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Practical Techniques for Utilizing Ultrasonic Technology To Complement Vibration Analysis

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Ultrasonic energy data is collected in the 20 kHz to 100 kHz. range where operating machinery will produce a high frequency "footprint" pinpointing defects long before said defects become a major problem. Ultrasonic waves are very short in nature as compared longer wave audible sounds which makes them directional-traveling well in air but tending to be blocked by solids. Since high frequency signals such as these only travel on the order of a maximum of ten inches or so, direct contact in the correct direction assures positive failure detection for bearings. Barring direct contact on the bearing, a probe can be employed on the housing into which the bearing is mounted.

When the subject of ultrasound is brought up, most people tend to reflect on the monitoring process that doctors employ to view an image of a fetus during pregnancy. Ultrasonic analysis is also extremely effective in industrial applications to detect steam or air leaks, electrical corona and bearing defects among other things. As we know supersonic to be beyond the speed of sound so is ultrasound as beyond the range of human hearing generally defined as being anywhere from 20 Hz to 20 kHz (one hertz being one cycle per second).

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While vibration analysis can detect a problem with a bearing often a year or more in advance of a failure NASA has conducted extensive research showing ultrasonic techniques can reveal failure modes before being detected by normal vibration data collection.

Any ultrasonic signals produced will be mixed with a broad range of sounds most of which need to be filtered out in order to collect good, solid high frequency data. Ultrasonic detectors/analyzers convert or heterodyne a high frequency signal into an audible sound so that the operator can hear the tone associated with the particular characteristics of each individual signal, recognize and analyze it based upon recommendations, industry standards or simply repeated experiences.

__Figure 1__ - Prepare a "y" cable that will plug into the detector on one end with the other end plugged into the data collector.

The ability to recognize and interpret this input is, of course, paramount to failure detection. Trending of the data is possible by introducing the signal from the detector into a standard vibration data collector for downloading to software which can produce either a time waveform, a spectrum or both. In this way, data can be analyzed, trended and even compared just like regular vibration data. The problem with this plan is that the intensity of the signal is subjective just about negating the trending capabilities without imposing some guidelines.

One good method for objectively monitoring equipment is to prepare a "y" cable that will plug into the detector on one end with the other end plugged into the data collector (Figure 1). The third connector will be for the headphones. With the probe nose attached, it will be necessary to establish a baseline by touching the probe to the bearing housing to be monitored, adjust the settings on the ultrasonic detector then leave them at those positions until all the data has been gathered for that run. Please note that if a monument is not mounted on the machine in concert with a threaded probe to assure readings are gathered consistently, then the effort must be made to hold the probe the same way each time data is gathered.

Start by setting the meter mode to linear with the frequency set between 20 to 30 kHz. This particular setting seems to be most conducive to capturing bearing tones and is variable in that it will have to be adjusted once the headphones are on. Put the headphones on, touch the probe to the machine, pull the trigger while adjusting the sensitivity to a comfortable level then leave that setting alone as this will be the setting for all the same types of machines in the route. Now the frequency span can be adjusted to a level where the sound is clear and distinct. Plug in the data collector and collect. At this point it should be noted that some form of notation is required indicating the relative positions of the dials so those settings can be repeated on a consistent basis for accurate trends. Naturally different kinds of machines will require different settings. Taking a regular vibration reading at the same time is also recommended.

The software we use has the capability to be set up to accept the ultrasonic detector as a kind of accelerometer. Edit collection specifications for the transducer, the window as Hanning, the signal detection as peak, the maximum frequency as a standard envelope of 60,000 cpm (this can be adjusted depending on the machine speed). Resolution should be as high as possible in linear mode at 4 averages. The transducer options must be set for a generic accelerometer at ImV/unit sensitivity, 12 volts DC faults high and low and uncheck the Enable Power box. Both a spectrum as well as a time waveform can then be generated for each point.

For the purpose of demonstration, data is taken on a hydraulic pump for both ultrasonic as well as vibration readings (Figure 2). The pump is suspected to have bad bearings but the call cannot be made to overhaul the pump simply by analyzing the vibration data.

The L-10 life of a bearing is designed to be on the order of 100 to 1000 years where 10% would fail even though actual operating conditions do not bear this out. Hydraulic pumps themselves tend to be pretty beefy, sometimes operating satisfactorily for years in a damaged condition. This becomes a particularly notable when analyzing these assets wherein if the call is made too soon, the maintenance crew repairs the unit noting no visible problems thus damaging credibility to be able to call these problems effectively. With ultrasound enhancing vibration, items such as these can be addressed by recommending repair much closer to the inceptive failure itself.

So just how does the data compare between a bad pump versus a new one? Figure 3 is an ultrasonic spectrum from a brand new pump known to be in excellent running condition.

