Machinery Lubrication

INDIA May-June 2018
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THE POWER
OF USING MULTIPLE TECHNOLOGIES FOR MACHINE INSPECTIONS

NORIA

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EDITORIAL FEATURES

Publisher's Note

Machine fault problems are broad sources of high maintenance cost and unwanted downtime across the industries. The prime objective of maintenance department is to keep machinery and plant equipments in good operating condition that prevents failure and production loss. If the department organizes a predictive maintenance program, this goal as well as cost benefits can be achieved, while accurate information at the right time is a crucial aspect of a maintenance regime.

Machine fault identification can be done with different methodologies as vibration analysis, lubricant analysis, acoustic analysis, and thermography with the use of appropriate sensors, different signal conditioning, and analyzing instruments. Vibration analysis techniques for machine fault identification are the most popular among other techniques.

Modern manufacturing plants are highly complex. Failure of process equipments and instrumentation increase the operating costs and results in loss of production. Undetected or uncorrected malfunctions can induce failures in related equipments and, in extreme cases, can lead to catastrophic accidents. Early fault detection in machines can save millions on emergency maintenance and production-loss cost. Gearbox and bearings are essential parts of machinery. The early detection of the defects, therefore, is crucial for the prevention of damage and secondary damage to other parts of a machine or even a total failure of the associated large system can be triggered.

Machinery failure reveals a reaction chain of cause and defect. The end of the chain is usually a performance deficiency commonly referred to as the symptom, trouble, or simply the problem. The machine fault signature analysis works backwards to define the elements of the reaction chain and then proceeds to link the most probable failure cause based on failure analysis with a root cause of an existing or potential problem. Accurate and complete knowledge of the causes responsible for the breakdown of a machine is necessary to the engineer, similarly, as knowledge of a breakdown in health is to the physician. The physician cannot assure a lasting cure unless he knows what lies at the root of the trouble, and the future usefulness of a machine often depends on correct understanding of the causes of failure. The proper maintenance can be done only after the knowledge of root cause of failure.

Prevention of potential failure is required for reliable and safe operations of machineries and the prevention of catastrophic failure can be done by appropriate maintenance. Condition-based maintenance is the best suitable technique to avoid unwanted futuristic failures through condition monitoring or signature analysis for rotating machineries. Besides lubricant analysis, vibration analysis, acoustic and thermography are the best suitable technique available for fault identification. These should be used optimally for avoiding any breakdown.

We would like to thank our readers for the heartening response to our previous edition's cover story – "How to change your Lubrication Culture" and other articles. Our current issue's cover story is on "The power of using multiple technologies for machine inspections". This will help our readers to know both good and bad examples of the coordination between these two powerful inspection methods so analysts and asset owners alike can see what to do and what not to do in certain situations.

As always, we look forward to your valuable suggestions and feedback.

Warm regards,

Udey Dhir

Jim Fitch | Noria Corporation

How to Make Your Oil Analysis Program **Produce More Alerts**

I want bad news fast. Why? Problems tend to compound. Rarely do they heal themselves. Instead, the worse things get, the faster they get worse. As time passes, the cost of repair and lost production can soar exponentially.

Maintenance resources need focus and preemptive timing. The longer you wait to respond to what causes failure, the more machine conditions take over control of your schedule and budget. Fix the roof while the sun is shining. It's not just about keeping machines running but rather keeping them running at the lowest possible cost.

Condition monitoring is an essential troubleshooting tool. It provides examination skills to find the cause or source of an impending problem. When issues are caught early, you have the luxury of convenience and the option of simple remedies, usually with minimal (if any) business interruption.

> "You can't fix a problem **that you can't see.**"

The Wisdom of Early Detection — Not Just-in-Time Detection

Several years ago, I performed a root cause analysis on a rash of gearbox failures in helicopters used for the logging industry (heli-logging). These failures were the cause of serious accidents and human casualties. Because of the high power density of these gearboxes, mild problems could quickly escalate into life-threatening conditions.

A helicopter's planetary gearbox conveys power between the main drive shaft (from the engine) to the main rotor, giving the helicopter aerodynamic lift and thrust. The condition of the lubricant (the right health, cleanliness and supply) is essential for reliable, safe operation. Any failure of the lubricant can quickly start a disastrous chain of events, from lube failure to bearing failure to gear failure to rotor failure to lift failure to helicopter failure (crash and burn).

While the helicopter example may be an extreme case, it is still an important and vivid illustration of the seriousness of early detection and response. What might seem like a mild condition now (rising varnish potential, cloudy oil, elevated particle count, uptick in fuel dilution, out-of-grade viscosity, low oil level, etc.) can abruptly worsen to a runaway catastrophic outcome.

Root Cause Alarms

Proactive maintenance should always be "job one" in condition monitoring. To do well, it requires a solid understanding of root causes that are ranked by likelihood (the Pareto principle). There is also a need to understand the criticality of each machine. What you perceive as "the cause" may be nothing more than a transitional step in a sequence of many in route to functional failure. The real root cause you are seeking is the one that could have been controlled or prevented. That is not to say your purpose is to look for someone to blame.

I was once surveying a steel mill and noted that the needles on most of the pressure-differential gauges (used on filters) were in the yellow or red zones. My escort quickly commented that the maintenance staff no longer used the gauge readings to schedule oil changes. Instead, all oil filters were changed on six-month intervals regardless of the gauge reading. Needless to say, I was shocked. On-condition maintenance should always take precedence over scheduled maintenance.

See the fault tree in Figure 1 used to troubleshoot the root cause of a large process pump failure. Asking the "repetitive why" takes you to the pump (and not the coupling or motor) that failed. Next, the pump bearings were found destroyed. An examination of the lubricant revealed heavy contamination. An effective functioning filter would have prevented such contamination. In fact, the filter was found to be plugged, as indicated by the red-alert pressure gauge reading that went unnoticed.

Had an operator reported the high gauge reading and followed up with a filter change, the pump might have been saved. A red-alert gauge reading is not a pump failure unless it does not get reported with corrective action. If the filter became plugged prematurely, it should have been examined. Analyze the used filter to determine the type and source of particles. How have they invaded the machine and the oil? Don't just change the filter. Correct the ingression points, i.e., the source of particles that plugs the filter.

Many root causes can be detected by oil analysis. These include various types of contaminants, wrong oil and degraded oil. If cleanliness targets and other alerts are adjusted to promptly weed out root causes, they won't advance to even the earliest state of failure.

I recently finished a case related to diesel engine failures. The lab was using a 5-percent

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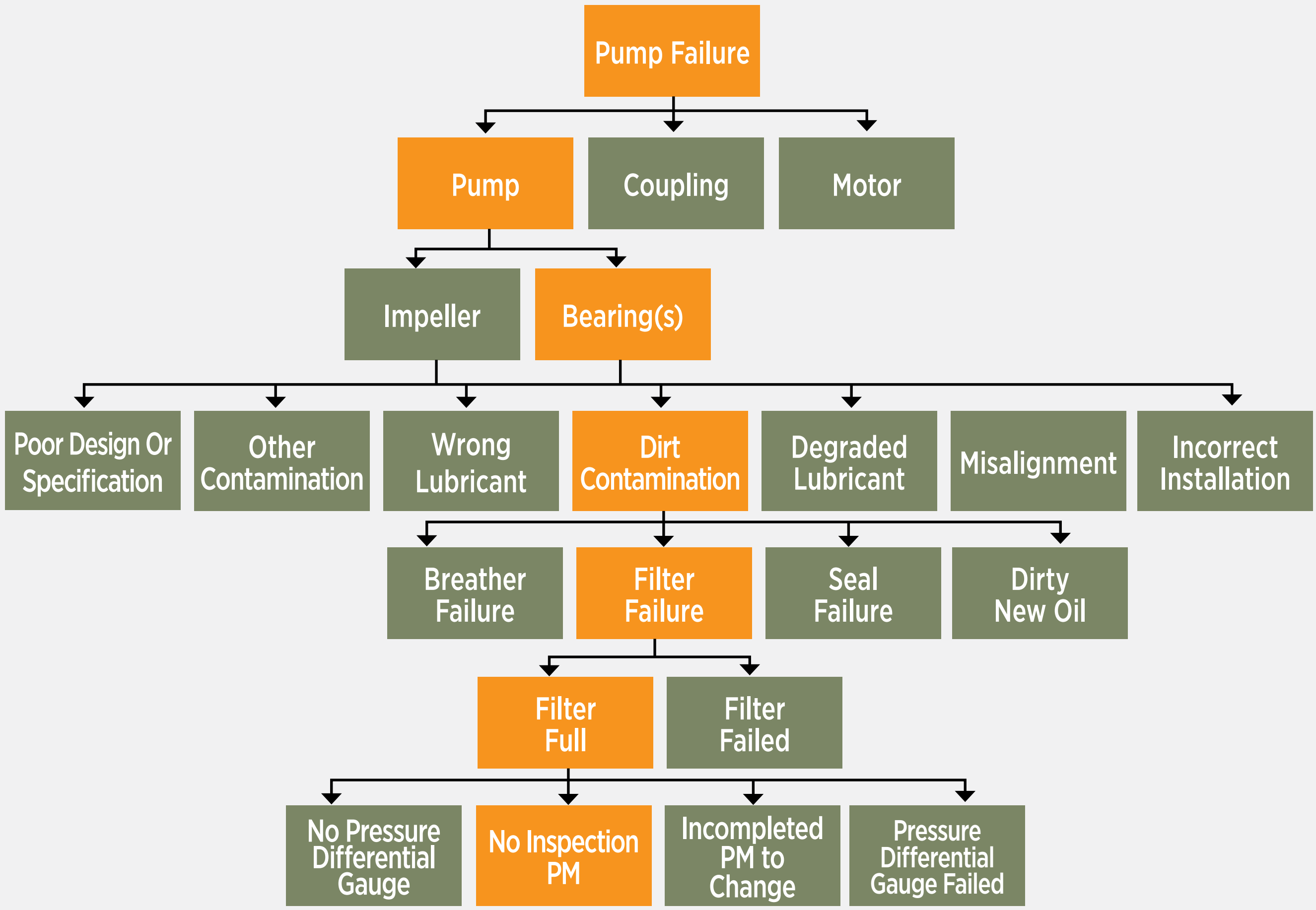


Figure 1. Fault tree used to troubleshoot the root cause of a large process pump failure

alarm limit for fuel dilution. Anything less than 5 percent was reported as normal. No wonder the many defective fuel injectors were not detected until catastrophic engine failure had occurred. Coolant leak detection is also poorly deployed in diesel engine oil analysis. In my opinion, even the slightest amount of coolant leak is cause for concern.

Weak Signal Alarms

Long ago, researchers and tribologists discovered that the strength of signals being emitted during machine failure depends on the state of failure. Incipient failure produces weak signals, while precipitous (advanced) failure creates strong signals. This applies to various types of signals, including wear debris generation, vibration, heat and acoustics. Hence, if you want to catch failure early, you need to be good at detecting and responding to weak signals.

Sadly, many oil analysis programs are structured to do the opposite. You can't fix a problem that you can't see. Rather than setting tight alarms and limits that are a slight offset from normal conditions, some programs don't alarm until problems advance to a state of imminent danger, such as two or even three standard deviations over the mean based on data history. Loose alarms equate to failure blindness.

Some of the best oil analysis programs use cautionary alarms to alert condition-based maintenance (CBM) technicians of abnormal lab data or a reportable inspection condition. This way, the alarm results in a more measured or throttled response. People who wrongly push the panic button often discredit the value of condition monitoring. Remember, "if it ain't broke, don't fix it." A "possible problem" needs to be vetted before you tear down a machine and cause even more serious or real problems. Cautionary alarms should start the vetting process.

