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Predictive Maintenance Case Study

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Tags: predictive maintenance (/Meta/Tags/predictive maintenance), maintenance and reliability (/Meta/Tags/maintenance and reliability)

The case studies provided in this article are actual data analyzed by the author. The predictive maintenance case study representing vibration analysis will present examples and comparisons of bearing faults, unbalanced conditions and impact testing for natural frequencies. Each example will be represented as a spectrum and, in some cases, a timewave form which will provide evidence of a fault that is present in the particular segment of data.

Oil reports are also presented to give conclusive evidence of a dirty oil condition, with the target ISO cleanliness level identified for reference.

Oil cleanliness is critical in eliminating premature component failure and extending equipment life. It enables maintenance departments to work toward increasing uptime and machine availability.

Infrared thermography is represented by thermal images of equipment components with temperature variations. Even slight temperature variations can indicate a potential problem in a machine component. Trained personnel capable of interpreting thermal images are a valued commodity in the reliability maintenance arena.

Electric motors are essential to the operations of an industrial manufacturing facility. There are primarily two potential failure modes that affect electric motors, bearing failure or electric winding failure. Each type of failure mode can be detected and predicted, enabling maintenance to plan and schedule removal of the motor to avoid unwanted downtime.

Electric winding insulation breakdown can be detected by motor current analysis enabling predictive maintenance personnel to predict the premature failure of a potential problem.

Vibration Data (Gear Mesh) Case Study

All gear sets create a frequency component referred to as gear mesh. The fundamental gear-mesh frequency is equal to the number of gear teeth times the running speed of the shaft. In addition, all gear sets create a series of sidebands or modulations that are visible on both sides of the primary gear-mesh frequency.

The data shown in Figure 1 below represents a block of data collected on a planetary gearbox in a dimensional lumber operation. The frequency of interest is visible at 37,915.8 cycles per minute (CPM) with a harmonic of that frequency visible again at 75,831.6 CPM. The sidebands are clearly visible on either side of the frequency in question. The diagnostics of this problem were somewhat difficult to diagnose because of the complicity of the configuration of the gear unit. This particular unit was a planetary gear set, meaning that the input shaft (sun gear) has three gears that rotate or orbit around the sun gear, which in turn meshes with the outer ring gear.

With all of the meshing of gears inside the gear box, identifying gear-mesh frequencies can be difficult. In Figure 1, the frequencies were identified and matched to the frequencies in the spectrum. Notice the impacting in the time waveform at the bottom of the example. This is a good indication of meshing teeth with defects on the teeth.

This type of pitting and spalling on the gear teeth is caused by contamination in the oil inside the unit. The pressures between the teeth when meshing with each other can reach 300,000 pounds per square inch (psi). Sand and dirt are much harder than metal; when pressed between the teeth of the gears, they cause indentions in the teeth, leading to spalling and pitting. After the problem was diagnosed, a report was generated and the unit was taken out of service. It was sent out to a repair shop, and after disassembly, it was found that all three planetary gear units had visible defects on the teeth.

