

Integrating Ultrasound and Vibration Technologies

Together, Each Achieves More

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Predictive maintenance technologies are extensions of our senses that enable us to see, hear, and feel beyond our human capabilities. Infrared cameras allow us to see and measure heat energy residing outside the boundaries of visible light. Vibration data collectors broaden our ability to sense, measure, and interpret small movement of our production machinery. Ultrasonic data collectors expand the range of the human ear enabling us to hear, measure, and trend micro changes in friction levels within the elements of our production machinery. Alone, each of these technologies (and others) provides us with critical insight about the health of our equipment. By integrating data collected from predictive technologies we position ourselves to make a more informed, and confident decision. Everyone is familiar with the medical cliché “ask for a second opinion.” By combining the strengths of ultrasonic and vibration data collection we are practicing the same life philosophy.

When the senses work together an assortment of information is delivered to the brain. Given the brain’s ability to process this complimentary data a complete and better decision is reached. For example, when the sense of touch feels “*this is hot*” and the sense of sight sees “*the pot is boiling*” and the sense of hearing detects “*the smoke alarm ringing*”, the brain tells the rest of the body how best to react. What happens when the predictive technologies we use to diagnose machine condition are combined to work together, instead of separate and isolated from each other? The technologies working properly together become an integral force with one main goal. Like a true and honest teamwork – ***Together, Each Achieves More***. The goal; avail ourselves with a variety of accurate, reliable information that empower informed and confident decisions to sustain and extend the useful life of machines.

This paper is dedicated to exploring the possibilities for enhanced predictive maintenance through the integration of two important technologies; ultrasonic condition monitoring and vibration analysis. It recounts how one company’s approach to integrating multiple predictive technologies helped them establish a world class reliability department that is the envy of their peers.

Ultrasound using an SDT Ultrawave 170MD, Vibration using a CSI 2120, Oil Analysis, and Infrared Thermography are four complimentary predictive technologies used extensively by Ralph Copp and the Predictive Maintenance and NDT team at Potash Corporation of Saskatchewan (PCS) New Brunswick. Ralph is head of the Predictive Analysis Dept. where he is responsible for the vibration program, oil analysis and lubrication, infrared temperature, ultrasound, and NDT. PCS/NB Division is a Potash and Salt Mine near Sussex, New Brunswick Canada. Both products are mined approximately 2000 ft below the surface. The potash, after going through a concentrator (mill) on the surface, is shipped around the world and used primarily in the fertilizer industry as one of the main ingredients. The mined salt is used mostly for road salt in the winter months. The benefit of using PdM technologies together is seen not only with cost savings in dollars and time but also in recognition that they get from other industries in the area. PCS New Brunswick is a model of how a proactive maintenance department should be.

Conventional ultrasound technology senses high frequency sound waves and translates them to corresponding audible signals that can be heard with noise attenuating headphones. Advanced ultrasound technology, in addition, accurately measures ultrasonic data for storage, processing and trending. All production machinery produces sounds that are represented through a broad frequency spectrum. Airborne/structure borne ultrasonic detectors use a sensitive piezoelectric crystal as a sensing element to detect the high frequency portion of this sound while filtering out the parasitic low frequency waves. These ultrasonic waves pulsate against the crystal creating an electrical charge that is amplified and then translated into an audible frequency. Inspectors can listen to the qualitative signal through a headset and accurately measure the signal on the detector's display. Some industrial applications for Airborne Ultrasound include:

1. Leak Detection
2. Electrical Inspections
3. Valve and Steam Trap Inspections
4. Mechanical Condition Monitoring
5. Predictive Lubrication Monitoring

Four and Five are commonly referred to by operators as Acoustic Vibration Monitoring or AVM.

For all mechanical applications, Copp uses the Ultrawave 170MD first to do bearing inspections. This is their “first line of defense” since it allows them to check as many bearings as they want quickly, then prioritize which equipment needs to be looked at further. Ultrasonic energy is generated by the frictional forces of rolling element bearings regardless of their condition. Frictional energy from a well lubricated bearing is measured and logged to establish baselines. Changes in lubricant condition is heard and measured with the Ultrawave 170MD at a very early stage; normally before the bearing enters initial failure stage. The same technology can then be employed to properly lubricate and extend the useful life of the bearing.