Nuisance alarms or false positives are always a concern. Oil analysis is far from perfect, and there

73%

of MachineryLubrication.com visitors use the ISO cleanliness code to set target alarms for system cleanliness levels

are many unavoidable data errors, including false negatives. Exception testing can be extremely useful for confirming an alarm condition and obtaining a better understanding of severity. It involves resampling and running more extensive tests by the lab. Because many exception tests are costly or time-consuming, it is not practical to use them with routine samples. Good examples of exception tests are analytical ferrography and scanning electron microscopy/energy dispersive X-ray spectroscopy (SEM/EDS).

3 Ways to Produce More Alerts

As discussed many times in *Machinery Lubrication*, the primary goal in making lubrication and maintenance decisions is to achieve the optimum reference state (ORS). You are trying to optimize reliability, not maximize it. You seek the reliability you need at the lowest possible cost and distraction.

This holds true for producing more alerts. You don't want "alert overkill" but rather an optimized, effective level of cautionary and critical alarms. This can best be done with three methods working in unison:

1. More Frequent Testing and Inspection

It's a false promise to expect even the best oil analysis or condition monitoring program to catch incipient faults and root causes if testing or data collection is conducted infrequently. Many machines can fail start to finish in just a matter of hours. Other failure modes may take weeks, months or years. For instance, if the failure development period is two months, a test or inspection interval of two weeks provides real opportunity for early detection. Conversely, a test or inspection interval of two months may not offer an advanced warning at all. Inspection 2.0 is a great strategy for achieving frequent and effective inspection alerts.

2. More Comprehensive Examination

You've probably heard the expression, "If all you have is a hammer, everything looks like a nail." This also relates to oil analysis and condition monitoring in general. You need bandwidth. Many companies pretend to save money by cutting oil analysis to the bone. This includes reducing the number of machines that are sampled as well as conducting fewer and less effective tests. For good detective work, you need to cast a wide net. This can be done by expanding the screening tests used on routine samples but also by unifying oil analysis with a penetrating inspection program and other condition monitoring technologies (e.g., vibration).

3. Pin-drop Sensitive Alarms and Limits

I've described the virtues of recasting your alarms and limits for greater early detection sensitivity. You get rid of this data blindness in some cases by taking away control of how alarms and limits are set from commercial laboratories. This is done through education of CBM personnel and analysis of each machine based on failure modes, criticality and reliability history.

In sum, oil analysis needs to produce more quality alerts. Perhaps 30 percent of all oil analysis reports should have some reportable condition, and certainly no fewer than 10 percent. Of course, this statistic depends greatly on the types of machines and their field of application. Don't be afraid of alerts. Instead, view them as a real opportunity for continuous improvement. Like most organizations, your resources for improvement (people and budget) are probably lean. In the reliability space, alerts can help you use these resources in the most efficient and effective way possible.

About the Author

Jim Fitch has a wealth of "in the trenches" experience in lubrication, oil analysis, tribology and machinery failure investigations. Over the past two decades, he has presented hundreds of courses on these subjects. Jim has also published more than 200 technical articles, papers and publications. He serves as a U.S. delegate to the ISO tribology and oil analysis working group. Since 2002, he has been the director and a board member of the International Council for Machinery Lubrication. He is the CEO and a co-founder of Noria Corporation. Contact Jim at jfitch@noria.com.

THE POWER
OF USING MULTIPLE TECHNOLOGIES FOR MACHINE INSPECTIONS

BY ANDY PAGE, **ALLIED RELIABILITY GROUP**

Both oil analysis and vibration analysis are powerful tools when employed to identify defects in rotating machine train elements such as bearings and gears. However, if used together, these tools can become even more beneficial. When the oil analyst and vibration analyst compare notes, use one another's findings to complement their own analysis, and present a cohesive picture of asset health, it creates a more complete analysis of the asset's condition and instills confidence in the asset owner. However, when the two analysts do not compare notes and present their results independently, the opposite effect is often produced. The asset owner may become confused or frustrated with the apparent lack of coordination or confusion caused by reports with apparent conflicts.

This article will provide both good and bad examples of the coordination between these two powerful inspection methods so analysts and asset owners alike can see what to do and what not to do in certain situations.

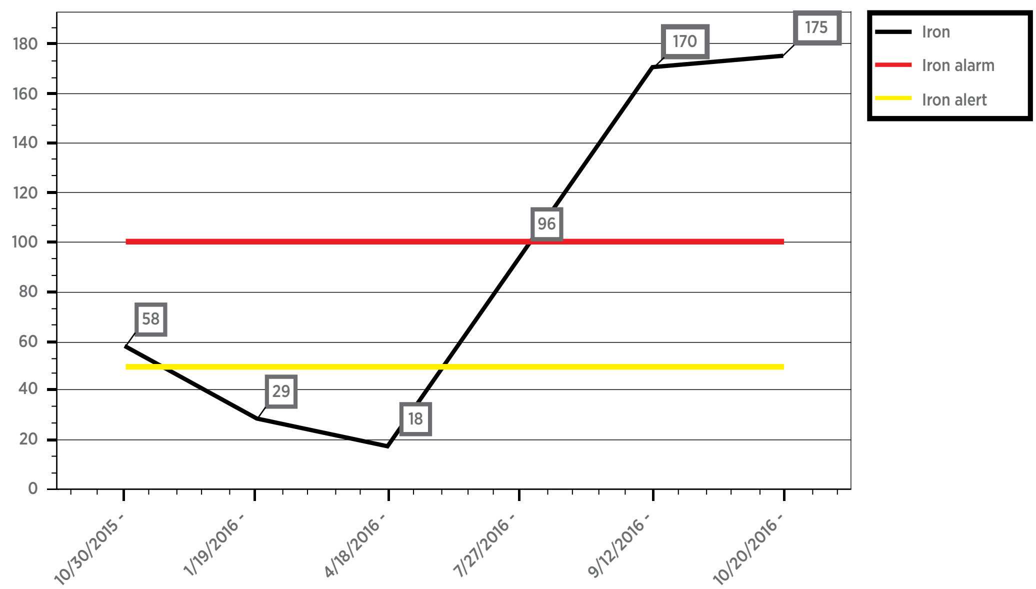


Figure 1. Iron content of an oil sample trending upward over time

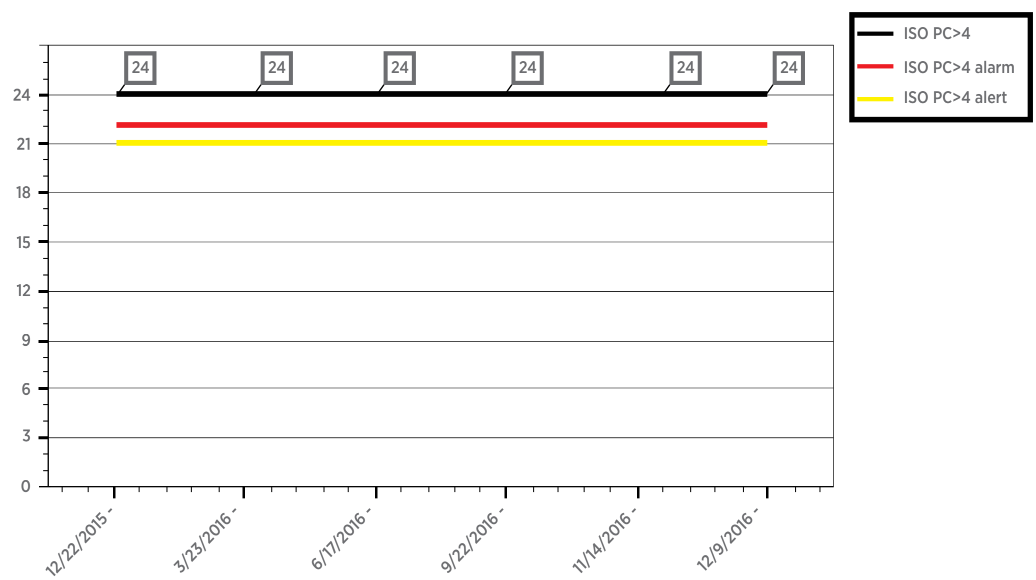


Figure 2. High ISO cleanliness codes for more than a year

THE PREMISE OF TECHNOLOGY INTERACTION

The basic premise of multi-technology inspection programs is that more than one method should be used to confirm or corroborate the findings of another inspection method. For example, within the field of vibration analysis, when the spectra indicate shaft misalignment, the analyst can use phase analysis to validate the data in the spectra. Likewise, when the vibration signature indicates an electrical fault in the rotor of an AC induction motor, online and offline motor testing should be used to corroborate the vibration analysis findings and provide a more in-depth analysis into the nature of the problem.

Never have two inspection methods been better suited to complement each other in the validation of rotating machine train defects than have vibration analysis and oil analysis. For many bearing and gear faults, when one technology detects an issue, the other should as well. The findings should also be presented together to form a cohesive narrative

