
- For screening all machines 100 percent by using overall vibration, bearing impacts and bearing temperature to determine if a machine is good or bad. The vibration meter is five tools in one, not just one like the vibration pen.

VIBRATION PEN

(or simply a screwdriver)

PROS/CONS

- Single function; vibration number only
- Relies on experience of the operator to provide any sort of result

A vibration pen is a single-use tool that measures vibration caused by rotational and structural problems. It also can help identify some rolling element bearing or gear mesh problems.

Vibration pens are easy to use and provide a simple number that represents the overall vibration coming from the machine. However, the number requires knowledge about the machine to determine what the number means. For instance: Is this number bad for this machine? How bad is the fault? What is the fault? and What action is needed?

WHEN TO USE:

- For simple diagnostics of less complex machines.

Vibration Testing Principles

Vibration measurements are not like temperature or voltage measurements. Using electrical test equipment, you might expect to read a number that is repeatable time after time. Using a piezoelectric accelerometer to measure vibration from a dynamic machine train is a different story. That's because you aren't measuring the vibration at the source of the vibration, which is the rotating shaft. Instead, you are measuring from the bearing housing of the machine. This means you are really measuring the response of the machine's structure to the vibration from the rotating shaft inside, the components on the shaft, the bearings, the covers and the foundation. There are many random vibrations mixed in with rotating shaft vibrations. Even the repeatable vibration from the rotating shaft has many variables, such as resonance, speed and load, location, sensor mounting, environment, operational, noise, excitation and other machine influences.

> "Recent developments in the field have enabled a broader application of the practice"

To reduce random vibration, noise and variables:

- Make sure the machine is at the same speed and load each time a measurement is taken.
- Make sure the machine is running at the same operating conditions.
- Make sure the same machines in the area are running at the same operating conditions.

You can do your best to minimize random vibrations and reduce the variables, but vibration spectrum is never going to be exactly the same. The only way you would ever see this kind of repeatability is in a lab environment in space. That's why using the right tool is so critical because by the time the vibration from the rotating shaft transmits through the bearing to the outside of its housing and into the sensor that is attached with a magnet and mixed with the resonances and noise of the machine, foundation, surrounding structure and adjacent machines, there are just too many variables to expect exact repeatability.

After decades of either primitive (think screwdriver) or extremely unwieldy and expensive vibration analysis, recent developments in the field have enabled a broader application of the practice. Now a critical component of condition-based monitoring programs, vibration analysis continues to evolve, with tools more easily accessible and affordable to the average user.

John Bernet *is a Mechanical Application and Product Specialist for Fluke. Using his 30-plus years of experience in maintenance and operation of nuclear power plants and machinery in other plants, John has worked with customers in all industries implementing reliability programs. He is a Certified Category II Vibration Analyst with over 20 years of experience diagnosing machine faults and a Certified Maintenance Reliability Professional (CMRP). John served in the U.S. Navy as an electrician for 12 years. www.fluke.com*

Figure 2: At Alpenrose Dairy, regular vibration analysis provides data for trend analysis used in proactive maintenance

CASE STUDY:

The Tool that Saved the Dairy

At Alpenrose Dairy in Portland, Oregon, a vibration analysis contractor performing a semiannual check of a critical air compressor warned of bearing deterioration. One of the bearings had gone bad and the maintenance team was advised to take care of it within several months. However, the next week, the air compressor went down, limiting the plant's production.

At that point, the dairy's maintenance manager realized the outside contracting firm might not fully understand the workings of the dairy's equipment. Knowing the ramifications that down equipment could cause, the dairy decided it would be advantageous to have the capability in-house to check its equipment every couple of weeks.

After much research and consultation, Alpenrose Dairy decided to invest in a vibration meter. The maintenance team takes a reading once a month or once a week, depending on the equipment and their findings. If something different is observed, a trend analysis is built with the data. If a change in frequencies is noticed, it is immediately scheduled to be looked at by the maintenance team.

Since it is not economically feasible to test every piece of equipment at the dairy every single month, the maintenance manager prioritizes which equipment to check on a monthly or quarterly basis. Factoring into the decision are the baseline readings from the vibration meter.

By investing in a vibration meter for vibration analysis, Alpenrose Dairy now has a better idea and feel for what's going on with its equipment.

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