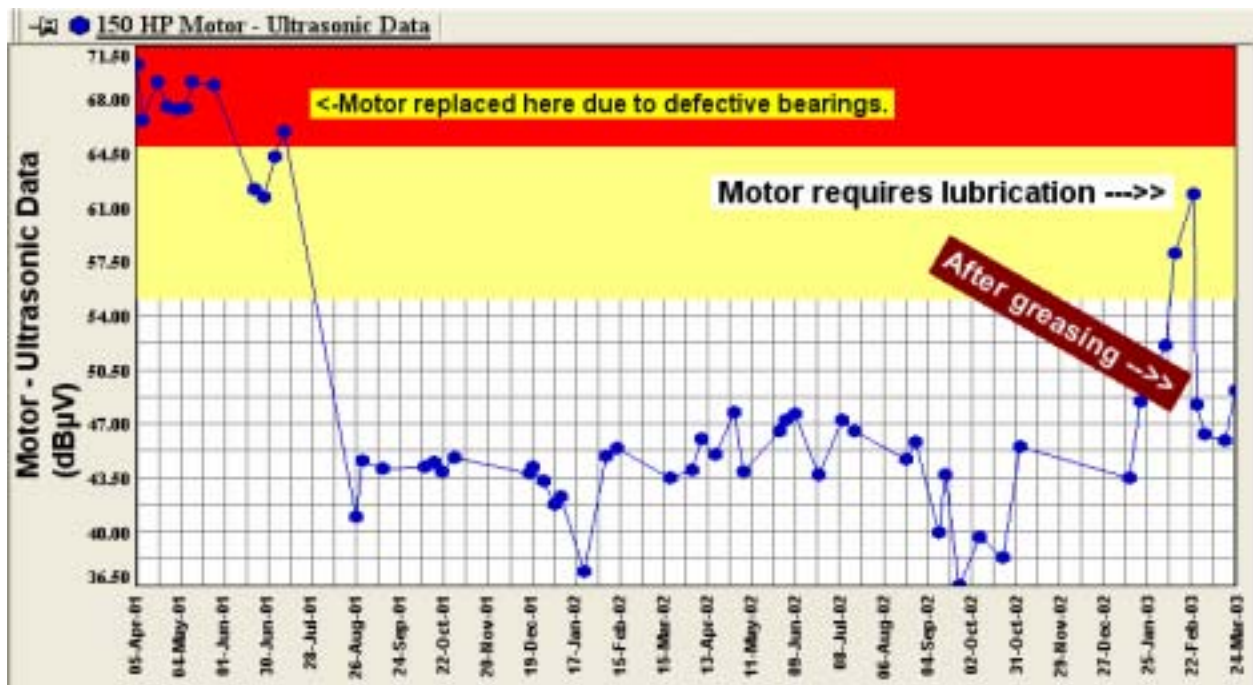


Figure 1 – Ultrasonic dBµV readings on 65-028 #2 XLR Re-circulating Pump Motor

Figure 1 graphs ultrasonic data from the drive end bearing on 150HP electric motor used to power a re-circulating pump. Between January 15, 2003 and February 22, 2003, as span of only 5 weeks, ultrasonic values taken with the Ultrawave 170MD raised 12 dBµV over normal baseline indicating the bearing needed re-lubrication. Using proper lubrication techniques, the bearings frictional forces returned to a normal level. This was confirmed by retaking dBµV readings after greasing. Ultrasonic data collection saved the bearing from running without proper lubrication, and afterwards confirmed that the lubricator applied the correct amount of lubrication; equally important as too much grease would cause the dBµV and temperature levels to rise again.

Only one point of contact on the bearing housing is required to display an acoustic reading on the screen. In addition to sensing lubricant failure, ultrasound detects very slight friction forces produced when two metals are in contact with each other. Deformations in the shape of the rolling elements, pitting and spalling of the raceway, and other deteriorations create sharp spikes of energy known as bearing defect energy. This ultrasonic activity is measured as a dB μ V (decibel/microvolt) reading for each bearing point, stored in the unit's internal data collector, downloaded to a PC database, and trended over time. PCS has established alarm levels for their ultrasonic readings. Figure 2 below is a trending graph of 63-023 XLR Slurry Pump.