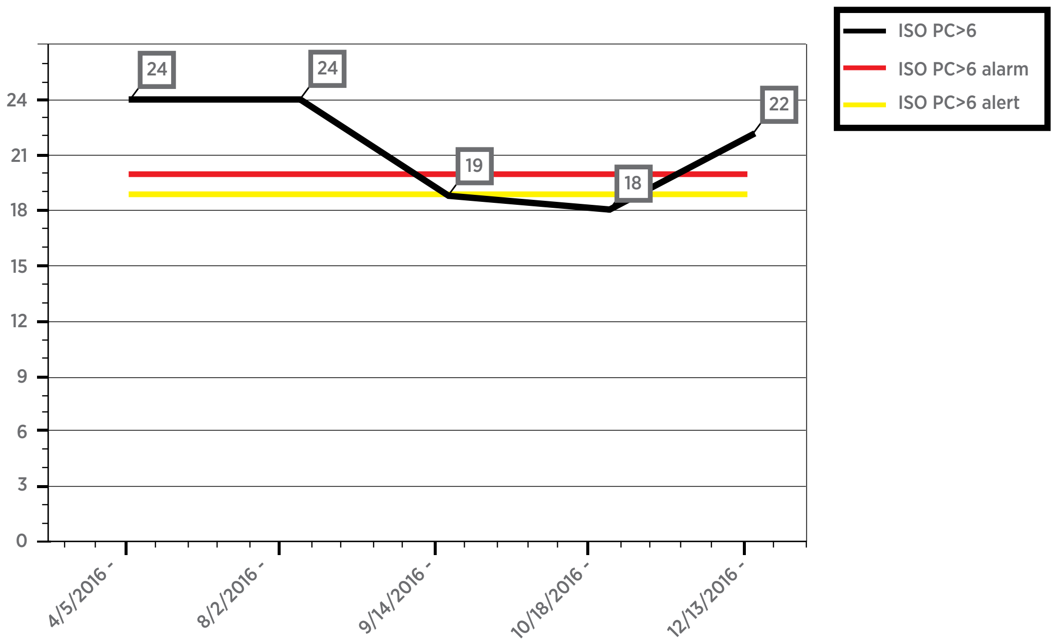


Figure 3. High ISO cleanliness for more than eight months

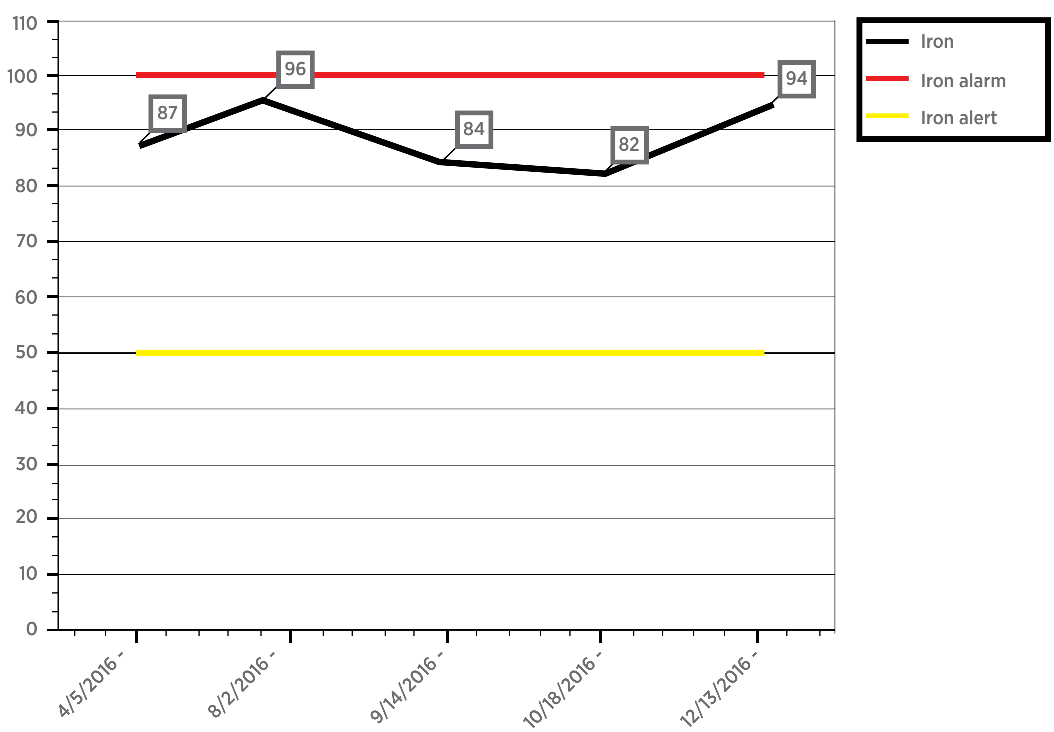


Figure 4. High iron content in oil samples for more than eight months

Figure 5. An example of leaking gearbox seals

about the nature of the problem. Typically, it does not matter which technology was able to find the defect first. In many cases, it will alternate back and forth as to which technology initially discovers the fault.

When oil analysis identifies wear metals in the oil, vibration analysis should be spotting the defect as well as any mechanical forces that might have produced the wear, such as misalignment or imbalance. If oil analysis has been reporting excessive contaminants in the oil for more than a month or two, then vibration analysis should be detecting wear on the bearings and gears as well. The reverse would also be true. If the vibration signature is showing bearing or gear defects, then the oil analysis results should reveal signs of wear metals in the oil samples.

If these complementary conditions are not being found, then both analysts should question whether representative samples of either the lubricant or the vibration signature have been captured. The only caveats would be when contaminants in the lubricant have just appeared and have not had time to produce any significant abrasive wear and therefore have not been seen in the vibration signature, or when subsurface fatigue occurs in bearings where no material has been liberated from the surface of the races and cannot be detected in the oil sample. Regardless, if these exceptional conditions exist, the

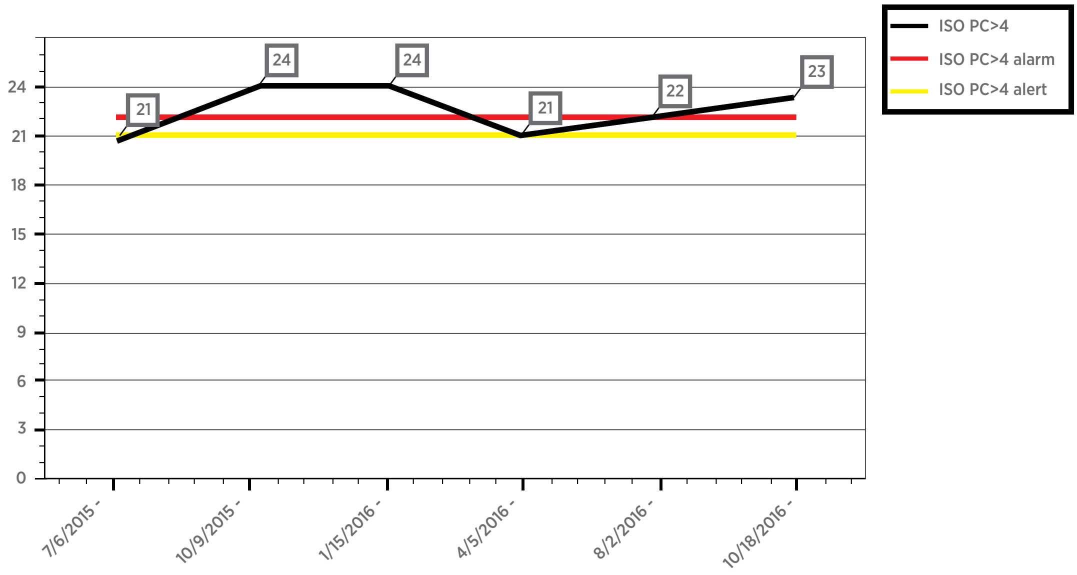


Figure 6. High ISO cleanliness for more than 16 months

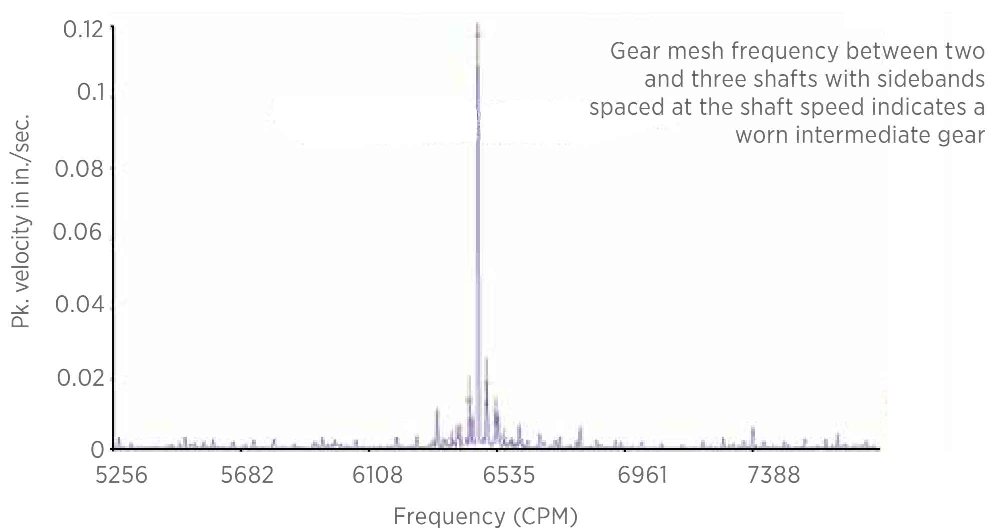


Figure 7. Intermediate gear wear

> **"Never have two inspection methods been better suited to complement each other in the validation** of rotating machine train defects than have vibration analysis and oil analysis."

analysts should be stating it in their reports to the asset owner.

EXAMPLES OF POOR INTERACTION

In the following example of poor interaction between oil analysis and vibration analysis, the trend plot offered by the oil analyst showed iron content in the oil samples as being high and rising for four months (see Figure 1). The analyst commented that the ferrogram revealed cutting particles, indicating abrasive wear in the gearbox, and recommended that the unit be checked for misalignment and high vibration. At the same time, the vibration analysis for the same unit found no identifiable defects.

From the perspective of the asset owner, some questions at this point should have been: Why did the vibration signature not show what the oil analyst thought it might? Does the oil analyst know what to look for in the vibration signature? Is there actually a problem in the vibration signature that the analyst did not recognize or catch? What does misalignment have to do with abrasive particles in the oil? Why did I not get a picture of the ferrogram showing

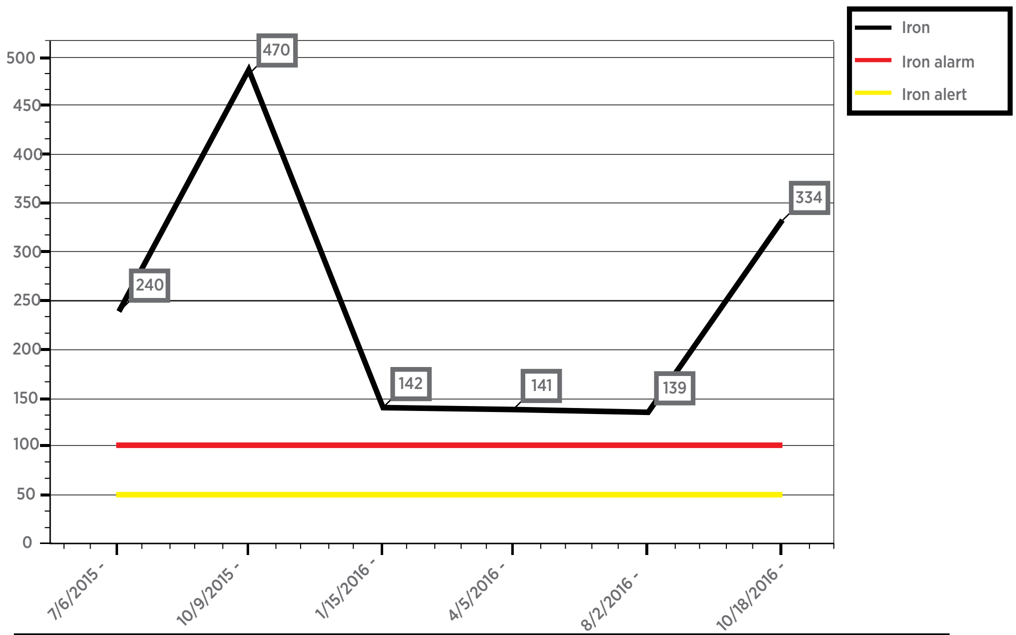


Figure 8. High iron counts for more than 16 months

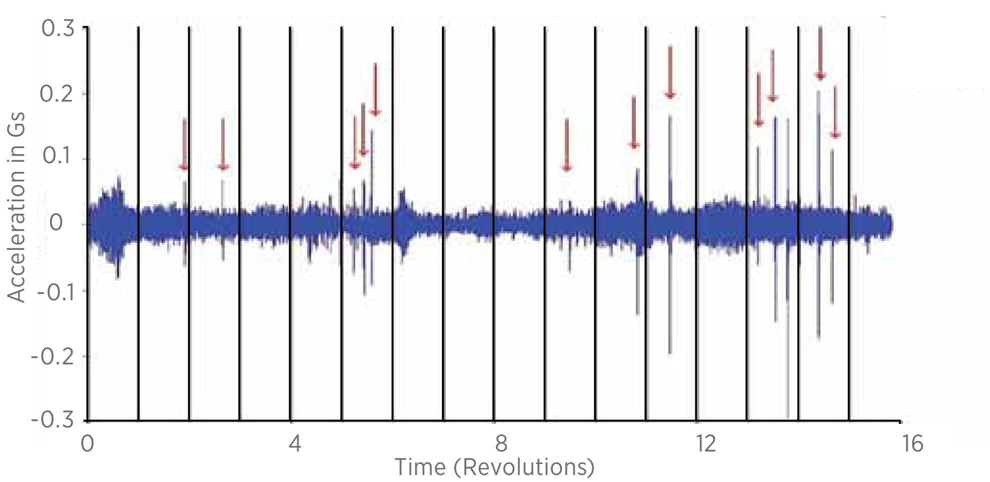


Figure 9. Impacting and looseness in the vibration signature

the cutting particles? Why did the two analysts not talk before they submitted their reports so I do not have to make the connections for them?

In a second example, the trend plot from the oil analyst showed the ISO cleanliness code of the oil samples as high for more than a year and steady over that time period (see Figure 2). The analyst recommended that the unit be checked for the source of contaminant ingression and that the lubricant be filtered to a greater degree. On the other hand, the vibration analysis for the unit revealed no identifiable defects during the past year.