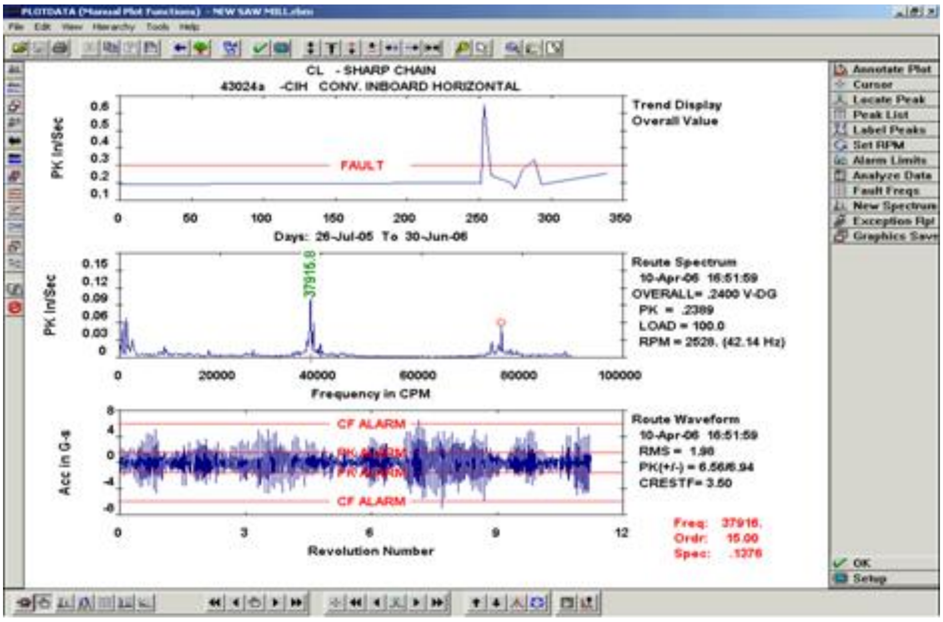

Figure 1. Gear Mesh Data

This is just one example of the benefits of predictive maintenance technologies, in this case vibration analysis. If this problem had not been detected by vibration analysis, it would have continued to progress to the point of catastrophic failure. When defects form, the gear teeth continue to grind away the metal surface, putting metal into the gearbox and creating a domino effect.

This problem could have also been detected with oil analysis. By taking an oil sample, one would have been able to detect the wear metals in the gearbox through analysis.

Corrective predictive maintenance procedures can reduce the certainty of catastrophic failure. Figure 2 shows the vibration data of a blower that is in need of balancing. Figure 3 shows the reduction of vibration after the balance job was completed. This is just another example of how predictive maintenance can change the condition of a machine.

In Figure 2, notice the high amplitude at 1X running speed of the blower. This is an indication of imbalance in the rotating element of the blower.

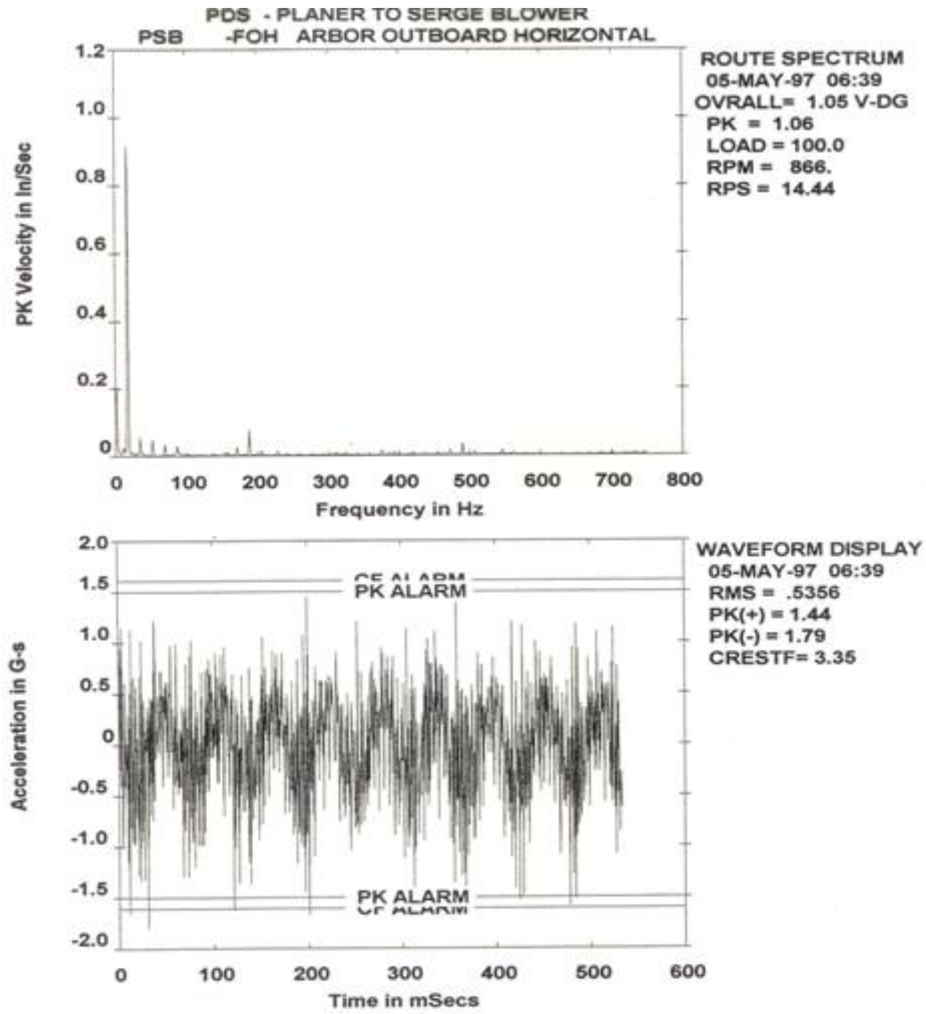

Figure 2. Vibration Data from a Fan

After completion of the balancing job shown in Figure 3, there was a drastic change in amplitude. The reduction of vibration will extend the equipment life and enable problem-free operation.