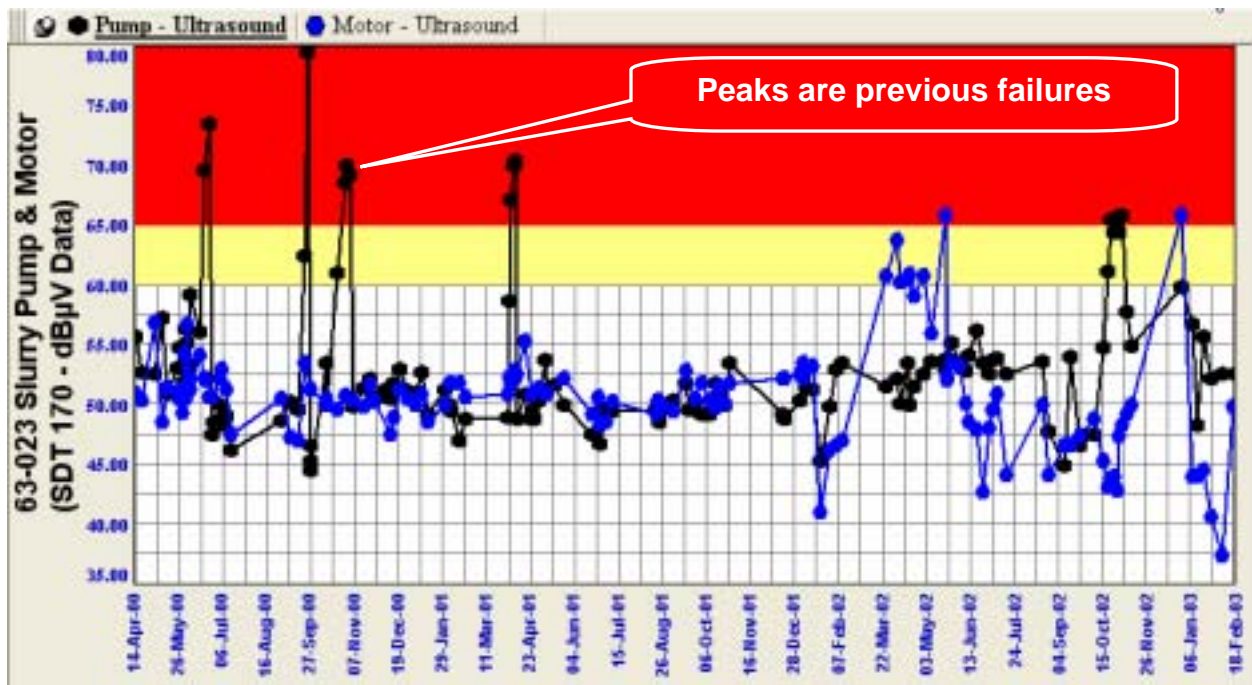


Figure 2 – Ultrasonic dB μ V readings on 63-023 XLR Slurry Pump and Drive Motor

Trending ultrasonic readings for this equipment started in April 2000. Every time a dB μ V reading enters the red portion of the graph (Alarm Level) the equipment is scheduled for repair as soon as possible. In Potash Corp's case, the ultrasonic alarm level for most of their equipments is set at 65 dB μ V. This level was set based on their previous historical experiences. One failure on this pump occurred at the end of September 2000 when the Ultrawave 170MD detected an 80 dB μ V reading, up from 62 dB μ V in the early part of September. The pump was replaced with a rebuilt assembly. Only a couple of weeks later the ultrasonic readings entered the

alarm level again. Further investigation showed a defective rebuild of the pump assembly. After the pump was rebuilt again and properly this time, ultrasonic readings stayed low for several months.

Potash Corp uses SDT 170MD ultrasonic data collection to monitor weekly the condition of most rotating equipment. This technology provides the earliest possible indication of deterioration and potential failure. When the inspector wants to know the reason why ultrasonic readings increased, he uses his CSI 2120 data collector and looks at the vibration readings. Ultrasound answers several questions for the PdM inspector:

- Do I have a good or bad bearing?
- Does the bearing need of lubrication?
- How much lubrication should be applied, being careful not to over-grease?
- How fast is the bearing deteriorating?

By itself and in general ultrasound does not always tell on the spot, **why** the bearing is bad. It cannot tell, for example, that the bearing failed because of misalignment problems. There are a few cases however, when an inspector is very much in tune with the sound of his bearings and over time, can tell by the quality of sound heard from his ultrasonic data collector that the bearing needs lubrication or is entering an early failure stage. For most cases, the inspector uses the principles of Acoustic Vibration Monitoring (AVMTM), which incorporates the science of ultrasound, True RMS signal averaging, and repeatable digital data to determine when the bearing needs lubrication and exactly how much. For decades a time based lubrication program was used and within the same time period, bearing failures due to over-lubrication were constant. There is a new mentality emerging, shifting away from time based lubrication schedules to a predictive based schedule utilizing proper ultrasonic trending methods. In the near future, if not already, this technique will become the norm for establishing lubrication requirements on all production machinery.

Often times, the inspector can analyze information from a vibration data collector to draw conclusions about what is causing the bearing to fail prematurely. Ralph connects the Ultrawave 170MD to a CSI 2120 through a BNC cable to view the spectrum on the CSI data collector. Ultrasonic spectra is saved and analyzed with vibration software. This technique is used at PCS for verification purposes, regardless of machine speed and condition. When two technologies looking at different aspects of the machine can tell the inspector the same conclusion about machine condition, then the recommendation is stronger than if the diagnosis comes from just one technology.