These findings should have also raised questions for the asset owner, such as: How can the oil be dirty (in alarm) for more than a year and not cause a mechanical problem? Did the analyst not recognize or catch a problem in the vibration signature? Are the ISO cleanliness alarms set too tight?

In another example of poor interaction between the two technologies, the trend plots provided by the oil analyst showed the iron content and ISO cleanliness codes of the oil samples as being high for more than eight months (see Figures 3-4). Meanwhile, the vibration analyst only reported leaking seals on the gearbox (Figure 5) and no mechanical defects.

A reliability engineer might wonder why the two analysts did not mention that leaking seals allow for the ingression of contaminants. This could have been the perfect opportunity to mention this link and help the asset owner understand the importance of fixing the leaks. The asset owner might also question the reason for concern if the leaks and dirty oil are not causing any other problems.

For a final example of poor interaction, consider the trend plots presented by an oil analyst that showed the ISO cleanliness code in the oil samples as being high for more than 16 months (Figure 6), while the vibration analyst reported intermediate gear wear (Figure 7).

These results likely would have prompted a number of questions from the asset owner, such as: Are these two conditions related? Where are the analytics on ferrous wear? Are particles in the oil contaminants causing the gear wear or are there wear particles from the gear wear? If the oil is not dirty, what caused the gear wear? Why did neither analyst discuss the implications of the other findings?

EXAMPLE OF GOOD INTERACTION

In the following example of proper interaction between oil analysis and vibration analysis, the trend plots from the oil analyst showed a high iron count in the oil samples for more than 16 months (see Figure 8). The vibration analyst reported impacting and looseness as well as a possible problem with a thrust washer (see Figure 9).

From the perspective of a reliability engineer, this was a well-reported defect. Both analysts referenced the other's findings, and it was apparent they had communicated and likely discussed the results before submitting their report. Although the analysts did not state that one condition caused the other, they indicated the high probability of such an occurrence.

In conclusion, both oil analysis and vibration analysis are powerful inspection methods that are capable of identifying faults that the other cannot. However, there are also many defects with bearings and gears in which these technologies should be in lockstep. When they are, confidence in the inspection process grows and the asset owner can be more certain of the right action to take.

By Rendela Wenzel

The Benefits of a Lubrication Certification

To check the dates and locations of upcoming MLT exam sessions or to apply for an exam, visit the ICML website at **lubecouncil.org.**

Certification is an important step for anyone practicing in the field of machinery lubrication. It acknowledges your expertise in lubrication and your ability to troubleshoot lubricated equipment. A certification also shows that you are a professional with the ability to utilize lubrication successfully to enhance and improve reliability programs within your plant or through a client. The lubrication and oil analysis community, your employer and peers will recognize this credential as a symbol of the skills and knowledge you have gained through experience.

However, certification not only benefits the individual but also his or her company. Through certification, employers can maximize their return on investment in oil analysis, help to create synergy in their organizations around lubrication best practices, develop a standardized method of determining training needs and measuring results, as well as devise a reliable benchmark for hiring, promoting and career planning.

The International Council for Machinery Lubrication (ICML) offers multiple certifications for those in both professional and technical roles. The organization's Machine Lubrication Technician (MLT) certification has two levels. Level I targets in-plant technicians who perform daily lubrication tasks, such as oil changes, top-ups, greasing bearings, lubricant receiving and dispensing, and lubricant storage and handling. Level II is intended for in-plant technicians or engineers who are responsible for managing their lube team, selecting lubricants, troubleshooting abnormal lubricant performance and supporting machine design activities.

Certified MLT Level I practitioners have demonstrated a working knowledge of applying best lubrication practices and products. With this certification, technicians can move away from outdated methods of vague, non-specific lubrication procedures and job plans, and implement an effective lubrication program in any industrial workplace. Individuals with this certification have proven their knowledge of industry methods for selecting, storing, filtering and testing lubricants to boost reliability and generate lasting results in machine availability and overall reliability. They also have an understanding of oil analysis, which enables them to align their efforts with those of maintenance professionals or oil analysis experts.

Certified MLT Level II technicians have advanced knowledge of lubrication topics like lubricant selection, troubleshooting, predictive maintenance and advanced lubrication techniques. They also understand the benefits and potential of excellent lubrication practices and can assist others in making comprehensive improvements in the workplace that save significant time, money, storage space and training resources.

To check the dates and locations of upcoming MLT exam sessions or to apply for an exam, visit the ICML website.

Al Smiley | GPM Hydraulic Consulting

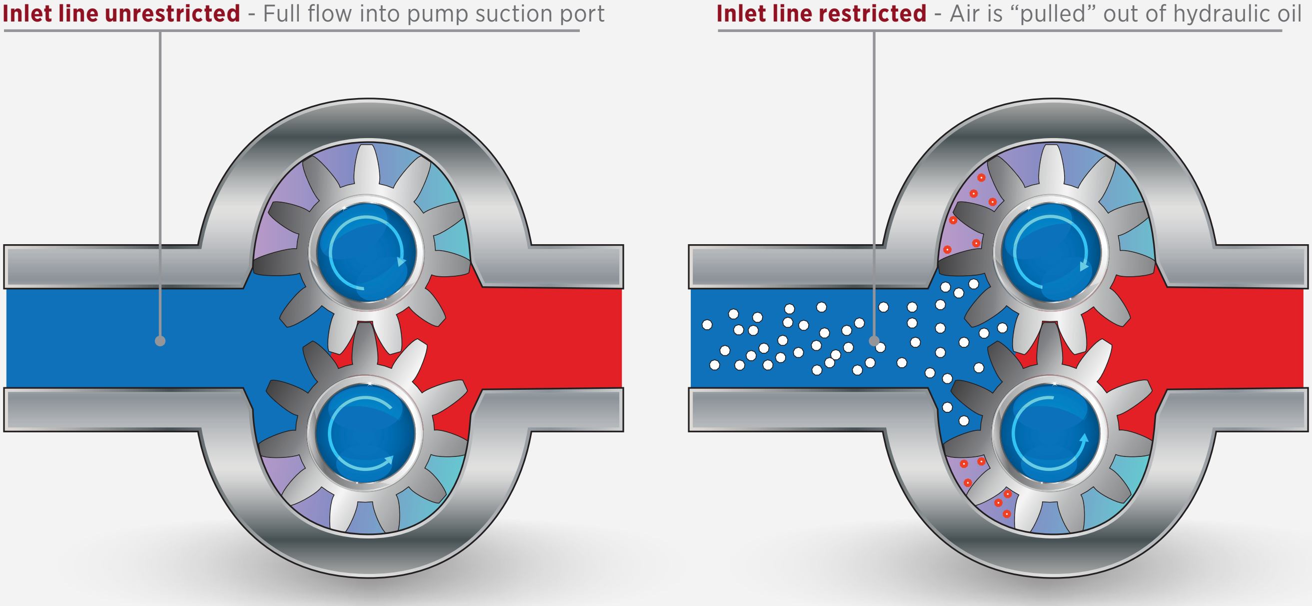
Troubleshooting Hydraulic Pumps

When a hydraulic issue occurs, the pump usually is one of the first components changed out, but it actually should be the last. Why? Because a pump is the most time-consuming part to replace and the most expensive. It should never be changed before several tests are conducted. The easiest tests and checks should be made first.

Visual Tests

Is the electric motor running? This sounds like a no-brainer, but it should not be overlooked. I was teaching a class at a plant in Kentucky a few years ago when a student came in one morning and said they had an overheating problem on the press the previous night. He said they changed the filtering and cooling pump to only find out later that the motor had been turned off.

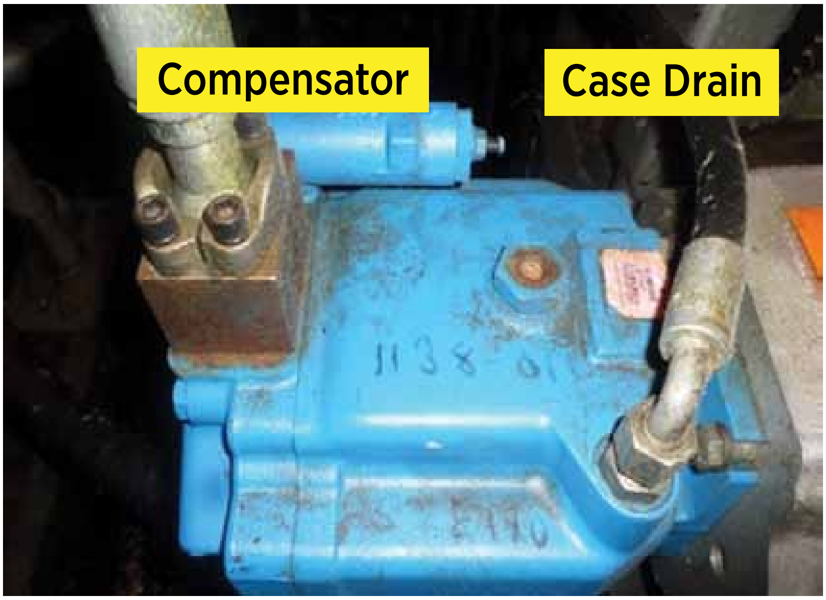
Is the pump shaft rotating? Many times this is difficult to tell because of coupling guards and C-face mounts. I know of one plant where the pressure at the



High vacuum pressure occurs when a pump does not receive adequate oil volume at its suction port.

A pump with a cracked mounting bracket led to shaft misalignment and a worn seal.

An arrow on the gear pump's housing indicates the direction of rotation.



The compensator setting limits the maximum pressure at the outlet port of a variable displacement pump.

pump outlet port was fluctuating. They changed the pump and found that the worn key on the shaft had damaged the keyway on the coupling.

Check the oil level. This also should be obvious, as it often is the only thing checked before the pump is changed. The oil level should be 3 inches above the pump suction. Otherwise, a vortex can form in the reservoir, allowing air into the pump.

If the oil level is low, determine where the leak is in the system. Leaks can be difficult to find. A press-roll hydraulic system at a paper mill in South Carolina had a continual problem with low oil levels, but the leak could not be found. The hydraulic unit was in the basement, and the piping ran up through the deck to the roll upstairs. To help find the leak, dye was added to the reservoir. An ultraviolet flashlight and goggles were then used to locate the leak, which was 30 feet in the air just below the second level.

Sound Checks

What does the pump sound like when it is operating normally? Vane pumps generally are quieter than piston and gear pumps. If the pump has a high-pitched whining sound, it most likely is cavitating. If it has a knocking sound, like marbles rattling around, then aeration is probably occurring.

Cavitation

Cavitation is the formation and collapse of air cavities in the liquid. When the pump cannot get the total volume of oil it needs, cavitation occurs. Hydraulic oil contains approximately 9 percent dissolved air. When the pump does not receive adequate oil volume at its suction port, high vacuum pressure occurs. This dissolved air is pulled out of the oil on the suction side and then collapses or implodes on the pressure side. The implosions produce a very steady, high-pitched sound. As the air bubbles collapse, damage is caused inside the pump.

Aeration

Aeration is sometimes known as pseudo cavitation because air is entering the pump suction cavity. However, the causes of aeration are entirely different than that of cavitation. While cavitation pulls air out of the oil, aeration is the result of outside air entering the pump's suction line.

A number of things can cause aeration, including an air leak in the suction line. This could be in the form of a loose connection, a cracked line or an improper fitting seal. One method of finding the leak is to squirt oil around the suction line fittings. The fluid will be momentarily drawn into the suction line, and the knocking sound inside the pump will stop for a short period of time once the air flow path is found.

Last year I received a troubleshooting call from a paper mill in Wisconsin where one of the pressure-compensating pumps had been changed because it would not build and maintain pressure. When the new pump also did not build pressure, the manual valve in the outlet line was closed to isolate the pump from the system. Pressure still would not build up. Since there were no other valves in the outlet line, the issue had to be in the suction line. After closer inspection, a crack was found in the suction line pipe.

