Machinery Lubrication

INDIA

NOVEMBER - DECEMBER 2021

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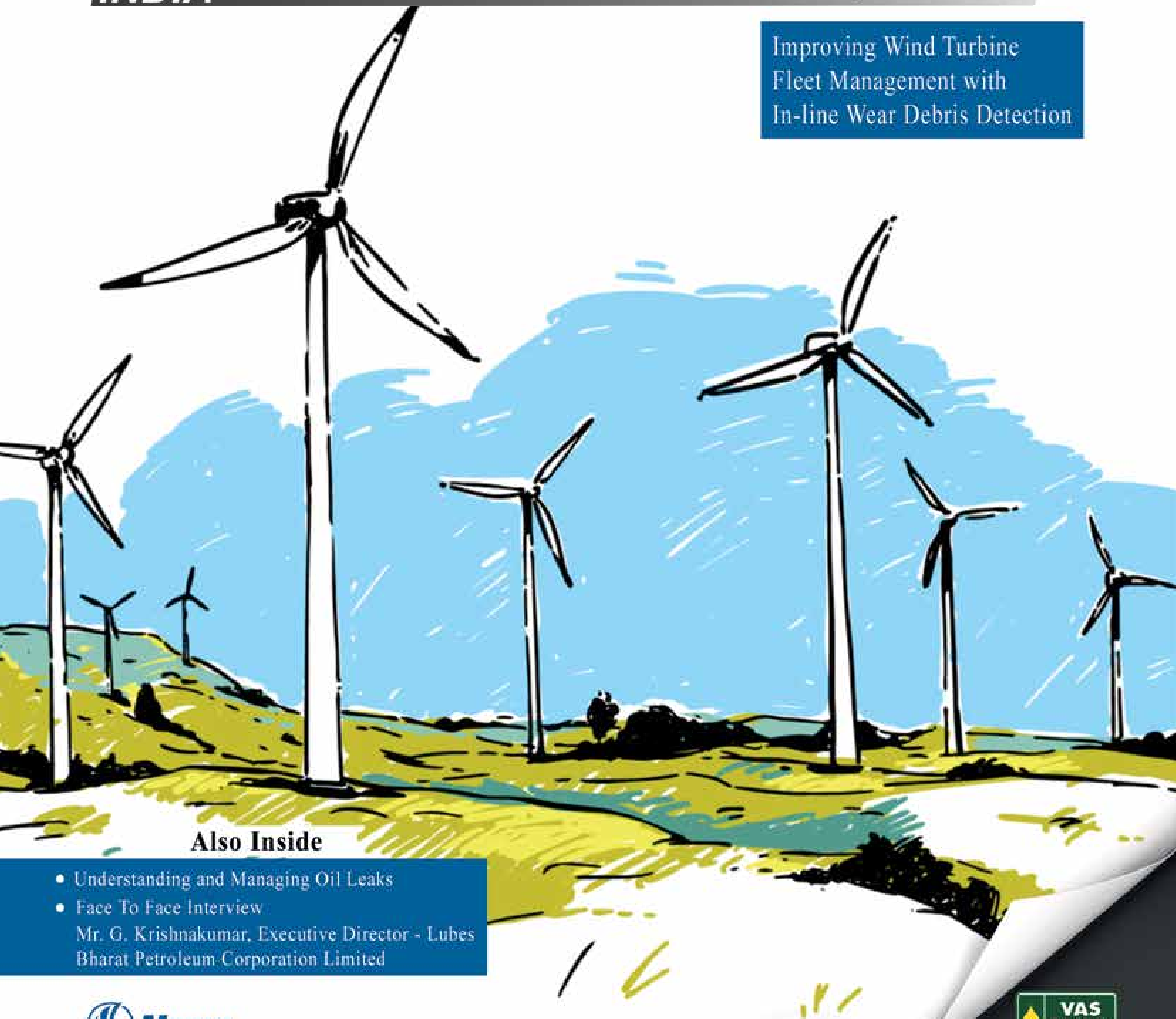
Improving Wind Turbine Fleet Management with In-line Wear Debris Detection



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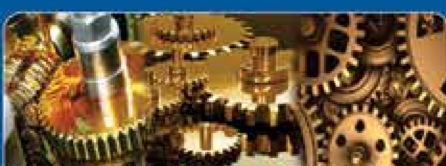

Machinery Lubrication Level - I (MLA I / MLT I)