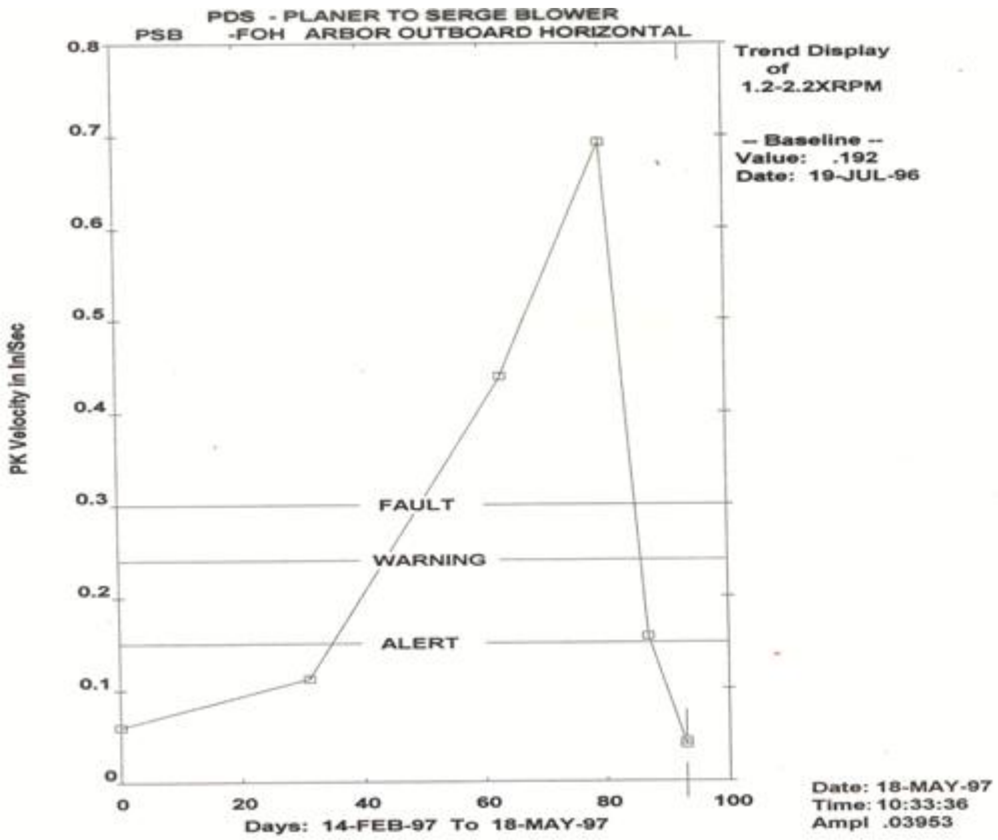

Figure 3. Vibration Trend Data

Notice the trended data in Figure 3. After balancing the fan vibration, amplitude dropped well below the alarm levels set for the machine.

Diagnosing the problem is just the beginning in the predictive maintenance process. Once the problem has been detected, making sure that the problem does not repeat itself again in a few months or even a few years is the goal. One of the goals of a good analyst should be not only to detect failure modes but find the root cause of the problem and prevent it from happening again.

Figures 1-3 examined gear-meshing problems and the data associated with them, as well as an imbalance condition in a blower. Figure 4 represents a bearing problem with an outer race defect. Notice the side bands around the outer race fault frequency? This is caused by modulation in the time waveform. If you look at the time waveform below the spectrum, you can see the amplitude modulation that is present.

Generally, this type of modulation will represent the operating frequency of the rotating element of the machine in question.