A bad shaft seal can also cause aeration if the system is supplied by one or more fixed displacement pumps. Oil that bypasses inside a fixed displacement pump is ported back to the suction port. If the shaft seal is worn or damaged, air can flow through the seal and into the pump's suction cavity. This recently occurred on a refiner where the hydraulic pump was used to maintain a precise gap between the discs. Several minutes after the system was turned on, foam started coming out of the reservoir. After the pump was changed, a crack was found in the mounting bracket. This led to the shaft being out of alignment, wearing the seal. A misaligned coupling can cause a shaft seal to wear prematurely as well.

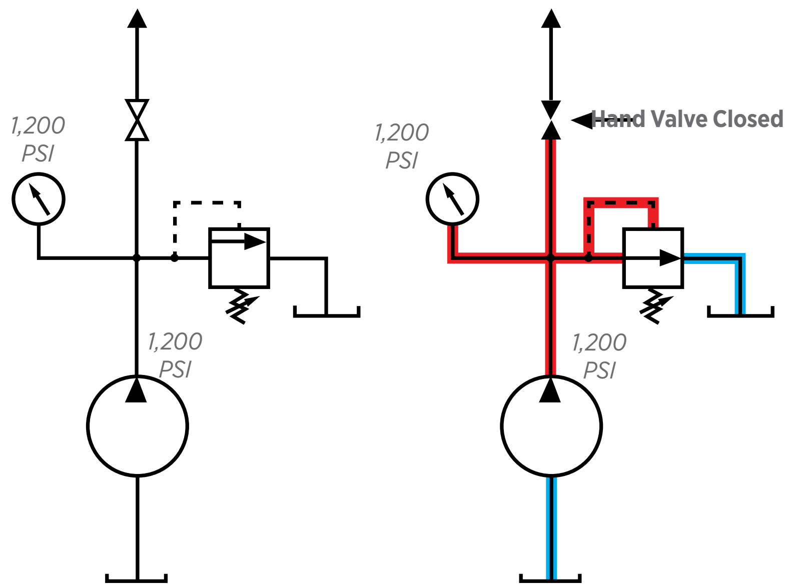
3 Reasons Why a Pump Cavitates

1. The oil viscosity is too high. Low oil temperature increases the oil viscosity, making it harder for the oil to reach the pump. Most hydraulic systems should not be started with the oil any colder than 40 degrees F and should not be put under load until the oil is at least 70 degrees F. Many reservoirs do not have heaters, particularly in the South. Even when heaters are available, they are often disconnected. While the damage may not be immediate, if a pump is continually started up when the oil is too cold, the pump eventually will fail prematurely.

A dirty suction strainer is shown.

2. The suction filter or strainer is contaminated. The strainer typically is 74 or 149 microns and is used to keep "large" particles out of the pump. The strainer may be located inside or outside the reservoir. Strainers located inside the reservoir are out of sight and out of mind. Many times maintenance personnel are not even aware that there is a strainer in the reservoir. The suction strainer should be removed from the line or reservoir and cleaned a minimum of once a year. I was called in to help a plant troubleshoot a system where they had already changed five pumps in a week's time. I noticed that the breather cap was missing, which was allowing dirty air to flow into the reservoir. A check of the hydraulic schematic showed a strainer in the suction line inside the tank. When the strainer was removed, a shop rag was found wrapped around the screen mesh. Apparently, someone had used the rag to plug the breather cap opening, and it had then fallen into the tank.

3. The electric motor is driving the hydraulic pump at a speed that is higher than the pump's rating. All pumps have a recommended maximum drive speed. If the speed is too high, a higher volume of oil will be needed at the suction port. Due to the size of the suction port, adequate oil cannot fill the suction cavity in the pump, resulting in cavitation. Although this rarely happens, some pumps are rated at a maximum drive speed of 1,200 revolutions per minute (RPM), while others have a maximum speed of 3,600 RPM. The drive speed should be checked any time a pump is replaced with a different brand or model.



To isolate a fixed displacement pump and relief valve from the system, close a valve or plug the line downstream **(left)**. If pressure builds, a component downstream of the isolation point is bypassing **(right)**.

As mentioned previously, if the oil level is too low, oil can enter the suction line and flow into the pump. Therefore, always check the oil level with all cylinders in the retracted position.

If a new pump is installed and pressure will not build, the shaft may be rotating in the wrong direction. Some gear pumps can be rotated in either direction, but most have an arrow on the housing indicating the direction of rotation. Pump rotation should always be viewed from the shaft end. If the pump is rotated in the wrong direction, adequate fluid will not fill the suction port due to the pump's internal design.

Testing a Fixed Displacement Pump

A fixed displacement pump delivers a constant volume of oil for a given shaft speed. A relief valve must be included downstream of the pump to limit the maximum pressure in the system.

After the visual and sound checks are made, the next step is to determine whether you have a volume or pressure problem. If the pressure will not build to the desired level, isolate the pump and relief valve from the system. This can be done by closing a valve, plugging the line downstream or blocking the relief valve. If pressure builds when this is done, there is a component downstream of the isolation point that is bypassing. If the pressure does not build up, the pump or relief valve is bad.

If the system is operating at a slower speed, a volume problem exists. Pumps wear over time, which results in less oil being delivered. While a flow meter can be installed in the pump's outlet line, this is not always practical, as the proper fittings and adapters may not be available.

To determine if the pump is badly worn and bypassing, first check the current to the electric motor. If possible, this test should be made when the pump is new to establish a reference. Electric motor horsepower is relative to the hydraulic horsepower required by the system. This is shown in the following formula: electric motor horsepower (hp) = gallons per minute (GPM) x pounds per square inch (psi) x 0.00067. For example, if a 50-GPM pump is used and the maximum pressure is 1,500 psi, a 50-hp motor will be required. If the pump is delivering less oil than when it was new, the current to drive the pump will drop. A 230-volt, 50-hp motor has an average full load rating of 130 amps. If the amperage is considerably lower, the pump is most likely bypassing and should be changed.

The temperature of the pump housing and suction line should also be checked. A severe increase in temperature indicates a badly worn pump.

Testing a Variable Displacement Pump

The most common type of variable displacement pump is the pressure-compensating design. The compensator setting limits the maximum pressure at the pump's outlet port. The pump should be isolated as described for the fixed displacement pump. If pressure does not build up, the relief valve or pump compensator may be bad. Prior to checking either component, perform the necessary lockout procedures and verify that the pressure at the outlet port is zero psi. The relief valve and compensator can then be taken apart and checked for contamination, wear and broken springs.

If a volume problem exists in the system, perform the following tests:

1. Check the tank line temperature of the relief valve with a temperature gun or infrared camera. The tank line should be near ambient temperature. If the line is hot, the relief valve is either stuck partially open or is set too low.
2. Install a flow meter in the case drain line and check the flow rate. Most variable displacement pumps bypass 1-3 percent of the maximum pump volume through the case drain line. If the flow rate reaches 10 percent, the pump should be changed. Permanently installing a flow meter in the case drain line is an excellent reliability and troubleshooting tool.
3. Check the current on the drive motor.
4. Ensure the compensator is 200 psi above the maximum load pressure. If set too low, the compensator spool will shift and start reducing the pump volume when the system is calling for maximum volume.

Performing these recommended tests should help you make good decisions about the condition of your pumps or the cause of pump failures. If you change a pump, have a reason for changing it. Don't just do it because you have a spare one in stock. Conduct a reliability assessment on each of your hydraulic systems so when an issue occurs, you will have current pressure and temperature readings to consult.

About the Author

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Simple as Soap? The Risks of Grease Mixing

In the amusement park's maintenance area, I learned that the park was experiencing a rash of motor bearing failures. With such a long operating history, it was surprising to find this sudden uptick in problems. I brainstormed some possible reasons with the maintenance team and was told, "Our motors had been running great ever since Henry took over the motor rebuild program." When I asked if we could discuss the issue with Henry, I was informed that he had retired the previous year.

With a little more investigation, we discovered that Henry had been personally sending a new tube of grease with each motor sent out for rebuild, attaching it to the motor with duct tape. When Henry retired, this practice was lost, and the motor rebuild shop reverted to its standard bulk grease. As you may have guessed, the amusement park was using a grease that was not compatible with the one at the rebuild shop — not very amusing!

53%

of lubrication professionals say grease compatibility has caused problems at their plant, according to a recent poll at Machinery Lubrication.com

Henry had developed an effective strategy to avoid the negative consequences of grease mixing: ensuring that one product — the correct grease for the application — was being used by everyone servicing the motors. This starts by validating the product, including the right base oil viscosity, base oil type, NLGI grade, thickener type and additives. But even when you know the right grease to use, the opportunities for the wrong grease to be mixed are many. These would

include someone grabbing an incorrect grease gun, new machines or bearings coming supplied with a different grease, contractors adding the wrong grease during repairs, and grease guns being incorrectly labeled.

Determining Incompatibility

Just like Henry's motor shop, those who have experienced grease mixing have seen the impact. Most times, the greases soften. The thickeners interact and become runny. In some cases, the thickener bleeds

PRODUCT	MANUFACTURER A 'BEARING' GREASE	MANUFACTURER A 'SPECIAL' SEVERE CONDITION GREASE
Thickener	Lithium Complex	Lithium Complex
NLGI Grade	2	2
Base Oil Type	SHC Polyalphaolefin (PAO)	SHC Polyalphaolefin (PAO)
Additives	Anti-Wear (AW)	11% graphite/1% moly (EP)
Base Oil Viscosity	100 cSt at 40°C	1,000 cSt at 40°C
Intended Use	Higher speed motors	Extremely slow speeds, higher temperatures, boundary lubrication

excessively, releasing large amounts of the vital oil and additives, which leaves behind mostly thickener. In a few instances, the mixed grease can harden.

These most obvious signs of incompatibility of the "soap" or non-soap thickener have driven an oversimplification of the approach to grease mixing. An internet search will return no fewer than 17 different compatibility charts which only address families of thickeners. An article in the January-February 2017 issue of *Machinery Lubrication* cited several examples of grease mixtures that appear to be compatible according to these popular charts, but after a more thorough review obviously are not. These would include the two lithium-complex greases shown in the table above:

It's more than just the soap that determines compatibility. Even when the thickeners are the same, differences in the base oil types, viscosities and additives can render a mixture inadequate or even damaging to a critical machine. For the two lithium-complex greases in the table above, many of the considerations matched up, including the base oil type (PAO), NLGI grade and even the manufacturer. However, a mixture of these products would certainly not produce an optimal outcome for a given machine, as each is designed for a very different application (speed, temperature and lubricant film type).

In addition to these issues, the compatibility charts themselves are often in direct contradiction. For example, some charts indicate that "polyurea" grease is compatible with calcium complex, while others list them as being incompatible. Barium complex and clay greases are identified as being compatible in several charts, but this is contradicted by other charts that describe the mixture as incompatible. After some review, it becomes clear that basing your grease mixing decisions on these charts is fraught with danger.

Trust but Verify

Some turn to lubricant suppliers for guidance. Although most suppliers are quite familiar with the performance capabilities of their products, few have conducted testing on the thousands of competing lubricants to establish which are compatible and which present problems. A "trust but verify" policy can be a sound strategy to ensure success. If you are consulting with a lubricant supplier on a product changeover and are concerned about the impact of grease mixing, take the supplier's advice under consideration but ask for a copy of the testing that was performed to determine if the product will be compatible in the mixture of concern.

Laboratories that test in-service grease samples report that one of the most frequent causes of failure is grease mixing. In electric motor repair, it is quite common to receive reports of "overlubrication" leading to grease being found in the motor windings instead of the bearing housing. However, this sometimes may be a result of grease mixing, which produces a thinning of the grease mixture and allows it to be drawn past the housing shields and into the windings where it is distributed by movement and air flow.