JANUARY	MAY	OCTOBER
18-20th	17-19th	18-20th

Oil Analysis Level - II (MLA II) Ferrography and Interpretation

FEBRUARY	JUNE	DECEMBER
22-24th	14-17th	13-15th

Machinery Lubrication Engineer (MLE)

AUGUST
22-26th

Machinery Lubrication Level - II (MLT II)

JULY
26-29th

Oil Analysis Level -III (MLA III)

SEPTEMBER
20-23th

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Publisher's Note

Wind turbines are often subject to extreme mechanical stress. Condition Monitoring Systems (CMS) help ensure the stability, long service life, and optimal design of wind turbine components (rotor blades, drivetrains, inverter, gearboxes etc). Thus, it prevents complete failures, which are expensive, and allows significant savings.

More and more of the wind industry is recognizing the value of condition monitoring. To combat this, owners and operators are deploying condition monitoring systems (CMS) to detect faults before they cause secondary damage. Through this early detection, repair costs can be reduced, representing significant savings. With several technologies available (e.g. vibration, oil debris, SCADA), determining which one provides the highest value can feel like comparing apples to oranges. Unfortunately, there is no performance standard or benchmark for comparison. A prospective buyer is left with the difficult task of deciding what CMS will provide the right performance at the right price. To succeed in this assessment, it is important to focus on the overarching goal for the system: CMS are designed to provide users with recommendations that enable them to make optimal operations and maintenance decisions.

Despite the wind industry's dramatic development during the past decade, it is still challenged by premature turbine subsystem/component failures, especially for turbines rated above 1 MW. Because a crane is needed for each replacement, gearboxes have been a focal point for improvement in reliability and availability. Condition monitoring (CM) is a technique that can help improve these factors, leading to reduced turbine operation and maintenance costs and, subsequently, lower cost of energy for wind power. Although technical benefits of CM for the wind industry are normally recognized, there is a lack of published information on the advantages and limitations of each CM technique confirmed by objective data from full-scale tests.

Gearbox-failure represents a big part of wind turbines' downtime; therefore, gaining reliability is key. Efficiency is also important in the drivetrain; hence, measurements can be used as a tool to increase both. Using monitoring, it's possible to keep track of the component's condition and detect potential breakdowns in time, thus preventing damage and most probably increasing the components' operational lifetime.

Online wear debris monitoring allows Wind turbine operators to plan, prevent and predict the damage of gearboxes, main bearings, and other costly components.

For Wind (focusing on gearboxes), an Oil Wear Debris Monitoring Sensor is installed on the gearbox to gauge the life and health of the critical asset. Operators receive real-time data from the sensors to improve maintenances, catch damage missed by oil samples and vibration monitoring, and potentially prevent catastrophic asset failures.

As a real-life analogy, wear debris sensors are like the check engine light in your vehicle. While you may feel your car is running smoothly, engine sensors alert you of potential catastrophic – and oftentimes costly – engine failures down the road.

We are receiving lots of compliments on publishing a series on Ascend (A guide to lubrication excellence) where we are giving detailed breakup of all 40 elements. We are sure readers are taking advantage by implementing these in their manufacturing facility.

As always, we welcome your feedback on how to further improve the content and presentation of our publication.

Wishing all our readers Merry Christmas and a Happy 2022.

Warm regards,
Udey Dhir

Jim Fitch | Noria Corporation

Deciphering Important Visual Features of Wear Particles

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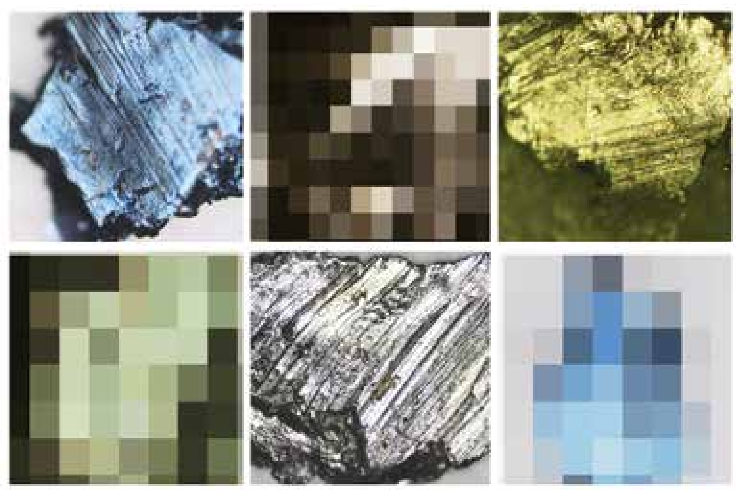
When working from a single sample, it is common for labs to classify wear particles according to standardized shapes such as platelets, chunks, ribbons and spheres. The task of deriving meaning from the number and size of particles in the different classifications is much more difficult. Condition monitoring is not about science — it's about understanding and reporting what is happening, why it's happening, where it's happening and how severe or threatening the condition might be. This can be a daunting task, to say the least.