Figure 4 - is another ultrasonic spectrum of our suspect pump showing definitive peaks with sidebands.

This type of a monitoring method will negate the tedium of writing down a lot of dial settings manually to determine how many dB down or dB increase has occurred in a trend, then having to go back over the numbers. It is much more efficient to download the data to trend and analyze conveniently in the software where all the data is present complete with annotation right on the screen. The software also has the capability of creating a magnitude trendline for the various spectra collected so in this way eliminating the need to trend manually. Any number of machines can be compared to the grouping as can single machines be trended historically.

One of the problems with using ultrasonics is that since it does have a detection rate higher than that of vibration analysis (remember, NASA uses ultrasound to detect bearing degradation now rather than vibration), care must be taken...especially on critical equipment...to make the call on the bearings as close as possible to what the incipient failure might be. This way the bearings can have the last drop of usefulness squeezed out of them as possible without impacting production. Since a vibration analyst will already have considerable training in concert with experience in spectrum analysis, reading ultrasonic data becomes another tool that soon becomes familiar.

Trending is a recognized, valuable tool in vibration spectrum analysis that can often have trends of incipient failures practically leap off the page at you. Figures 5-9 (next page) are examples from an ASAT (Auto Spar Assembly Tool) spindle that has ceramic bearings. This particular type of machine is a line stopper that is monitored for critical downtime and not just because the spindle cost $75,000.00 to rebuild!

Figure 2 *- For the purpose of demonstration, data is taken on a hydraulic pump for both ultrasonic as well as vibration readings.*

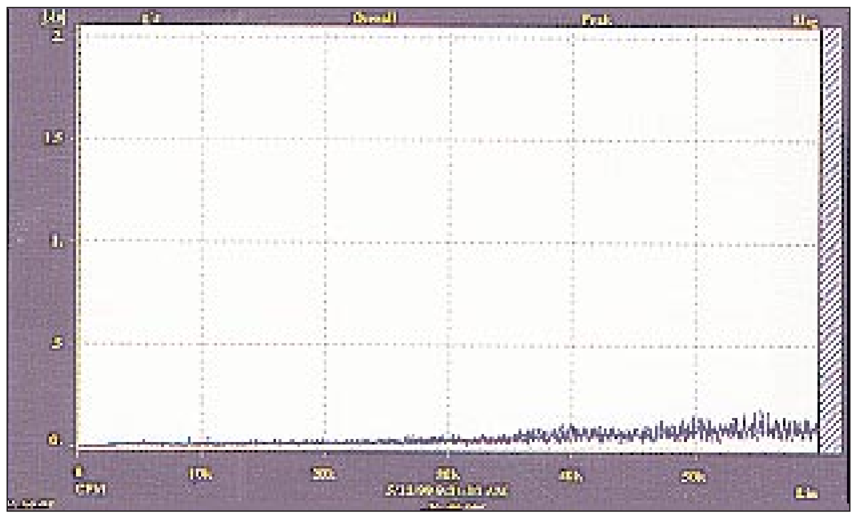

Figure 3 *- Ultrasonic spectrum on a normally operating hydraulic pump with no bearing defect indicators.*

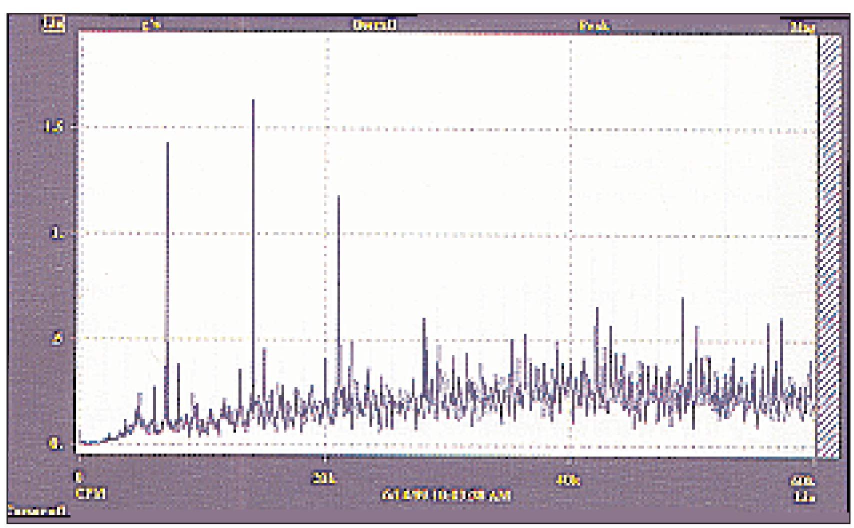

Figure 4 *- Ultrasonic spectrum of a hydraulic pump with bearing problems showing distinct repeating peaks and accompanying sidebands.*