The risks and incidents of grease mixing are widespread, so how do you know if two greases are incompatible? In 2011, ASTM issued D6185, the "Standard Practice for Evaluating Compatibility of Binary Mixtures of Lubricating Greases." It involves preparing ratios of the greases in question and performing three tests. The mixtures are 50-50, 10-90 and 90-10, but could also be 50-50, 75-25 and 25-75. The tests are cone penetration (D217), dropping point (D566 or D2265) and storage stability at an elevated temperature, which is also

> "Even when you know the right grease to use, the **opportunities for the wrong grease to be mixed are many.**"

determined by cone penetration. It is interesting to note that these methods are cited in ASTM standards as not being useful in predicting the performance of in-service greases. Therefore, after a few minutes of mixing, a test that does not predict how a grease behaves in a machine is used to evaluate the suitability of a mixture to perform in bearings or gears for months or years with constant mixing.

Addressing these concerns, an ASTM committee has created a working group to evaluate more advanced approaches used by some laboratories to test grease compatibility and decide if improvements in the D6185 standard are warranted. Some of these enhanced tests include extended grease mixing and working prior to testing, as well as using techniques such as a stress rheometer to predict performance issues like hardening, separation of the oil and thickener, and tendencies of the mixture to tunnel or channel in the machine housing.

Certainly, avoiding grease mixtures should be the strategy employed whenever possible. Of course, sometimes it is not cost-effective to do so, such as when products in use are discontinued or when lubricant consolidation has been implemented as a cost-savings initiative. Successful organizations will carefully consider all the performance parameters and differences between the greases in question. Simply checking a box on a compatibility chart is not sufficient to protect your critical machinery.

The "Lube-Tips" section of *Machinery Lubrication* magazine features innovative ideas submitted by our readers.

New Grease **Gun Caution**

Before installing grease into a new grease gun, consider disassembling the gun and cleaning it thoroughly. Metal shavings have been found in new grease guns. These metal shavings appear to be from the manufacturing process of the grease gun.

Avoiding Contamination **in Dirty Environments**

Machines operating in an extremely dirty environment, such as in a forge or foundry, require extra care to prevent contamination. Try to keep the equipment sealed and avoid unnecessary opening of the reservoirs. Install quick disconnects in tanks and on fill vessels for filling or topping up hydraulic tanks. Add mainstream sampling taps on all equipment. This will result in a true indication of the oil's condition, avoiding any bottom sampling.

Preventive Measures **Make Sense**

Catastrophic pump failure on circulating and hydraulic systems can damage more than just the pump. Consider using oil strainers or filters upstream of all equipment components to prevent pump failure debris from damaging these machines. This is also important for kidney-loop systems with expensive heaters and oil/water separators.

Did You Know?

Additional tips can be found in our Lube-Tips email newsletter. To receive the Lube-Tips newsletter, subscribe now at

MachineryLubrication.com.

Have Some Tips?

If you have a tip to share, email it to editor@noria.com.

8 Lubrication Failure **Mechanisms for Rolling-element Bearings**

Rolling-element bearings are some of the most frequently used mechanical components that require a lubricant. Their application is very broad, ranging from small, non-critical knob-adjuster support bearings to large, critical wind-turbine main bearings. In general, bearings tend to fail well before their design life. This is often because the environmental and operating factors are not controlled or taken into consideration when the lubricant is selected. In this article, I will refer to rolling-element bearings simply as bearings. However, this does not necessarily address the topic as it relates to journal bearings.

> **"Whether it's excessive contamination or an incorrectly applied lubricant, it is important to understand the** root causes that can contribute to lubrication failure mechanisms."

Regardless of whether a bearing reaches its design life, the life you should strive to achieve from your bearings should be based on the optimum reference state (ORS). When considering a bearing's application and its associated reliability objectives, a certain maintenance strategy should be deployed to help attain an optimized return on investment. For example, if the result of a bearing failure does not lead to any immediate downtime and the corrective action costs are insignificant when compared to using regular proactive and predictive maintenance over the life of the bearing, then a run-to-failure strategy may be the ORS.

It's not uncommon for small bearings (with low speed factors) to be kept sealed without any relubrication and very little maintenance required. However, in

most cases, a carefully selected relubrication schedule and a maintenance strategy that is more comprehensive than simply reactive maintenance will be recommended, depending on the optimum reference state.

When performing a failure modes and effects analysis (FMEA) on a bearing, a series of questions must be asked. These would include the following:

- To what type of application is the bearing subjected?
- What function does the application perform for the organizational goals? (How critical is the piece of equipment containing the bearing?)
- What are the potential failure modes? (In what ways can the machine fail?)
- What are the effects of the failure modes? (What is the consequence of failure on operations?)
- What is the severity of each of these effects? (What's the relative impact of these failure modes on operations?)
- What are the failure mechanisms for each failure mode? (What is the underlying root cause?)
- How likely is it for the failure mechanism to exist? (What is the probability of the failure mechanism?)
- What failure detection mechanisms are deployed? (What methods are there to predict the failure?)
- How effective is the detection mechanism? (What is the probability of detecting the failure early?)

With the answers to these questions, a risk/priority number can be calculated and recommendations for the best maintenance strategy determined.

This article will highlight the most common failure mechanisms for a bearing as a result of lubrication (or lack thereof). When analyzing these failure mechanisms, one can perform a lubricant FMEA. With this approach, questions are asked similar to those in the machine FMEA discussed earlier, but in this case the lubricant's failure root causes are identified as well as how they can result in a failure to provide lubrication to the machine.

In his book, *Machinery Failure Analysis and Troubleshooting Vol. 2*, Heinz Bloch states, "Lubrica-

42%

of lubrication professionals say contamination is the most common cause of bearing failures at their plant, according to a recent poll at MachineryLubrication.com tion-related bearing problems, according to our experience, are most frequently caused by lack of lubrication or lubricant contamination." This information is not new and has been reiterated by bearing manufacturers and end users through countless failure root cause analyses (FRCA). But why?

Consider that rolling elements in bearings ride on a thin film of lubricant (often less than 1 micron) at the mating surface of the bearing race. With small contact areas, the pressure exerted on the surfaces can exceed 500,000 pounds per square inch (psi). If any lubricant is displaced by a foreign contaminant, such as dirt or water, at these critical load zones, the bearing eventually will experience increased wear. If the wear is excessive, the life of the bearing will be reduced significantly. The result is a contamination-induced bearing failure.

But even when contamination is minimized, if the lubricant selected for the application does not meet the operating and environmental requirements, a lubricant-induced bearing failure will occur. Therefore, whether it's excessive contamination or an incorrectly applied lubricant, it is important to understand the root causes that can contribute to lubrication failure mechanisms along with the most common reasons why bearings prematurely reach the end of their life. Following are the top eight lubrication failure mechanisms for rolling-element bearings:

1. Unsuitable Lubricant

First, you must choose the correct lubricant for the application. Fundamental properties, such as the viscosity, additive package and consistency (for grease), should be carefully selected based on the bearing type, speed factor and operating conditions. If these factors are not thoroughly considered and an unsuitable lubricant is applied, the lubricant may become overly stressed or be insufficient for the machine's lubrication needs. In either situation, the bearing will likely undergo premature wear and failure.

2. Lack of Lubricant

For greased bearing applications, the correct regreasing volume and frequency must be established to ensure the bearing load zones are lubricated properly. Too much time between regreasing intervals or applying too little grease will cause excessive boundary conditions and bearing wear. This type of failure mechanism also tends to trigger a chain reaction of other failure mechanisms, such as hot running conditions, and generate wear particles, further perpetuating the failure mode. Even in oil applications, routinely monitoring the oil level can mean the difference between optimal lubrication and no lubrication.

3. Excess Lubricant

More grease is not always better. When too much grease is added to a bearing in medium to high-speed applications, the temperature will rise from the churning, and the machine must work harder to overcome the fluid friction. As the temperature rises for the excessive grease charge, the viscosity will drop and other adverse effects will ensue.

4. Hot Running Conditions

A bearing running at a higher than expected temperature can be either a root cause or a symptom. If the bearing is exposed to an external environment that is exceptionally hot, this would indicate a root cause. If the temperature increase is from an internal condition, then this would be a symptom with possible root causes such as excessive lubricant, lack of lubricant or misalignment. Regardless of the source of the hot running conditions, the heat will lead to increased lubricant oxidation, thermal degradation, additive depletion, viscosity changes and other failure modes. If the source of the higher temperatures is mechanical, this can be identified as part of the FMEA process.

5. Solid Contamination

Solid contaminants can enter a system in a number of ways, including through a new lubricant, ingested from a headspace port or hatch, via defective seals, etc. The type of solid contaminants can vary depending on the source, but typical airborne dust/dirt will consist primarily of silica and alumina. Excessive contamination will result in lubrication failure, as the lubricant likely will not be able to overcome the various wear modes, like three-body abrasion. Additionally, if the contaminants are metal catalysts, they can contribute to lubricant degradation in the form of oxidation, particularly when in combination with water, higher temperatures and air.

6. Moisture Contamination

Similar to solid contaminants, moisture can enter a system in many different ways, including through the headspace entry point, seals or new oil. When the headspace is humid, thermal cycles can cause moisture to escape the air, sweat onto surfaces and find its way into the oil through gravity. Moisture may exist in a lubricant as dissolved, emulsified or free water. Emulsified water has the most destructive potential in oil. Water is not a good lubricant, so when it displaces oil in a bearing's load zones, the water collapses, producing a lubrication failure and mechanical wear. Water also contributes to oxidation and hydrolysis, with the lubricant undergoing permanent chemical degradation and additive depletion. These can lead to a lubrication failure by changing the lubricant's viscosity, removing additive functionality, and forming other contaminants, insolubles and acids. Of course, when considering the machine, water is the primary cause of rust.

7. Mixed Lubricant

Topping up (if oil) or regreasing (if grease) a bearing with the wrong lubricant can drastically change the physical and chemical properties of the resulting lubricant mixture. Not only can factors like the wrong viscosity impact lubrication, but additives can also react negatively with each other, impeding their functionality.

8. Other Contaminants

Depending on the machine type, bearings may be introduced to other process chemicals, blow-by contaminants, glycol, etc. Based on the type of contaminant, the lubricant can change chemically or physically, resulting in a lubrication failure.

In conclusion, regardless of whether you have a lubricant- or contaminant-induced failure mechanism, the result will either lead to lubrication failure modes or contribute directly to mechanical failure modes of the bearing. When multiple failure mechanisms are combined, there is greater potential for a lubricant failure. A machine FMEA performed on a failed bearing can frequently reveal mechanical wear signatures that indicate whether the failure was lubricant-related, although often the damage during the final stages of a catastrophic failure will destroy or overshadow the evidence of the failure's true root cause. In these cases, it usually is best to perform lubricant analysis (either grease or oil) to detect clues of the root cause, like a thermally degraded lubricant, abnormal levels of contaminants, changes in viscosity, etc.

When developing a conclusion, it also helps to include available maintenance records or condition monitoring data, such as vibration analysis, thermography or maintenance logs on relubrication and inspections.

Again, just because a lubrication failure has occurred doesn't necessarily mean the lubricant was insufficient in volume. Many failures are associated with too much of something, like the lubricant's viscosity or amount. Moreover, if a contaminant is taking the place of the lubricant or disrupts the function of the lubricant, the contaminant will be the ultimate cause of the lubrication failure.

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About the Author

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"Do you have any suggestions for problems with the solubility of **oxidation products in turbine oil at low temperatures?**

Recently, my clients have had a problem with the solubility of oxidized products in turbine and hydraulic oils. At operating temperatures (60-80 degrees C), they are dissolved, but in stoppage (i.e., temperatures below 25 degrees C), they become insoluble and begin to deposit on working surfaces. This is a problem with the hydraulic piston pumps, and it does not matter the type of turbine (gas/steam/etc. or manufacturer) or the working hours."