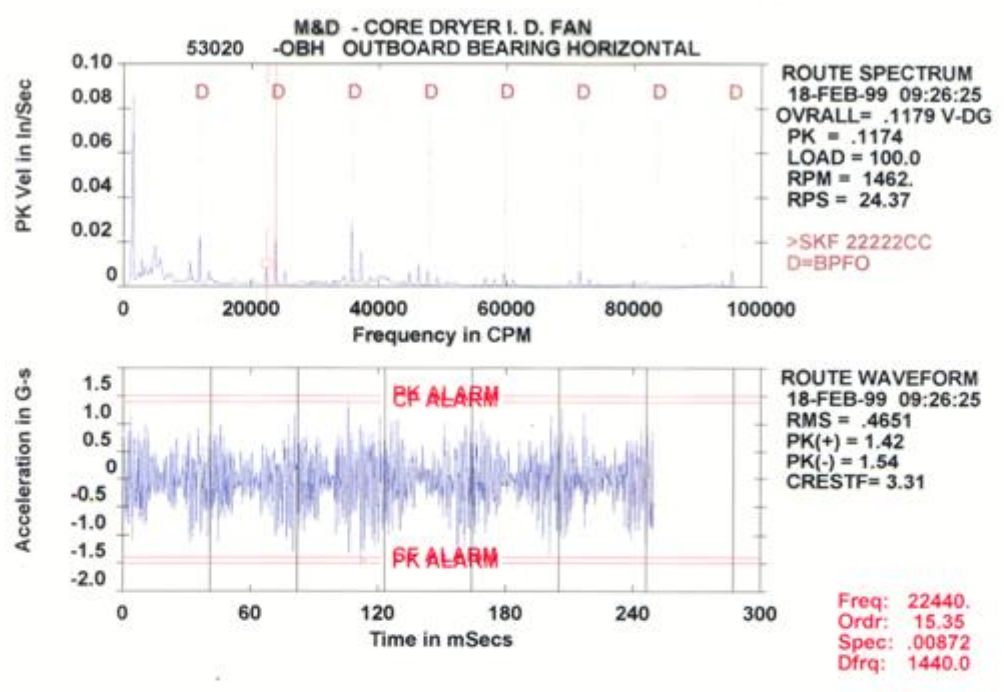

Figure 4. Vibration Data from a Bad Bearing

Other information that is present on the data presented is the bearing type SKF 22222CC. This information is entered into the software to allow the software to label the fault frequencies within the spectrum. The software has a database that has more than 10,000 bearing fault frequencies calculated. This helps cut down on valuable time and makes the analyst’s job much easier.

Vibration analysis can be a powerful diagnostic tool. Identifying bearing failures, gear problems, and imbalance and misalignment conditions are not the only positives this technology provides. Determining operating parameters such as potential resonance conditions pays big dividends when designing and determining operating speeds.

The pressure to continue to speed up or change operating conditions will only increase with the highly competitive manufacturing facilities that we work in on a daily basis. The problem with changing speeds of a rotating machine is that at some point we venture into the natural frequencies of the structure or rotating element. When the operating speed of the rotating machine and the natural frequency become too close, a condition called resonance is excited. This will increase the amplitude of the machine by as much as 20 times and can cause it to shake itself apart. To determine the frequencies to stay away from when modifying or designing a machine, a test such as an impact test should be conducted. In Figure 5, an example of the results of an impact test is provided.

