

Combine vibration monitoring and ultrasound for more cost-effective predictive maintenance

The best overall machinery monitoring program is one that utilizes multiple, integrated monitoring technologies.

By Mike Bacidore, chief editor

In brief:

- *The best overall machinery monitoring program is one that utilizes multiple, integrated monitoring technologies that are well-suited to detect expected failures modes.*
- *One goal of PdM is to determine how much time is left before a machine will fail, so plans can be made to minimize downtime and damage while still getting the most useful life from the machine.*
- *An application where ultrasound and vibration work well together is a mechanical inspection.*

Reliability-centered maintenance programs are most effective and most profitable when a variety of appropriate technologies and tools are used to complement one another. Vibration analysis and ultrasound are as complementary as two sides of the same coin. **Ultrasound** is a useful monitoring tool, capable of detecting failing rolling element bearings and over- and under-lubrication conditions. The best overall machinery monitoring program is one that utilizes multiple, integrated monitoring technologies that are well-suited to detect expected failures modes. For low-risk machines, **vibration analysis** can be performed by a mechanic or operator using a vibration data collector or vibration meter. For machines of higher criticality, a certified vibration analyst should use advanced vibration data collection and analysis hardware and software.

“A lot of people have used vibration as the first indicator,” explains Robert Perez, author of [“Is My Machine OK?”](#) “If you go around and take vibration **data** and your **spectra** indicate a bearing failure, you can follow up with ultrasonics. Maybe you have early signs of bearing distress, and you follow up with ultrasonics and you hear the bearing is a little noisy. Some people might use that to inject grease in the bearing. Some people use it so they don’t over-grease the bearing. You can optimize your **greasing program** with ultrasonics. You can use it to determine if you need to repair or replace the bearing. Some people do the same thing with vibration. You see a lot of noise in the bearing, and you add grease to see if it gets quiet. The ultrasonics let you hear what’s going on in the bearing. A lot of vibration programs don’t have the ultrasonic gun, but it is definitely good for leaks. One person’s critical equipment is not necessarily another’s.”

On a rolling element bearing, it might make sense to use vibration and ultrasound, says Perez. “On a big reciprocating compressor, we use vibration, pressure volume analysis on the cylinder, and then ultrasonics to determine if we have a leaky valve.”

An application where ultrasound and vibration work well together is a **mechanical inspection**, says Maureen Gribble, director of marketing at [UE Systems \(www.uesystems.com\)](http://www.uesystems.com). “There are a number of ways they support each other,” she explains. “The first is utilizing ultrasound as the primary tool for monitoring bearing condition. The ease, speed, and accuracy of ultrasound inspection has helped many **inspection** departments reduce their routine inspection times by as much as 30%.

To learn more about ultrasound and vibration analysis, read [How ultrasonic technology helps equipment speak](#).

Next, while vibration analysis can readily detect **faults** such as imbalance, cracked shafts, gear faults, and misalignments in high-speed machinery of greater than 60 rpm, detecting faults with vibration analysis becomes increasingly more difficult as the speed of the machinery decreases. This presents an opportunity to utilize ultrasonic analysis as an effective and efficient way to monitor bearings at slower speeds.”

At low speeds, such as 150 rpm, the vibration acceleration signals of a normal bearing and a defective bearing have similar characteristics, continues Gribble. “This makes it hard to note the difference and thus determine that there is a defect,” she says. “With ultrasound, a significant difference can be heard and seen in the magnitude and shape of the signal, making it far more easy to pinpoint and thus correct the defect.”

Ultrasound also can be useful when performing inspections on complex pieces of equipment, such as a gearbox, says Gribble (Figure 1). “While vibration is good for painting the whole picture of what is happening within an asset, ultrasound can really narrow in on a specific area, making localized fault detection easier,” she offers. “When all is said and done, there’s no denying that combining ultrasound and vibration analysis can greatly enhance the **diagnostic** process.”



Figure 1. Utilize ultrasound as the primary tool for monitoring bearing condition.

Vibration analysis and ultrasound work very well together in a **predictive maintenance program**, says Jason Tranter, managing director of [Mobius Institute \(www.mobiusinstitute.com\)](http://www.mobiusinstitute.com). “However, due to the cost and skill requirements involved with vibration analysis, it can be difficult to test the plant’s rotating machinery frequently enough to provide the earliest warning of a fault condition,” he warns. “One solution is to provide operators with an ultrasound tool to scan machines on a more regular basis. If there is a change in the sound emitted by the machine, the operator can call in the vibration analyst to perform additional measurements so that a detailed assessment of the potential problem can be made. Routine vibration measurement should still be performed to detect any problems not detected by the ultrasound tool, but this strategy reduces the likelihood of fault conditions will be missed.”