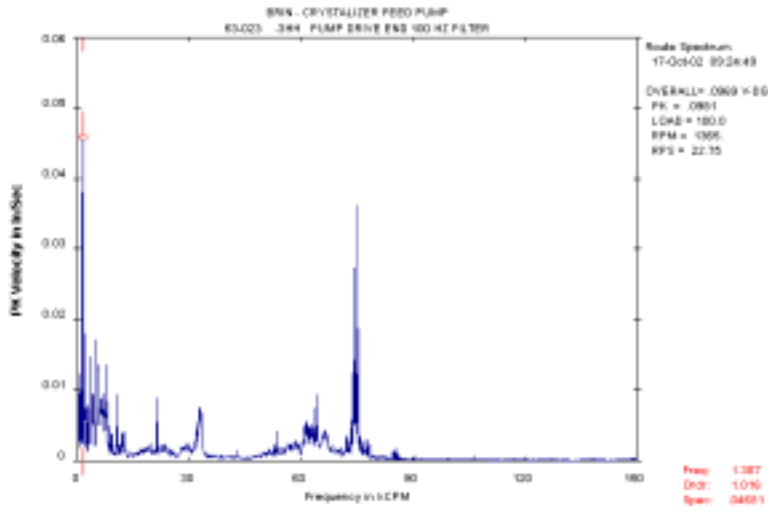


Figure 3 – Vibration Data from 63-023 XLR Slurry Pump

Figure 3 is vibration data on the same 63-023 XLR Pump from Figure 1, using the CSI 2120. Analysis on the sidebands of the dominant peak around 7500 CPM shows bearing fault from the cage, see Fig. 3A

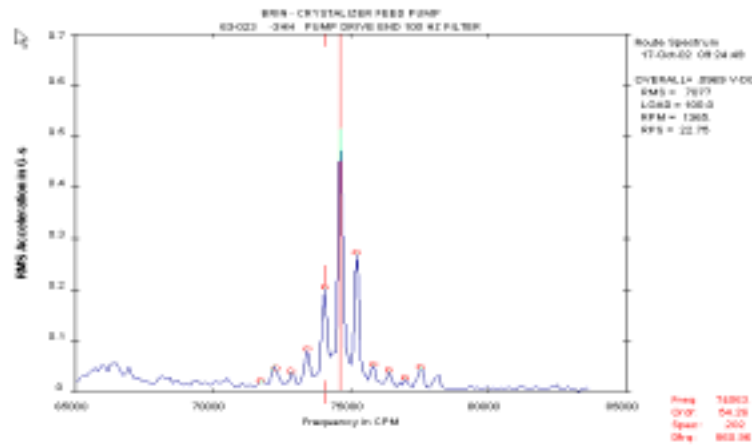


Figure 3A – Vibration Data from 63-023 XLR Slurry Pump

The same procedure is used with the ultrasonic spectra and the same conclusion is seen. Figure 4 is the Ultrasonic Data when the SDT170 is connected to the CSI 2120. It should be noted that the ultrasonic FFT has attenuated the low end of the spectra while emphasizing the higher frequencies. Figure 3A is the zoomed ultrasonic spectra on the CSI 2120.