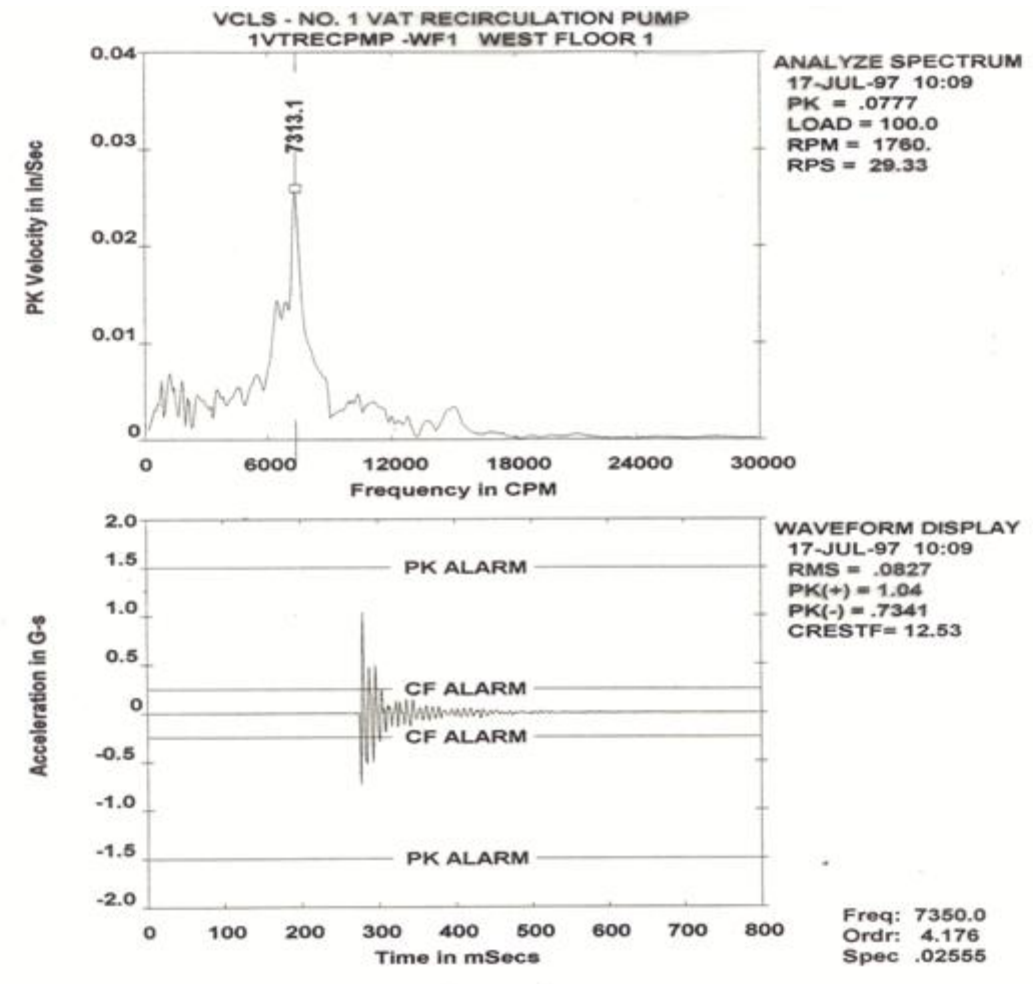

Figure 5. Data Identifying the Natural Frequency of a Structure

The data in Figure 5 represents a valid impact test. Trying to operate a rotating machine within 20 percent of 7,313.1 CPM will cause poor operating conditions and an unreliable machine throughout the life of the machine.

Infrared Thermography Case Study

Infrared thermography is a popular technology for predictive maintenance for obvious reasons. It is easy to see where the problem lies, and problems detected are somewhat easier to diagnose for the technician. National training and certification is still strongly recommended in order to become competent in analyzing thermography data. It is very important to consider ambient temperature when analyzing and trending collected data.

The data in Figure 6 represents a motor control starter with a loose connection on the “B” terminal lead.

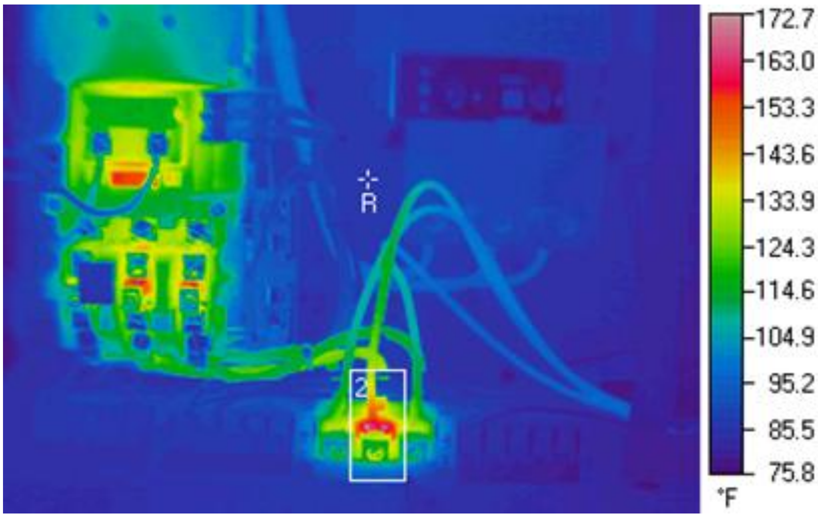

Figure 6. Infrared Data of Motor Starter, Taken by the Author

The temperature in the rectangle on the infrared image identifying the “B” terminal has a maximum temperature of 172.8 degrees Fahrenheit. When connections become loose, they generate excessive heat. When this condition occurs, the wire will burn in two, causing the motor that is being controlled to single-phase. This condition will cause the electric motor to fail prematurely.