Based on your comments, you may be dealing with varnish formation, which is a frequent problem in high-temperature and high-pressure systems such as steam turbines or high-performance hydraulic systems.

Varnish is the accumulation of oil oxidation and degradation compounds on machine surfaces or components. It can be the result of several possible root causes, including high temperatures, electrostatic discharges, lubricant degradation and microdieseling. Varnish can produce a number of problems related to machine operation, such as valve stiction, lubricant flow restriction, clogged filters, etc.

Varnish begins as dissolved impurities. When these impurities accumulate and reach the saturation point, they migrate to the surfaces of the lubrication system. If these deposits remain on the surfaces, they cure (harden) with time, causing failure of the lube system and lubricated components.

Oxidation resistance and solubility are two important lubricant properties to consider. Oxidation resistance refers to how molecules resist the chemical reaction with the oxygen in the air. Oxidation degrades oil and is one of the main reasons to change it. The greater the oxidation resistance, the longer the oil life.

Solubility is the property that allows a lubricant to hold polar substances like varnish in suspension without damage to the machine. Oil solubility increases at higher temperatures. Group III oils also have lower solubility than Group II and Group I oils. There have been many instances of machines experiencing varnish deposits due to lower solubility of the oil after switching from a Group I oil to a Group II or III oil.

If you are facing varnish deposits, two actions are recommended to control it. First, identify the root causes. This will require a systematic study of the possible factors supported by oil analysis. Next, remove the existing varnish in the machine. This can be achieved by adding solvent or detergent additives to the oil, using a synthetic product with high natural solvency or installing varnish removal systems. In cases of hardened varnish, the solution will be mechanical and may simply involve changing the components.

"Why aren't more machine shops using natural biodegradable oils? **Is it the cost, availability or marketing?**

Don't they outperform the others? I am confused why more machinists don't use them."

Much of the reason for this may be due to old practices and mindsets. If your mineral oil worked for you yesterday, why would you want to change to a vegetable-based oil today and take a chance that the new product won't perform as well?

People often fall into a routine, and unless something upsets that routine, the current practices tend to stay the same. It's usually not until an event like a discharge, government agency involvement or new personnel entering the facility that old practices are questioned and new ideas are considered.

Many machinists may not even be aware of the other products on the market. In today's economy, it seems as if no one wears just one hat on the job anymore. The pressing issues at hand must be addressed, so the thought of looking for new products frequently gets pushed aside. Of course, there are those who are constantly looking for the best-performing products on the market and taking proactive steps to save the environment.

The other issue is that biodegradable oils usually have a higher cost than mineral oils. This hinders smaller shops from changing to environmentally friendly lubricants. The cost not only involves the oils but also ensuring that all equipment is cleaned out completely before making the switch, since most vegetable oils and mineral oils don't mix well.

Changing to biodegradable oils can be costly and take time away from production. Obviously, additional costs and downtime are two things most plants never want to hear and will be put off until absolutely necessary unless financial justification can be made.

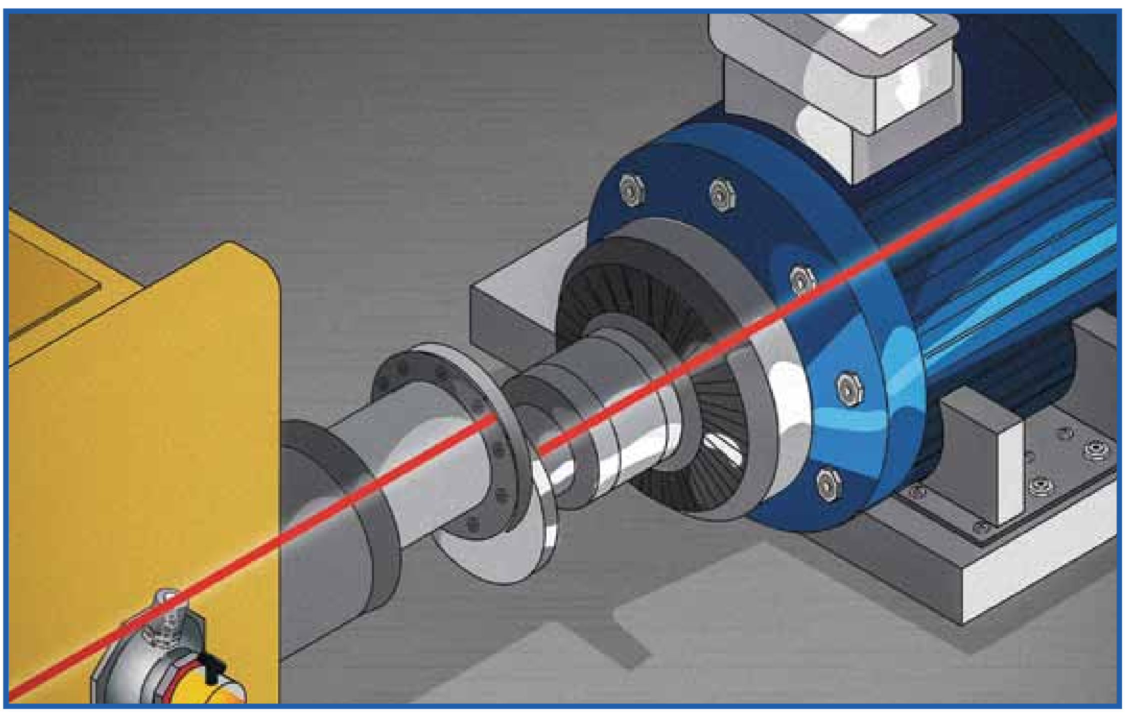
Biodegradable oils have many advantages over mineral-based oils. Anyone working in a machine shop knows of the dreaded oil mist. This mist consists of harmful volatile organic compounds (VOCs) and can cause dermatitis. With biodegradable oils, the oil misting is lessened, which means fewer VOCs entering the air and minimal skin-related issues. Using a vegetable oil may also improve lubricity.

When deciding which lubricant is right for you, consider the application as well as your company values. Some industries may have policies on environmental impacts or be forced to adhere to government regulations. The process might even demand a biodegradable fluid. Whatever the case, be sure to evaluate all of your options.

If you have a question for one of Noria's experts, email it to editor@noria.com.

Garrett Bapp | Noria Corporation

Consider Machine Alignment to Avoid Equipment Failures



> "There isn't a lubricant that **can protect against misalignment.**"

After several years of working in maintenance, I have found that there's no replacement for proper machine alignment. In every training course I teach for Noria, I explain that there isn't a lubricant that can protect against misalignment. With this in mind, along with the thousands of machines that die every year due to improper alignment, it's time to take the necessary steps to further your reliability program.

When performed correctly, an alignment can be an essential part of a proactive maintenance plan. The variety of methods and tools available makes it easy to justify investing the time to do the job right. With that said, my first alignment experience involved following an old-timer around as he showed me the ropes. After we set the new motor atop our hydraulic press and cleaned out the old grease from the grid coupling, he used a small 6-inch ruler or straight edge and laid it across the coupling halves. There was some shimming of the motor to get it parallel with the hydraulic pump shaft, but the whole process was "eyeballed."

Over time, what I learned from this experience was that the drive end of the motor ran hotter, the grease was almost always hardened or turned to dust, and we had to replace a broken coupling quite often. From this practice, it's safe to assume that we were a reactive maintenance culture, and we were. We never questioned why the coupling disintegrated or why the motors kept failing.

With a change of employers came a new culture and the desire to have a reliable plant. One of the first steps was purchasing a laser alignment tool, but this was only the start. Once we received formal training and began performing more machine alignments, we were able to achieve proper alignment quicker each time. It sure beat the previous methods of using straight edges and dial indicators. We also saw a reduction in failed bearings and couplings across the plant.

IDENTIFYING MISALIGNMENT

Proper machine alignment can be summed up in a simple statement: The shafts are aligned in both the horizontal and vertical planes. Misalignment takes place when the shafts are not parallel or a shaft has an angular misalignment. Parallel misalignment means that an offset of the shafts has occurred. Angular misalignment refers to when the shafts run at an angle to one another. Sometimes both parallel and angular misalignment may be present and need to be corrected.

Parallel misalignment can be seen in the horizonal and vertical planes. Vertical misalignment usually can be remedied by adding or subtracting shims from the motor or machine feet. Horizontal misalignment requires side-to-side movement of the motor or machine until the centerlines match. Angular misalignment can also occur in the vertical and horizontal planes.

EFFECTS OF MISALIGNMENT

The effects of misalignment can be catastrophic to a machine. Coupling damage is the most common symptom. When a technician pulls the coupling halves apart for internal inspection, the grid or teeth may be affected, resulting in replacement of the entire coupling. Of course, this only masks the true problem hidden inside the motor or machine.

Misalignment also increases friction along the bearing surfaces, which then turns into increased wear, energy consumption and premature breakdown of the machine. Seals can be damaged during any part of the process and lead to leakage. If the issue exists for an extended period of time, the shaft may be impaired as well.

Once the components begin to wear, a simple swap-and-replace is no longer sufficient. If the underlying cause of misalignment is not recognized and corrected, the problem will present itself again and again. It's my opinion that misalignment is often overlooked as a root cause of failure. Frequently, the problem is blamed on faulty seals or the bearing installation. It's not until the maintenance professional receives proper training and gains a better understanding of how detrimental shaft alignment is that the issue can be addressed through corrective alignment.

PREDICTIVE TECHNOLOGIES

There are several predictive technologies that can detect misalignment. The most popular options are laser alignment, vibration analysis, oil analysis and thermography.

Laser Alignment

Laser alignment makes it simple to align shafts with precision and accuracy. It works by using a laser that is directed into another sensor. This sensor feeds data to a device that deciphers the information and then provides you with accurate data to adjust your equipment. Once the laser and sensor are strapped to the driver and driven machine, the shafts are rotated and multiple points are read to determine which direction the driver must move.

Laser alignment tools can take into account the equipment's metallurgy and offer relative metal expansion rates to consider how the machine will expand during operation. A live alignment is also a possibility. For this, the technician aligns the machine as much as possible, then starts the equipment and allows it to reach its operating temperature. After a shutdown, a measurement is immediately taken to establish the machine's thermal expansion.

By routinely using laser alignment on critical equipment, you can make the necessary adjustments and address other potential issues. However, it isn't the most practical method for equipment in operation, as it requires a shutdown as well as dedicated hours for maintenance personnel to perform the task. With an increased focus on uptime, you may wish to select a different option when shorter intervals are required.

Vibration Analysis

Vibration analysis can also detect misalignment by analyzing the changes in vibration response, critical speeds and machinery stability when compared to an established baseline. Vibration readings usually are in the 1X range for axial vibration or 2X for radial vibration. An abnormal result doesn't always mean there is an alignment problem. Different samples must be taken from both the drive and driven ends to eliminate other possibilities and to determine if misalignment is the issue.

Depending on the extent of the misalignment, vibration analysis may not detect it until a larger problem with the bearings occurs. Therefore, a proper alignment must always be performed first. Screening tools should only be used for detection purposes.

Thermography

Thermography is another method that can provide early detection of alignment issues. Due to the increased friction that exists with misalignment, a rise in temperature will follow. By taking a heat map of the bearing areas, a technician can identify any abnormal hot spots.

When machines are inspected, an increase in temperature is not always alarming. This puts a little more responsibility on the user to compare similar machines and be consistent with spot checks.

Oil Analysis

Oil analysis may also be useful in detecting misalignment by providing the overall condition of the machine, oil and contaminants. It can identify active machine wear earlier than vibration analysis if performed correctly, i.e., sampling from the right location, flushing sample lines, using new sampling hardware, etc. However, without knowing the metallurgy of the machine's bearings, it can be difficult to establish a direct correlation to misalignment.