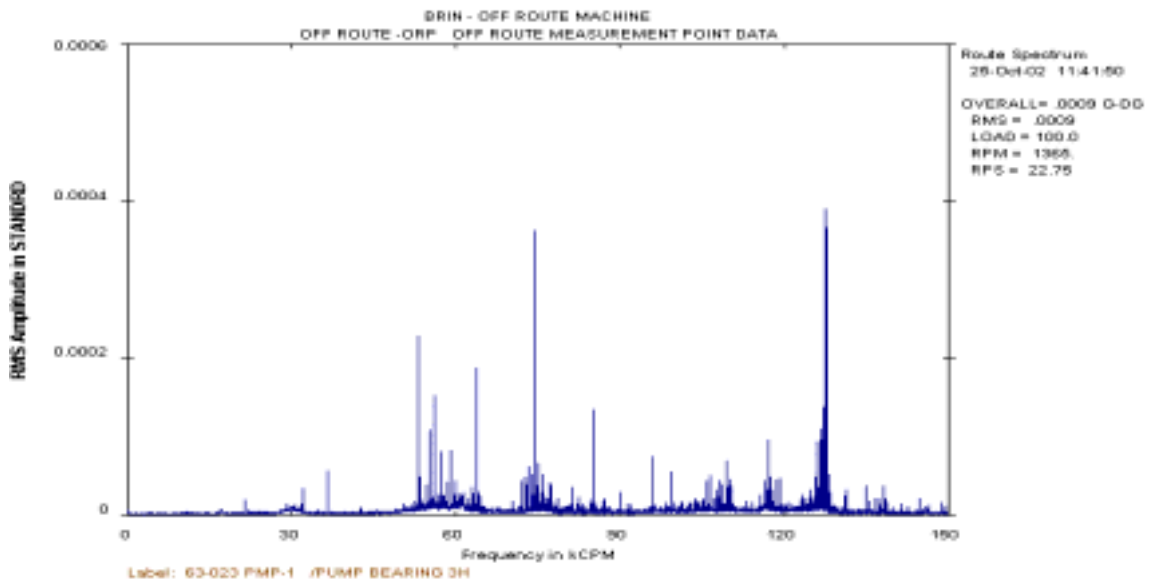


Figure 4 - Ultrasonic Data 63-023 XLR Slurry Pump

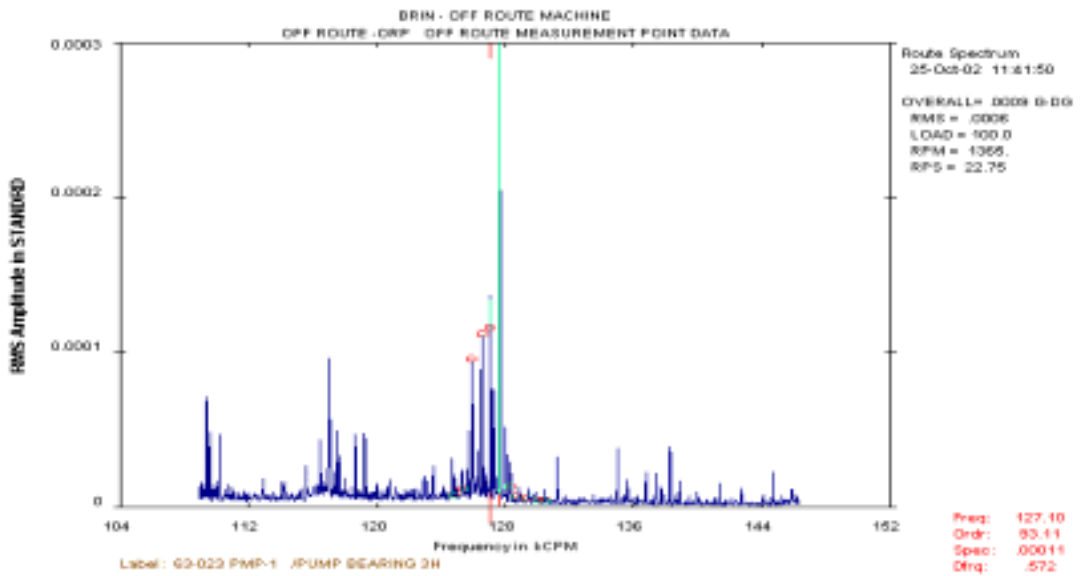


Figure 4A - Ultrasonic Data 63-023 XLR Slurry Pump

Here is another example of using Ultrasound and Vibration together for verification process. Figure 5 is an FFT taken on a large gearbox that was rebuilt during a summer outage. The gears are still wearing in, which causes some elevated vibration. This is a common occurrence when the gears are not matched.