The lubricant co-exists with the machine and has an active presence in its critical frictional zones. As such, the progression of wear-related machine failures does not go unnoticed by the lubricant. The byproducts of wear and surface damage become suspended in the lubricant, embedded in the filter or stratified as sediment in nooks and crannies.

As failure advances, most wear modes produce more particles, and some also produce larger particles. In certain cases, what was thought to be an advanced failure state may suddenly appear benign or in decline. There are reasons for this, so do not be fooled. The wounds and excavations from wear do not heal over on their own.

The time has come to increase the specificity of wear particle characterization. The four basic shapes were a good start, but there is much more we can learn and apply. For those who understand vibration, imagine being limited to vibration overalls or only what is produced in the low-frequency velocity spectrum. Likewise, thermal imaging has shown us how to look far beyond discrete temperature values or trends. This analogy applies to wear debris analysis as well. The appearance of particles holds many clues that generally go unnoticed or are just not understood.

The Characterization of Particles (ASTM D7684)

Any good tribologist will tell you that real failure modes rarely conform to strict theoretical models — rather, they are more complex and are usually the combination of many contributing factors and conditions. There are exceptions — for instance, it is easy to recognize the shapes from cutting wear and normal rubbing wear — but that's basically where the simplicity comes to an end.

Understanding chunks and platelets requires closer examination and greater skill. Factoring in size, color, heat tinting, slide orientation, texture and count, plus an array of other features in the same debris field, is the tribologist's task. Yet, we don't really have many formally trained tribologists in condition monitoring.

The recently published standard ASTM D7684, Microscopic Characterization of Particles from In-Service Lubricants, went far to add greater granularity and guidance, as shown in the examples below from its classification grid:

- Color and texture: pitted, striated, smeared, tempered, colors from transmitted and reflected light
- Shapes: platelet, ribbons, chunks, spheres, etc.
- Composition: ferrous, cupric, sludge, dust, etc.
- Wear modes: abrasion, mild sliding, severe sliding, rolling contact (subsurface spall)
- Two-dimensional aspect ratio (minimum to maximum) and particle size distribution

Even with the help of D7684, many lab analysts fail to connect the dots between wear debris characterization and the needed maintenance response. Often, connecting the dots requires the aid of careful machine inspection and findings from other condition monitoring methods (vibe, etc.).

Introducing the WPCD Table

The discussion that follows offers some valuable tips on how to get more condition monitoring value from wear particle analysis and identification. A high percentage of wear particles found in in-service lubricating oils are produced from pure sliding contact (abrasion and adhesion), rolling contact (Hertzian) or various mixtures of the two. Therefore, this article will focus specifically on particle generation mechanisms from machine surfaces in various states of rolling and sliding contact.

To streamline the discussion, I'm not going to include the following types of particles, which will be addressed at a later time:

- **Laminar particles.** Reworked by over-rolling.
- **Cutting wear particles.** Usually, the

ZONE	ROLLING CONTACT	SLIDING CONTACT	EXAMPLE LOCATIONS
A	100%	0%	Rolling cam follower, roller bearing (load zone), spur gear pitch line
B	75%	25%	Rolling-element bearings, most gear-mesh contacts (root to tip), hydraulic pumps (rotating), screw compressors, some mechanical couplings
C	50%	50%	
D	25%	75%	
E	0%	100%	Sliding cam follower, pump swash plate, bearing cage, piston/cylinder, worm gearing, journal bearings, chains

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result of hard particles interposed between sliding surfaces.

- **Spherical particles.** A complex and still generally misunderstood subject.
- **Break-in particles.** An artifact of running in new machines (gears primarily).
- **Soft particles.** Also known as varnish potential.
- **Terrain dust.** This is a huge topic — the cause of wear but not the product of wear.