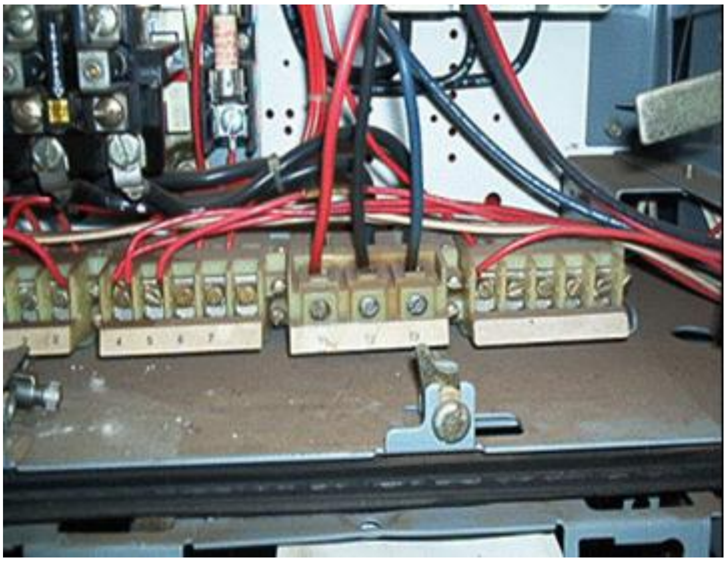

Figure 7. Image of Problem Area

Figure 7 is a control photo taken to aid the electrical technician in identifying the problem area. Part of the predictive maintenance process is to develop a report that will make the repair technician's job as easy as possible. The technicians that diagnose the problem are generally not the ones who make the repairs.

The applications for infrared thermography are still being discovered and utilized with each new predictive maintenance case study. The benefits of infrared as a PdM tool are by far the most beneficial from a monetary standpoint for manufacturing facilities across the world. Figure 6 is an example of a low-voltage application. Infrared has no limits when it comes to detecting minute changes in temperature.

Figure 8 represents data taken on a high-voltage power line. A failure on this application would shut down the entire plant, costing millions of dollars. Luckily, it was caught by an infrared technician on a scheduled monthly inspection route.

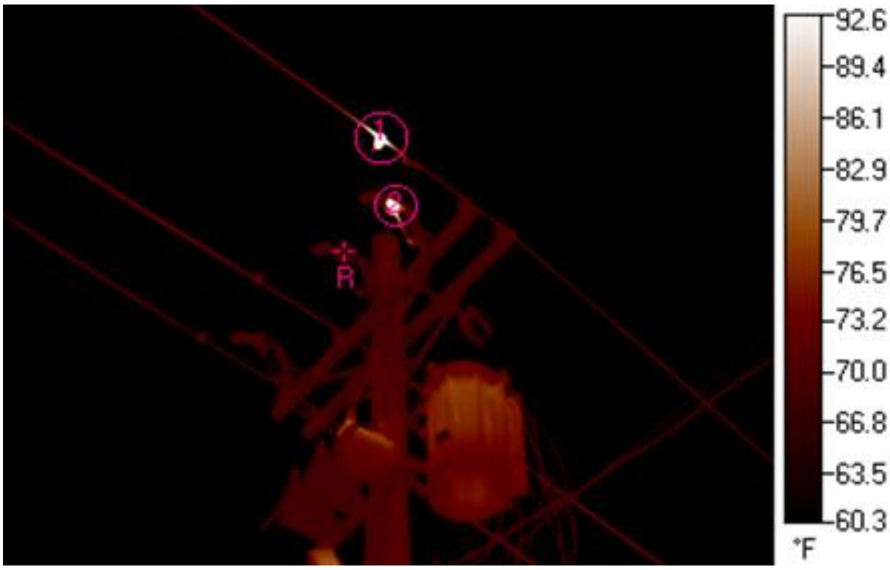

Figure 8. Infrared Data of a Loose Connection

The temperature on the line jack was recorded at 160.2 degrees Fahrenheit, more than twice the ambient temperature.

As you can see from the predictive maintenance case study of analyzed data, infrared thermography is an effective tool for predicting and preventing premature failure. When utilized to it fullest and combined with other PdM technologies, infrared thermography is a very beneficial technology to the condition base maintenance process.

Oil Analysis

In Figure 9 below, the ISO contaminant level is 22/21/17. This far exceeds the standard set for all operating equipment in most industrial applications.