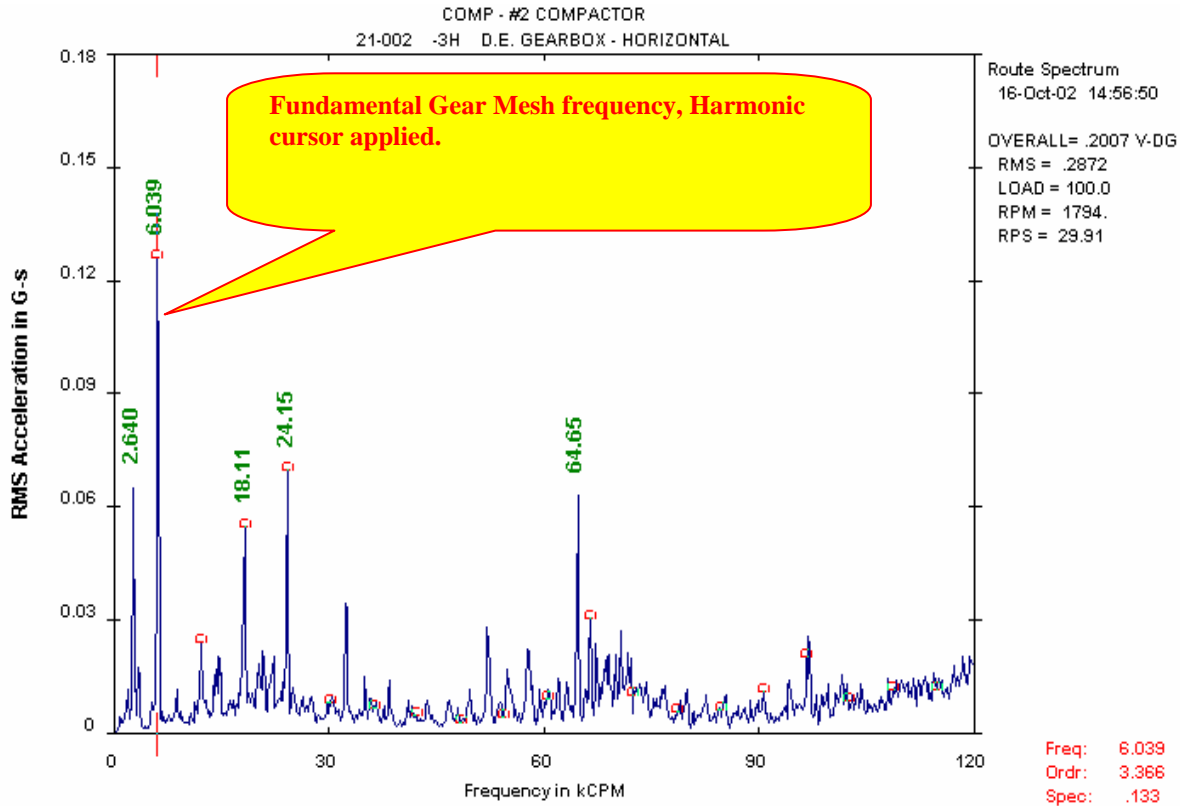


Figure 5 – Vibration Data #2 Compactor – Horizontal Gearbox

In the vibration spectrum, most of the dominant peaks seen are referred to as harmonics of gear mesh frequencies which are identified since the number of teeth on this particular gear (1st intermediate) and the speed of the shaft are known. Harmonics are defined as sinusoidal values that are sub-frequencies of the fundamental frequency. Because harmonics are integral multiples of the fundamental frequency (2x, 3x, etc.) they are obvious if the number of teeth, and the rotational speed of the shaft are known.

To verify the vibration findings, the SDT170MD is connected to the CSI 2120 and the sidebands looked at (Figures 6). Connecting an ultrasonic data collector like the SDT 170MD is a common practice that provides a wealth of knowledge; sometimes even better information that could be

gathered with spectral analysis of low frequency vibration only. At early stages of impacting resonant vibration frequencies will mask bearing defect energy in the lower spectra. The demodulated ultrasonic spectra show the spikes without interference from low frequency resonant frequencies.

The sidebands in Figure 6 and 6A, which are very obvious, are equal to the RPM of the same gear. Sidebands are frequencies on either side of the dominant frequency produced by modulation. This shows that both technologies have identified the noisy gear.