One goal of **PdM** is to determine how much time is left before a machine will fail, so plans can be made to minimize **downtime** and damage while still getting the most useful life from the machine, explains Allan Rienstra, international sales manager at [SDT International \(www.sdtthearmore.com\)](http://www.sdtthearmore.com). “To do this, we need to categorize **stages of failure** based on several factors, such as PF curve, mean time between failures, and stages of criticality,” he says. “The problem is that, when we have hundreds or thousands of machines, how do we filter down from 1,000 to only the 10 that are going to fail tomorrow? That is where ultrasound and vibration work symbiotically.”

Ultrasound is a **filter**. “I call it the first line of defense for determining that ‘my machine is not OK,” explains Rienstra. “We use ultrasound as the first filter to get from an initial list of 1,000 running machines to a secondary list of 100 machines that are in need of some form of maintenance intervention. But what stage of failure are they in? An increase in friction is the first stage of failure, so we can use ultrasound to filter which of the 100 machines have bearings that are in Stage 1 failure. We do this by simply lubricating the bearing and observing the ultrasound trend line.”

If 20% of those 100 machines were simply in need of lubrication, ultrasound has now filtered PdM tasks from 1,000 down to 80, says Rienstra (Figure 2). “Ask any vibration analyst and he will tell you that he would rather gather and analyze data on 80 machines that were in trouble than 1,000 that may be in trouble,” he explains. “You could argue that ultrasound helps make vibration analysts more efficient with their time by allowing them to focus on just the machines that are in trouble.”

Determine the failure modes in equipment and their individual components, says Trent Phillips, condition monitoring manager at [Ludeca \(www.ludeca.com\)](http://www.ludeca.com). “Once this determination is made, then the appropriate condition monitoring technology can be applied that provides the earliest warning of conditional changes in the equipment for each failure mode identified,” he explains. “Each condition monitoring technology has certain applications that it is best suited for. Almost all condition monitoring technologies have certain overlaps and can detect the same type of conditional changes in equipment. This is true when ultrasound and vibration analysis are compared. Both can be used in similar situations and have unique advantages in certain situations. Certain lubrication conditions in bearings and other bearing conditions can be detected with both ultrasound and vibration analysis. This is an example of the complementary aspects of both technologies. One can be used for detection and the other used for verification.”



Figure 2. Capturing dynamic ultrasound data on the non-drive end bearing of electric motor gives an indication of over- or under-lubrication and possible early stage fault condition.

Another aspect of condition monitoring that is becoming very important is the analysis and interpretation of **failure mode** on low-speed applications, such as bearings below 100 rpm and gearboxes, says Rienstra. "Vibration analysis for low-speed applications can be difficult," he explains. "It requires special accelerometers, patience from the analyst, and confidence, too. Advanced ultrasound instruments can now capture dynamic data, which can be analyzed in the same way as vibration data, in the time-and-frequency domain. Many vibration departments are using dynamic ultrasound data to detect faults in low-speed bearings. This is another example of the harmonious and symbiotic nature of these two companion technologies."

Good vibration

Vibration analysis has many uses in a predictive maintenance program (Figure 3) "The best uses include analyzing the **mechanical condition** of rotating machinery and as a detection method for all classes of mechanical faults," says Ken Piety, vice president of technology at [Azima DLI \(www.azimadli.com\)](http://www.azimadli.com). "It's also sensitive to some electrical fault in electric motors or generators."



Figure 3. Vibration monitoring can be used to analyze the mechanical condition of rotating machinery and as a detection method for all classes of mechanical faults.



Figure 4. If used correctly, vibration analysis can give the maintenance and production team a heads-up on developing problems so that maintenance can be scheduled at the most convenient and cost-effective time.

Vibration analysis can be used to detect a wide range of fault conditions before they turn into failures, explains Mobius' Tranter. "If used correctly, vibration analysis can give the maintenance and production team a heads-up on developing problems so that maintenance can be scheduled at the most convenient and cost-effective time," he says (Figure 4) "As part of a predictive maintenance program, it can aid in avoiding failures results in less downtime, elimination of secondary damage, reducing parts inventory, and creating a safer work environment."

The vibration analyst's skills shouldn't just be used to detect fault conditions, cautions Tranter (Figure 5) "They should be used to reduce the likelihood that the fault conditions will develop in the first place," he warns. "With an effective **acceptance testing**

program, problems won't be inherited by the plant. With an effective **proactive maintenance program**, where unbalance, misalignment, looseness, and resonance problems are eliminated, fault conditions are less likely to develop. And with an effective **root cause failure analysis program**, fault conditions won't be repeated.”