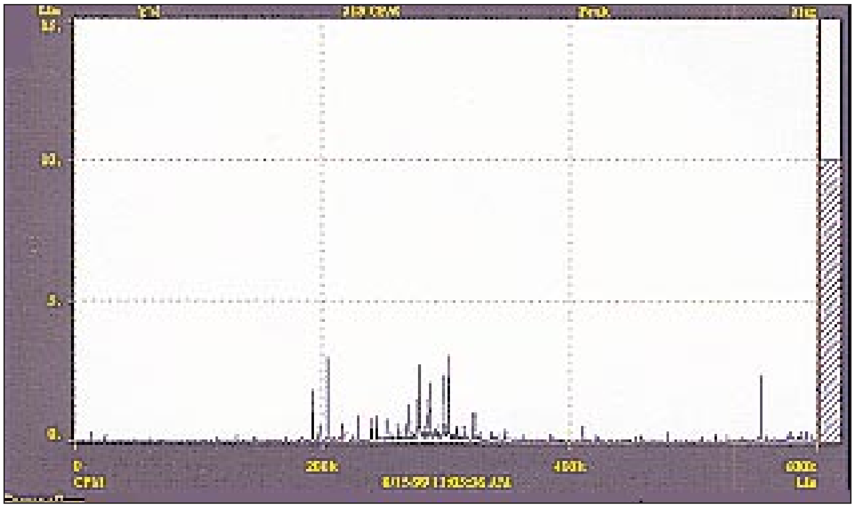

Figure 5 - *This vibration spectrum of a spindle shows peak activity of well under 5 Gs.*

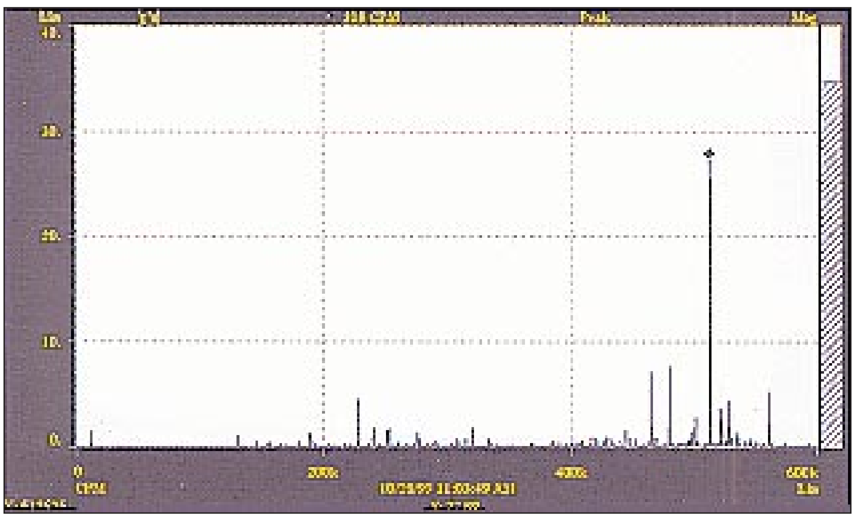

Figure 6 - *This view shows the same spindle two months later with a peak of over 27Gs.*

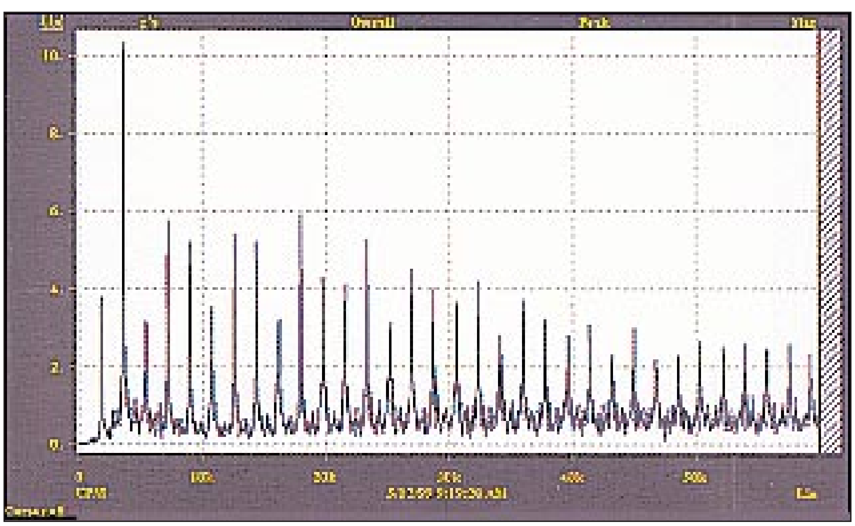

Figure 7 - *Ultrasonic spectrum of the ASAT spindle after rebuild.*

Note the amplitudes on the left sidebars.