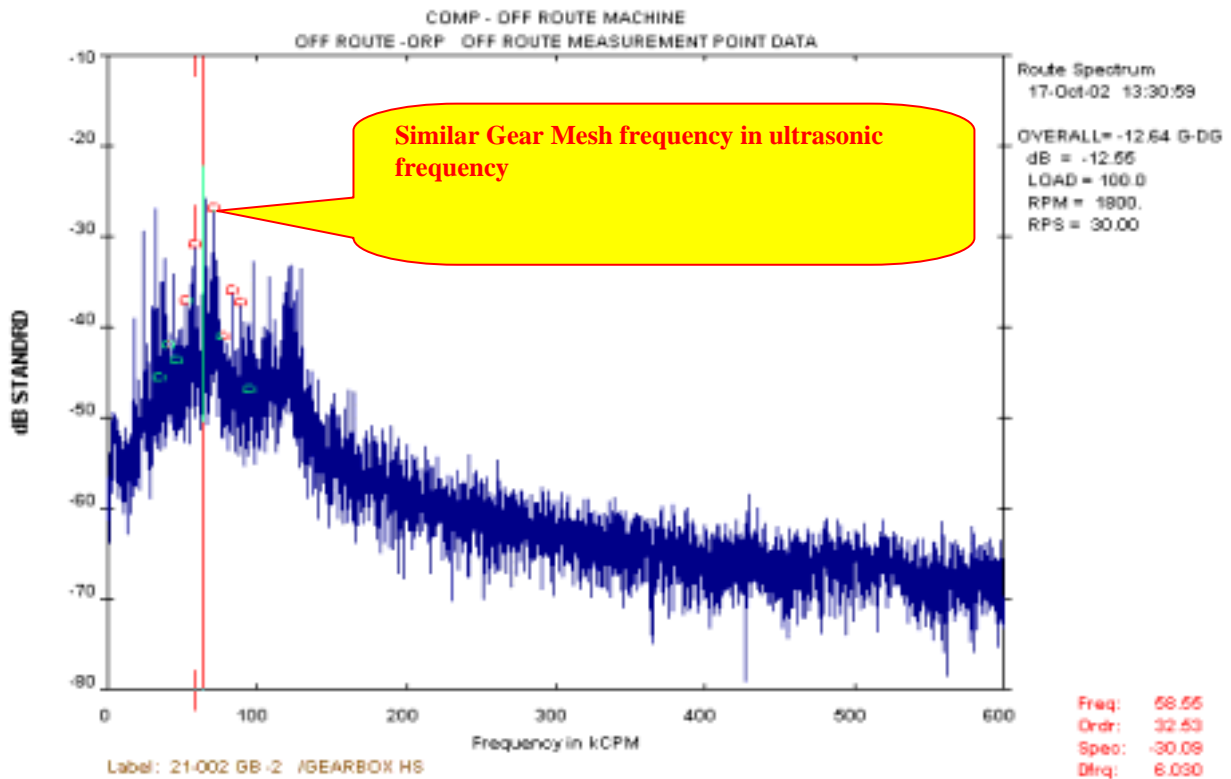


Figure 6 - #2 Compactor – Horizontal Gearbox – Ultrasound Data
First FFT was taken with the SDT170MD with a high Fmax.
Not a lot of noise above 150 kcpm.

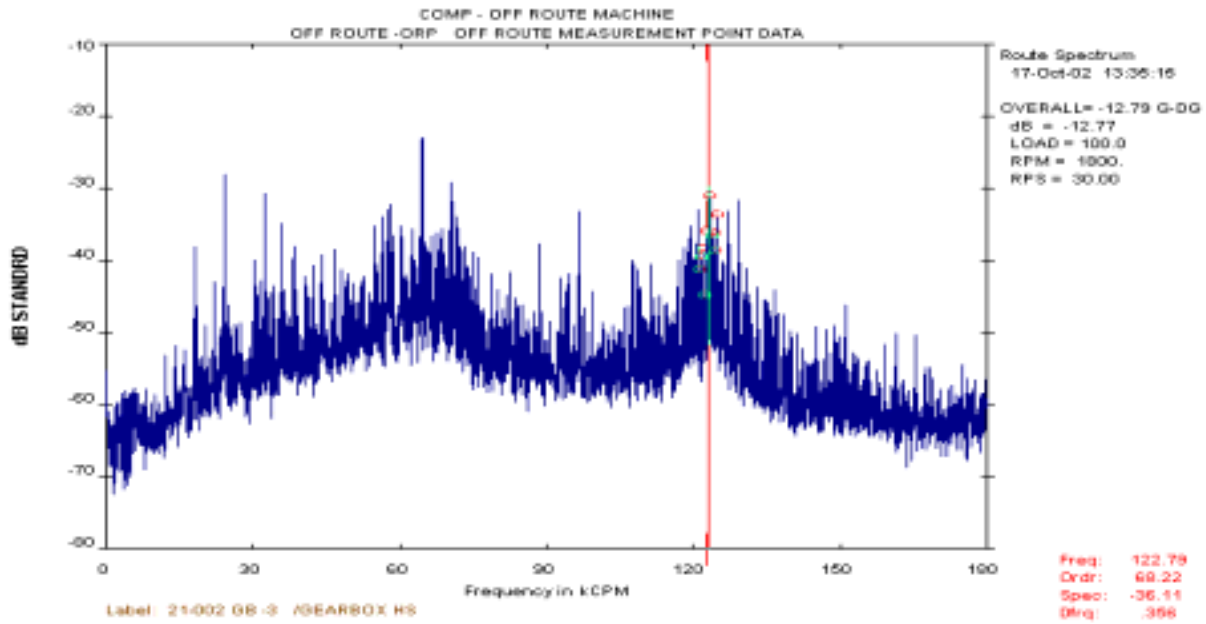


Figure 6A – #2 Compactor – Horizontal Gearbox – Ultrasound Data
FMax is set lower, and resolution is increased

A much closer look at the ultrasound spectrum from #2 Compactor reveals with even more clarity the matching of gear mesh event with RPM of gearbox.