Vibration analysis is best used to detect conditional changes in equipment before a functional failure occurs, reiterates Ludeca's Phillips. “Earlier detection through vibration analysis means that fewer equipment-inspection intervals are required, more time is available for corrective action, and the consequences of equipment failures can be avoided,” he explains. “Vibration analysis improves **planning and scheduling** activities, leads to increased equipment uptime, improves capacity, improves safety, and increases profits.”

Vibration analysis provides a window to certain equipment defects that other technologies cannot detect, continues Phillips. “Vibration analysis can be applied to most equipment that has rotating, lubricated, and certain electrical components,” he says. “Vibration analysis should be viewed and utilized as a critical foundational element for the overall reliability efforts within an organization.”

The best use of vibration analysis is certainly up for interpretation, depending on the process and the user, says SDT's Rienstra. “Everyone has an opinion, and they're usually all right, as it's not really white or black,” he explains. “The truth is that the technology is quite powerful and can be used for condition monitoring to trend changes, diagnosis to decide if it's time to act, and analysis of why the problem exists. For my money, vibration analysis is best used in a predictive maintenance program for the last two — **diagnosis** and **root cause analysis**. It doesn't make sense to use vibration analysis as a condition-monitoring tool because of the high cost per measurement to collect the data and to process it.”

Vibration analysis has been proven to be a key in any machine monitoring program, agrees Perez. “You'll only use it on equipment that has medium to high criticality,” he explains. “A 5-hp water pump can run to failure. Vibration analysis is a quantitative analysis, so people can monitor equipment on a regular basis and determine the condition and repair it before a catastrophic failure or shutdown, or they can have an outage planned. First, determine criticality. Second, what kind of equipment is it? Do you want to use accelerometers or proximity probes? Rolling element bearings? Sleeve bearings? Vibration analysis is proven on equipment from 5 hp to 50,000 hp and above.

Electrical motors, centrifugal compressors, centrifugal pumps, gas turbines — there's a huge library of vibration analysis spectra for comparison. There are libraries of different



Figure 5. Vibration analysts' skills should be used to detect more than fault conditions. They should be used to reduce the likelihood that the fault conditions will develop in the first place.

spectra for cavitation, bearing defects, or imbalance. All of these are known and published. It's easy to get the right training. There are expert systems out there. You can do qualitative and quantitative analysis with vibration analysis. People want consistency. We could call vibration analysis a very mature technology."

Ultrasound advice

"Airborne and structure-borne ultrasound has evolved into a powerful and versatile tool for anyone's PdM toolbox," offers UE Systems' Gribble (Figure 6) "With applications ranging from electrical inspection to compressed air, steam trap, and valve testing, the primary use has migrated to mechanical inspection, with an emphasis on bearing condition. New innovations in software and hardware find ultrasound being utilized to monitor and trend bearing condition. The maintenance team that can implement all of the applications for which ultrasound can be used in the condition-based-monitoring program is going to find themselves in the best position to reduce energy waste, reduce greenhouse gas emissions, eliminate equipment failure, increase production and safety, and decrease downtime."



Figure 6. When applying grease to bearing on a pump, apply a little at a time and observe the meter for a dB drop.

Airborne and structure-borne ultrasound is a very versatile tool, agrees Mobius' Tranter. "It can be applied to rotating machinery plus electrical apparatus and a host of process applications, for example, the detection of leaks and problems with steam traps," he reiterates. "The use of ultrasound has the additional benefit in that the cost of ownership is lower compared to vibration analysis, and the training required to operate the tool is less demanding. As applied to rotating machinery, ultrasound can be used to detect lubrication problems and other conditions where telltale 'stress waves' provide an indication of a developing problem, for example, coupling faults, looseness, damaged rotor bars, and damaged bearings."

SDT's Rienstra has a philosophy about ultrasound's role in PdM. "It's there to answer that simplest of questions, 'Is it OK?' he explains. "Ultrasound is the ultimate condition-monitoring technology because it provides us with reliable **baseline data** that can be trended over time to indicate a change has occurred. The data gleaned from ultrasound has many interesting features. Ultrasound data provide an indication that a change has occurred in a machine earlier than any other technology. This is a statement of fact that was confirmed by a NASA study in the 1970s. Ultrasound data are inexpensive to collect in comparison with other PdM technologies on a per-point basis."