Testing for elemental analysis can reveal slight increases in common bearing materials such as iron, aluminum, copper, lead and chromium. This data may serve as the first indication that a problem exists within the machine. Coupling oil analysis with vibration analysis can be an effective combination for detecting issues early and pinpointing their exact causes. The microscopic appearance of particles related to misalignment will show shapes, sizes, textures and colors commonly associated with two-body abrasion, scuffing and surface fatigue.

FINAL THOUGHTS

When setting up machines and trying to determine the root causes of failure, a proper alignment is often overlooked. Even if your team has the appropriate tools and training, you must have detail-oriented people who will stick with the job until it is done right. I have been on alignment jobs that only took 10 minutes to achieve an accurate alignment. Others have taken the better part of a day or two, depending on whether the motor had to be removed for machining.
Employing the right personnel can make all the difference in an acceptable alignment or a great alignment – and there is a difference. It comes down to how much of a variance you will allow. On small, low-cost or redundant machinery, being within a few thousandths of an inch may be all that's necessary. On larger machines that can shut down your plant, your goal might be as close to zero as possible.

Focus on proactive alignment and doing it correctly the first time, no matter what it takes. The best maintenance programs also document their results and have back-up measures to predict when something goes awry. By combining different condition monitoring tools, proper training and the right personnel, you should see a decrease in overall failures due to misalignment.

About the Author

Garrett Bapp is a technical consultant with Noria Corporation, focusing on machinery lubrication and maintenance in support of Noria's Lubrication Program Development (LPD). He is a certified lubrication specialist through the Society of Tribologists and Lubrication Engineers (STLE) and holds Level II Machine Lubrication Technician (MLT) and Level II Machine Lubricant Analyst (MLA) certifications through the International Council for Machinery Lubrication (ICML). Contact Garrett at gbapp@noria.com to learn how Noria can help you implement proactive maintenance practices at your plant.

TEST YOUR KNOWLEDGE

This month, *Machinery Lubrication* continues its "Test Your Knowledge" section in which we focus on a group of questions from Noria's Practice Exam for Level I Machine Lubrication Technician and Machine Lubricant Analyst. The answers are located at the bottom of this page. The complete 126-question practice test with expanded answers is available at store.noria.com.

1. The primary reason that machinery is replaced is due to:

A) Erosion
B) Accidents
C) Obsolescence
D) Surface degradation of the metal
E) Corrosion

2. Sampling crankcase oil from an engine should be done:

A) Through the dipstick hole with a drop-tube
B) From a valve mounted after the pump and after the filter with the engine running
C) From a valve mounted after the pump, before the filter with the engine running
D) From a valve mounted after the pump, before the filter with the engine shut off
E) From the drain plug

3. Elastohydrodynamic lubrication (EHL) is considered to occur primarily in:

A) Piston rings and liners
B) Journal bearings
C) Rolling bearings, gears and cams
D) Slow-moving pins and bushings
E) Worm gears

ANSWERS

1. D
Wear is the primary cause of machinery replacement. Surface degradation of the metal includes all types of wear such as abrasion, adhesion, erosion, corrosion, etc.

2. C
This will help assess the actual condition of the oil and the engine before the contaminants and wear metals are captured by the filter.

3. C
EHL occurs in systems where the contact area is small and the pressure is high, such as rolling-element bearings, gears (at the pitch line) and cams. The mating surfaces deform elastically to enlarge the contact area, which is why it is called elastohydrodynamic lubrication.

Gulf Oil and Cricket

Gulf Oil has been a pioneer in the Lube Industry, like in many other numerable instances, by associating with Champion IPL Teams, who dictate the true brand values of Gulf of Quality, Endurance and Passion, for almost a decade. The momentous mark of Gulf Oil's history began in 2011 when it became the associate sponsor of the iconic IPL team, Chennai Super Kings. With this partnership not only Gulf made strong inroads in the Southern market but won many millions hearts. Since then Gulf Oil India has become inevitable in the circle of cricket and has grown from strength to strength. In 2017, Gulf Oil put the fans of RPSG on the centre-stage with its Gulf 'Go Far Har Bar' campaign and celebrated the cricket passion of every Indian.

Recently, Hardik Pandya joined Mahendra Singh Dhoni, who has represented Gulf Oil since 2011. "I am excited to be associated with Gulf Oil, It is a global brand recognised for its high-performance products", said Hardik. Cricket is definitely not just a sports endorsement for Gulf but it's a medallion which Gulf wears with zeal to create an experience for its fans.

New-Gen Magnatec Range of Engine Oil Launched By Castrol

Castrol has launched the latest generation of MAGNATEC engine oil featuring unique DUALOCK technology. It uses a combination of two different protective molecules that lock together at the engine surface to create a powerful force-field of protection, delivering a ground breaking 50% reduction in warm-up and stop-start wear, according to Simon Edwards, Head of Technology. The DUALOCK technology is available on the full range of the MAGNATEC product portfolio across viscometrics, addressing the evolving needs of the Indian passenger car market.

Reliable Plant Conference- 2018

More than 1,000 maintenance and reliability professionals congregated at the Indiana Convention Center for Noria Corporation's annual Reliable Plant Conference & Exhibition held April 17-19, Reliable Plant 2018 marked the 19th instalment of the world's premier conference for those in the maintenance and reliability industry.

On April 17, Reliable Plant started with the opening general session emceed by Wesley Cash, director of technical services for Noria.

Following the opening general session, a steady stream of attendees explored the latest technologies and solutions to their everyday issues.

Several exhibitors used Reliable Plant 2018 as the platform for introducing their company to the market place and launching new products.

With a focus on education, Reliable Plant offers attendees the opportunity to expand their knowledge and skills through unique learning sessions. For 2018, attendees chose from nearly 90 learning sessions on topics ranging from vibration analysis and infrared thermography to condition monitoring and oil analysis. Reliable Plant also offered attendees the unique opportunity to participate in one of four certificate programs.

Reliable Plant 2018 wrapped up its successful week in Indianapolis with two post-conference workshops: "Lubrication Excellence Essentials for Leaders" by Jim Fitch, CEO of Noria, and "Designing and Procuring Equipment to Increase Reliability" by Jerry Putt, senior technical consultant for Noria.

Reliable Plant Conference & Exhibition will celebrate its 20th anniversary in Cleveland, Ohio, on April 16-18, 2019.

BASE OIL REPORT

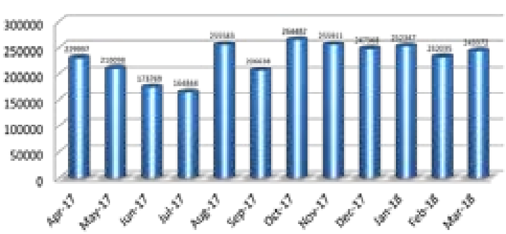
India's crude oil production fell for the sixth consequent year in 2017-18 to 35.68 million tonne, pushing the country's import dependence for crude further to 82.8 per cent and dampening prospects for the centre's plan to cut reliance on energy imports by 10 per cent through 2022.

The fall in the country's crude oil production may lead to increase India's oil import bill by 20 per cent to $105 billion in 2018-2019. Crude oil production has been on a decline primarily due to fall in output from nearly all offshore and onshore blocks.

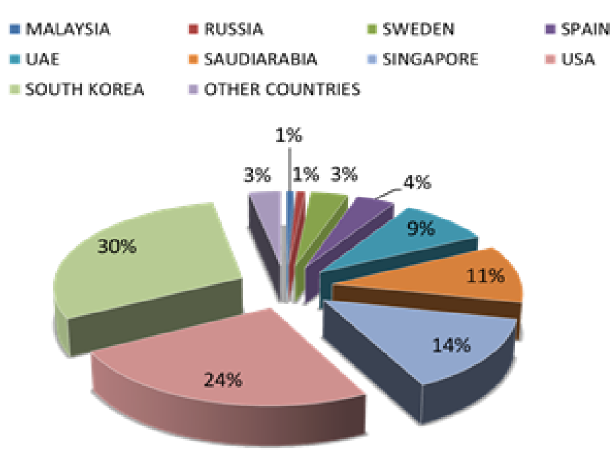
As per the data analysis, import of the country has gone up by 34% during Jan to March 2018, as compared to same period last year i.e. Jan to March 2017. Compared to last month i.e. February 2018, import of the country has increased by 5% in the month of February 2018. India import has gone up by 32% in March 2018, as compared to same period last year i.e. March 2017.

Dhiren Shah
(Editor – In – Chief of Petrosil Group)
Petrosil Base Oil Report offers solutions to the entire base oil value chain, from refiners, suppliers, buyers, traders, agents, consultants, lubricant companies, professionals and logistic providers as well as any other entity of the base oil value chain.

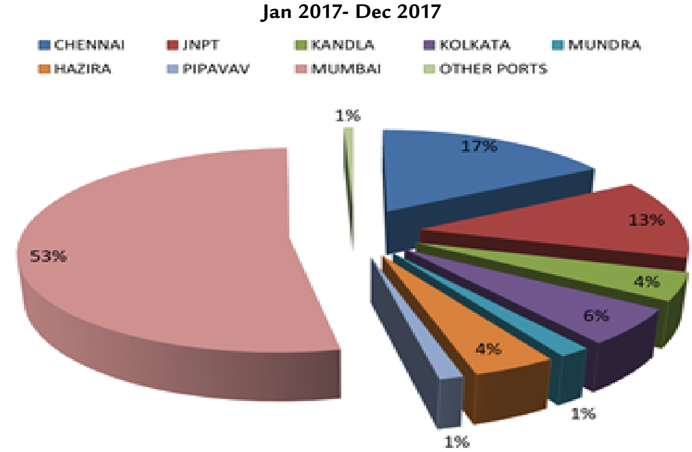
Month Wise Import of Base Oil in India



Origin Wise Import of Base Oil into India - Country & % Jan 2017 – Dec 2017



Port Wise Import of Base Oil into India Ports & % Jan 2017- Dec 2017



Base Oil Group I & Group II CFR India prices:-

Month	Group I - SN 150 Iran Origin Base Oil CFR India Prices	Group II -J-500 Singapore Origin Base Oil CFR India Prices	N- 70 South Korea Origin Base Oil CFR India Prices	Bright Stock Prices
March 2018	USD 750 – 760 PMT	USD 825 – 835 PMT	USD 755 - 765 PMT	USD 1165 – 1175 PMT
April 2018	USD 765 – 775 PMT	USD 820 – 830 PMT	USD 765 - 775 PMT	USD 1175 - 1185 PMT
May 2018	USD 775 – 785 PMT	USD 830 - 840 PMT	USD 775 - 785 PMT	USD 1185 - 1195 PMT
	Since January 2018, prices have gone up by USD 55 PMT (8%) in May 2018.	Since January 2018, prices have gone up by USD 50 PMT (6%) in May 2018.	Since January 2018, prices have gone up by USD 67 PMT (9%) in May 2018.	Since January 2018, prices have hike up by USD 45 PMT (4%) in May 2018

Training Calendar for 2018

Essentials of Machinery Lubrication

COLOMBO (Srilanka)
20th - 22nd June

DELHI (India)
28-30th June

DHAKA (Bangladesh)
26-28th Nov

KOLKATA (India)
29th Nov-1st Dec

Advanced Machinery Lubrication

MUMBAI (India)
19th- 21st Nov

Oil Analysis Fundamentals

MUMBAI (India)
25- 27th June

Advanced Oil Analysis

MUMBAI (India)
22- 24th Nov

ICML Certification testing is available after all the course

On-Site (Private) Training

We deliver customized training programs to meet your unique requirements. We'll provide expert instructors at a time and place most convenient for your group. Whether you have 5 to 500 people to train, we are the answer.

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