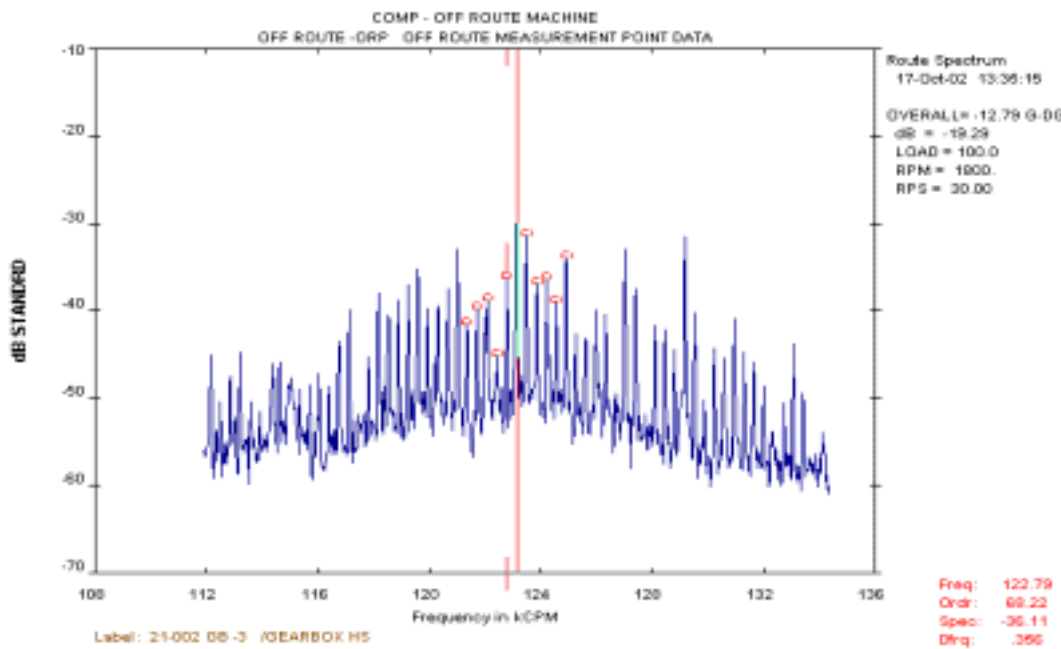


Figure 6B – #2 Compactor – Horizontal Gearbox – Ultrasound Data.
A Closer look at one of the mounds of energy from Figure 5A. The sidebands are spaced at the RPM of the noisy gear.

Procedure for Connecting SDT170 to CSI2120 or CSI2115 Data logger:

1. Plug the SDT 170 adapter into the accelerometer BNC side of the analyzer.
2. Set the Sensor Unit to Non-standard.
3. Set Sensor Power to off.

To get an ultrasonic spectrum, connect the SDT170 to the data logger, contact a bearing housing using the SDT170 transducer/sensor, follow the procedure for proper ultrasonic mechanical inspections, and watch the spectrum display on the CSI data logger.

Every technology has limitations. Better diagnosis of machine condition can be achieved when information is considered from multiple sources, so long as the sources are reliable. Ralph Copp's team at PCS is a fantastic model of successful predictive technology integration; especially when examples from their Ultrasound and Vibration programs are studied together.

It is also wise to look at the bigger picture when doing machine inspections. More positive results are achieved if we consider that in all programs there are four factors that affect success of the inspection. Ensure that:

1. Proper Inspector Training and Confidence is addressed
2. The Equipment used for inspection is capable
3. The Machine to be inspected is considered
4. Proper Inspection Procedure is used

Deficiency in one or more of these four factors could lead to erroneous machine diagnosis, inspector frustrations, or worse, loss of enthusiasm for a proactive culture. Predictive technologies are investments designed to extend our senses and enhance our ability to predict future roadblocks to success. By integrating the data afforded us by these technologies we create a collaboration of information working in harmony with our team of maintenance reliability professionals. *Together, Each Achieves More.*

About the Authors:

Liane Harris, M.S. ChE - has worked as Process and Energy Engineer in Food and Chemical Industries in the Philippines and in Pulp and Paper Mills in North America and has been in Airborne Ultrasound Technology since 1996. She currently holds the position of Corporate Manager of Certification Training at SDT North America.

Ralph Copp – Ralph has been working in industry for over 30 years as a Machinist, Industrial Mechanic, and Welder. For the past 20 years he has been employed with PCS as an Industrial Mechanic and Vibration Analyst. In 1990 Ralph was influential in forming the Atlantic Canada Chapter – Vibration Institute, now known as CMVA Atlantic Chapter. Since then Ralph has went on to get his Level 2 Certification in Vibration Analysis. At PCS Ralph is head of the Predictive Analysis Dept. where he is responsible for the vibration program, oil analysis and lubrication, infrared temperature, ultrasound, and NDT. His proactive approach to maintenance, hard work, intelligence, generous and humble spirit has gained him the respect of his peers.

For more information about integration of ultrasound with predictive technologies contact: **SDT North America 1-800-667-5325**