For each numerical increase in ISO contaminant level, the amount of contaminants in the oil doubles. If the standard is a 16/14/11, then the increase in contaminants in the oil for a 22/21/17 is 64 times dirtier than the standard.

Oil analysis is a reliable predictive maintenance tool and is very effective in detecting contaminants in oil that are a result of ingressed dirt or internal wear debris generated by the effect of machine degradation and wear. An increase in contaminant levels accelerates the wear-out process of all components in industrial machine applications.

Contaminants in oils can be prevented. Good filtration on the return side of hydraulic power units will help in taking out dirt and other ingressed particles. Usually 3-micron filtration with a 200 beta ratio is the standard set for most machinery.

Eliminating leaks and insuring that clean oil is used to refill any oil that may need replacing is another best practice that can help maintain oil cleanliness.

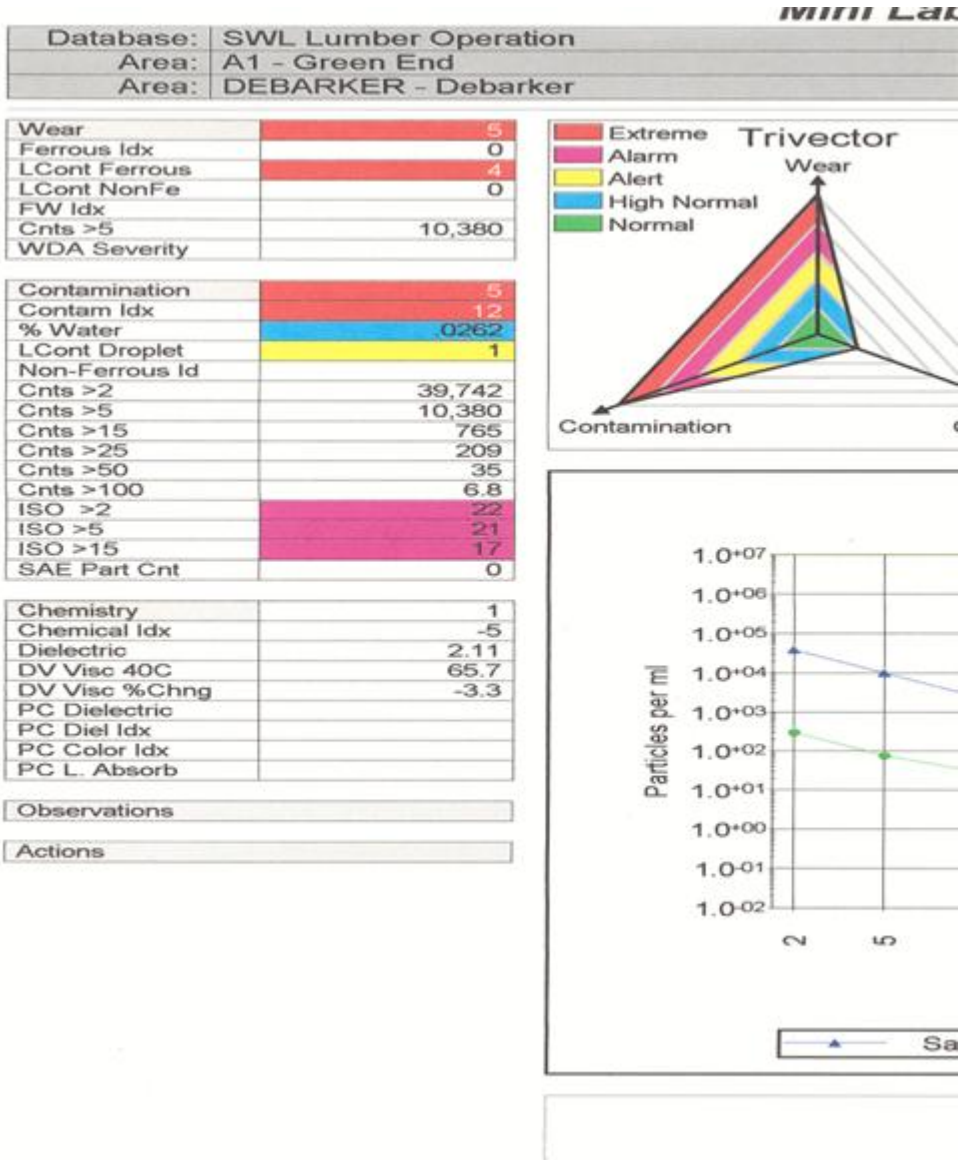

Figure 9. Oil Analysis Data

Motor Current Analysis Case Study

Motor current analysis is another PdM tool that has paid big dividends to manufacturing processes across the world. Predicting premature insulation breakdown in the windings of electric motors enables technicians to diagnose electrical problems before catastrophic failure. If you combine motor current analysis with infrared or vibration analysis, you can detect both electrical and mechanical failures of electric motors, drastically reducing the risk of unscheduled downtime. By instituting root cause failure analysis, one can then increase the reliability of a machine in a plant process.