Bearing Failure

As mentioned previously, bearings are designed to have a life of anywhere between 100 and 1000 years under ideal conditions. It has recently been discovered that if a bearing develops a stress defect without regard to outside influence such as contamination or improper lubricant, it will first appear as a crack one to three thousands below the race surface. This stress crack obviously cannot be seen but can be heard as every time a ball rolls over the top of the crack, it emits an ultrasonic "squeak". This is the kind of thing easily detected by ultrasonic analysis.

The question arises as to what point do we put in a service call to replace the bearing? Certainly as soon as the problem is detected maintenance could be contacted but when they pull the bearing they will see what is to them a nice shiny bearing with no physical defects whereupon the question will arise as to why was there a need to replace this bearing at all. There is also the problem of cost since the bearing could be run a long time without damage to the machine or impact to production. The answer, of course, would be to monitor with both vibration as well as ultrasonic analysis until the bearing degradation ran farther up the failure curve.

After bearing wear is detected, the next indicators will be heat then motor overload. We don't want to get to the overload stage, hi the event that a bearing is called too early to be able to see the actual defect, it can be detected by magnafluxing if such a procedure is warranted.

Low speed bearings are tough to call simply by the nature of their low inertia produced by the low speed. In addition, the grease that would be used tends to absorb almost the entire signal. In this case collecting the time waveform directly from the ultrasonic detector and downloading it into the software for analysis would tend to be more reliable than simply hearing the sounds produced, plus the data is demonstrable.

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About the Author -

Bert Anderson is Vibration Analyst Level II Lead at the Boeing Commercial Airplane Group in the Renton Washington plant and has been utilizing vibration analysis for six years specialising in spindles. He also has a Level II certification in thermography. The beginning of his fourteen years at Boeing was spent as an NC mechanic eventually leading, him to help form the beginnings of a CBM program at the Kent, Washington plant in association with the Equipment Reliability Improvement Team which is a sounding board for Boeing CBM technologies. Regular technical paper contributions are made by Bert to various trade magazines including P/PM Technology as well as speaking engagements at the Predictive Maintenance Technology National Conference. Prior to Boeing, Bert worked as a maritime mechanic for Marine Systems. He is currently pursuing an MBS.

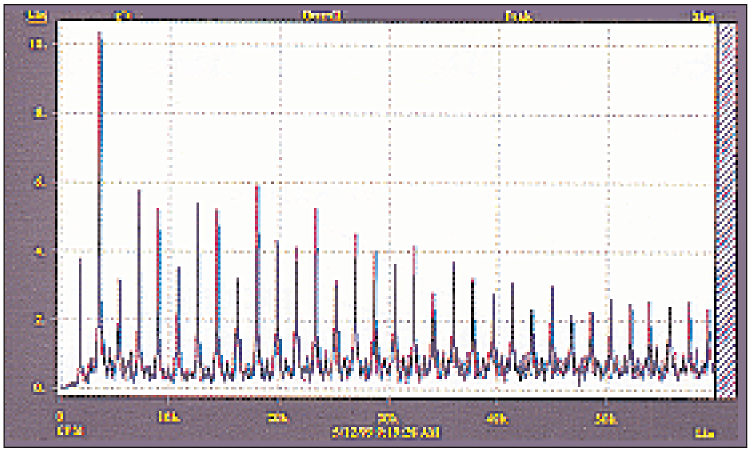

Figure 8 *- View of ultrasonic spectrum prior to pulling the spindle.*

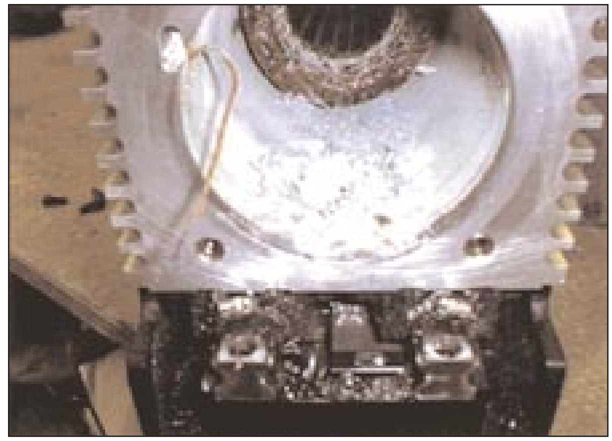

Figure 9 *- View of the spindle during disassembly showing the remnants of ceramic bearing. Talk about catching them in stage 4!*