Ultrasonics is more of a **qualitative analysis**, where people can look at the content and see the wave form and determine what's going on, explains Perez. "It's a comparative technology," he says. "The areas I'm aware of where it's useful are steam-trap leakage, pressure-safety-valve leakage, and reciprocating-compressor valve leaks. It can help to

Forrás: <http://www.plantservices.com/articles/2013/04-combine-vibration-monitoring-ultrasound.html?page=full>

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determine leakage and replacement. It also can be used for electrical, or coronal, discharge leaks. Ultrasound is subjective, and there's no value you can assign to a leakage rate."

Outside help

"If you have somebody who just does vibration analysis part-time, it'll be difficult to develop proper skills," cautions Perez. "Some locations use operators to collect the data. They'll sometimes lose the data-collection device because they don't want to do it. I've only seen it successful, that is, profitable, when it's a full-time job. If you had a site with 10 pumps, and you're going to check them monthly, that person isn't going to be competent. He'll have to relearn it every month."

There's probably a critical mass you'll need to determine what justifies a full-time person, suggests Perez. "He could also do other things to make him full-time," he says. "If this person's a mechanic, he might try to justify more work for himself. But he needs to have a reliability mindset. You may want him to report to the plant manager. You have to align his incentives with management's incentives. You want that person to be motivated and trained, but you want him to think the way you think. You want him to think like the plant manager. Why is this piece of equipment important? You need to be in tune with the operations. If you have someone outsourced, is he in tune with your operations? He may not understand the process. He may be more willing to repair something because he doesn't want to take a chance. When you have an in-house person, he's thinking of bonuses and viability of the plant and he has a different mindset. If possible you want an in-house person trained with enough work to keep him busy on reliability-type work."



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Ultrasonics should be performed by in-house staff because the equipment is relatively inexpensive and the interpretation of the data is performed by the operator's ears and brain by listening for characteristic patterns, says Azima DLI's Piety. "Vibration monitoring services can be effectively executed by in-house or contracted personnel," he says. "A third model should be considered where in-house staff performs the data collection, but the analysis of the vibration data is done via contracted services. This model gives the plant coverage whenever a problem occurs but engages a team of expert diagnosticians to interpret the data. I believe that this third model has the option of providing reduced cost, more accurate diagnosis, and a more sustainable program."

When resources are insufficient to allow maintenance of the program in-house, contracting is an option, says SDT's Rienstra. "Otherwise, it's always best if machines are cared for in-house by people who are around them each and every day," he says.

"The benefits of an in-house program are that the condition monitoring technicians should have a better relationship with the maintenance and operations staff and a greater familiarity with the machines," explains Mobius' Tranter. "Before they even lay a sensor on the machine, they may be able to tell that something is unusual with the machine or the process. An in-house condition-monitoring analyst should also be able to respond more quickly to problems that develop, and they should be able to test the machines more frequently. If a plant has a lot of rotating machinery and a commitment to using the right people who are using the right tools with the appropriate training and certification, then an in-house program can be very successful. On the other hand, if the client has a smaller number of machines, then the use of consultants can be far more cost-effective. Another benefit to using consultants is that they should have more experience with the condition-monitoring tools and possibly with the same types of machines being operated at the site. The staffing, purchase and maintenance of condition-monitoring tools, training, and certification are all responsibilities of the consultants, removing that burden from the plant's maintenance management."

Deciding between in-house and contracted condition-monitoring efforts depends upon many factors, such as available resources, qualifications of those resources, funds available, and certain business objectives, says Ludeca's Phillips. "If internal resources or experience is limited, then contracted resources may be the best solution," he explains. "Also, under certain circumstances, contracted resources may provide faster implementation and results, if that is an important factor. In-house staff can usually provide more routine monitoring capabilities versus contracted resources. Additionally, internal resources usually have a greater understanding of the normal operation and maintenance of the monitored equipment. Operators and maintenance staff can be utilized to collect the routine condition-monitoring data. The CM analyst, whether an internal resource or contracted, can focus more of their time on defect analysis of the collected data and root-cause elimination."

If a facility doesn't have the time or manpower for conducting the inspections, then outsourcing is critical, says UE Systems' Gribble. "Often, the decision is based on the plant manager's assessment of how to best utilize maintenance personnel," she explains. "If there is a restraint regarding flexibility or available man-hours or if there is a belief that an external inspection resource might be able to provide expertise that might not be available, then contracting ultrasound and or vibration services is to be considered. With regard to ultrasound, one of the biggest advantages of utilizing this technology in a PdM program is that the equipment is affordable and the training, while very important, is not nearly as time-intensive as some of the other predictive technologies available. A facility that can commit to taking the time to train personnel will find themselves getting the most value from the investment. Otherwise, the plant manager might be stuck with a very powerful piece of technology collecting dust on a shelf while equipment fails."