In Figure 9, the data provided represents a humidifier recirculation fan motor on which the analyst had been conducting monthly routine data analysis.

Test Name	**AC Standard**	
Motor Name	**1677**	
Asset ID	**N/A**	
Circuit ID	**N/A**	
Motor Condition	**Good**	
Test Date	***09/07/2005***	***07/27/2006***
Test Time	***10:23:15 AM***	***09/07/2005***
Frequency	1200	1200
Mohm Ph 1 to Gnd		
Charge Time	30	30
Voltage	500	500
Motor Temp	32	32

Measured Mohm	1700.0	303.0
Corrected Mohm	980.0	***174.0***
pF Ph 1 to Gnd	16250	16500
ohm Ph 1 to 2	0.86900	*0.88250*
ohm Ph 1 to 3	0.87000	*0.88250*
ohm Ph 2 to 3	0.80650	0.80450
mH Ph 1 to 2	22.940	23.110
mH Ph 1 to 3	*21.450*	23.730
mH Ph 2 to 3	21.740	21.950
Avg. Inductance	22.043	22.930
% Res. Imbalance	***4.95***	***6.07***
% Ind. Imbalance	4.07	4.27
$ Power Loss	21.85	26.84
Test Location	T-Leads	T-Leads
MCE #	030535	030535
User		
Notes	No	No

Figure 10. Data Taken by the Author

The data provided above shows a comparison from two readings; one is the baseline taken on September 7, 2005, and the other one taken July 27, 2006, indicating a breakdown in insulation is beginning to take place. Notice the increase in the percentage of resistance imbalance. This is a cause for alarm, and measures should be taken to schedule the motor to be removed from service and sent out to be reconditioned. This is just one of the examples of the benefits of motor current analysis in the PdM arena.

Another contribution, like vibration analysis, is the ability to detect air gap anomalies. If unchecked, air gap problems between the rotor and the stator can cause rotor and stator rubs that can lead to catastrophic failure of the motor. This can occur even if all other indications show that a healthy rotor and stator exist. Air gap as a fault zone describes the measurable distance between the rotor and stator within the motor.

The benefits of predictive technologies are evident in every example of data provided in this article. It doesn’t matter if a maintenance department starts with vibration analysis, infrared thermography, oil analysis or motor current analysis. Each will provide monetary benefits to the bottom line if implemented with commitment and well-trained personnel.

The data provided illustrates how vibration analysis can detect gear meshing defects in power transmission units, bearing defects in rotating equipment, imbalance conditions in fans and the detection of natural frequencies of structures supporting rotating equipment. Each problem represented and diagnosed has proved to save thousands of dollars in repair cost and downtime.

The data provided by thermal imaging shows how minute changes in temperature can be detected, enabling the analyst to head off a problem that would ensure eminent failure.

Oil analysis data provided has shown to identify contaminants in oil that can cause parts to wear out prematurely and reduce equipment life. Identifying wear particles in machine oil can detect bearing problems and gear problems that could otherwise go undetected.

Motor current analysis provides the analyst with the ability to diagnose insulation breakdown and predict failures that cannot be detected with other predictive equipment.

If a maintenance department can afford to employ two or more of these technologies, the process reliability goes up drastically. Overlapping data analysis by combining these technologies will aid in establishing an effective predictive maintenance program.

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Gary Fore, CMRP, is an I&E reliability specialist at Eagle Rock Energy. He has spent 22 years in the energy and building products industries, specializing in reliability engineering with a heavy emphasis on condition monitoring. He has a bachelors of science degree in mechanical engineering and an associates of applied science degree in electro-mechanical technology. His certifications include: Certified Maintenance and Reliability Professional (through the Society for Maintenance and Reliability Professionals), Category III vibration analyst (Vibration Institute), Level II infrared thermographer, Certified Lubrication Specialist, and Level I Machine Lubricant Analyst (International Council for

Machinery Lubrication).