Table 1 shows five Contact Dynamics Zones. The top zone is 100% rolling contact, and the bottom is 100% sliding contact. The three middle zones are binary mixtures of the two. I have added examples of where they might be found in common machines.

These zones also appear on the Wear Particle Contact Dynamic (WPCD) table in Table 2. The five columns across the top of the WPCD table are Wear Protection States, ranging from no protection to high protection. Based on the well-known Stribeck Curve (AKA the ZN/P curve), these states are directly influenced by oil viscosity, surface speed, contact load and additive film strength. For rolling contacts (e.g., ball bearings), specific film thickness (Lambda) is also influenced by composite surface roughness. Refer to the chart in Figure 1 and the article in the link below for more information on the Stribeck curve: **https://www.machinerylubrication.com/Read/27725/**

Rooted in Tribology

Very little of what happens between surfaces in relative motion should be viewed as simple or even predictable; this holds true for the formation of particles generated there. With this in mind, the 25 cells shown in the WPCD Table are coded with letters corresponding to likely wear modes — these are approximations based on experience and findings from controlled laboratory experiments. Let's get more specific about each of these likely wear modes.

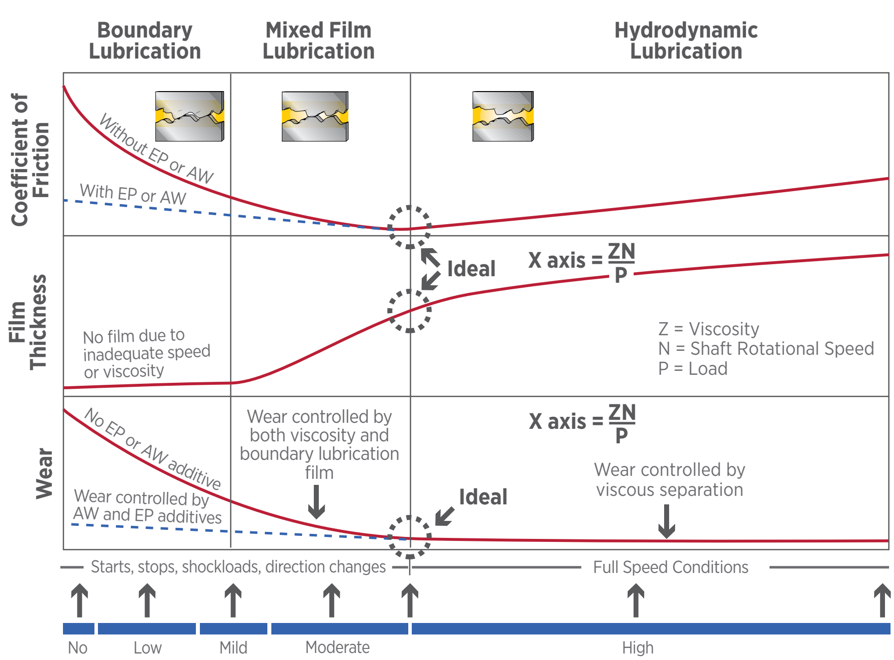

Figure 1 The Stribeck Curve showing the states of protection against mechanical wear.

Normal Rubbing Wear. These particles result from mild and slightly adhesive cyclic rubbing contact. They are often described as traction-induced exfoliation or peeling of the shear-mixed layer (asperities). Small abrasive particles interposed between frictional surfaces can increase the concentration of rubbing wear. Most appear as thin flakes or platelets with polished surfaces on both faces; others may be somewhat more granular from rolling-sliding contact.

Adhesive Wear. Caused by moderate to high traction forces from impaired lubrication or high contact loads in sliding frictional zones. The wear modes are more pronounced where longer sliding planes/tracks exist (e.g., large gear teeth). High tangential forces and frictional heat transfer loosened metal from one surface to the other or released it into the oil as dislocated fragments. Particles have smooth, distressed or striated surfaces; striation is generally from two-body abrasion. Many exhibit the appearance of a momentary molten state (micro-welding).

Pitting (Micro & Macro). These particles can be formed due to rubbing or adhesive contact, as well as rolling contact fatigue. Micropitting occurs where particles — usually less than 20 microns in size — dislodge. Macropitting is similar to micropitting, except the size of the pits and particles are larger than 20 microns, often as a result of an advanced state of micropitting.

Rolling Contact Fatigue. These are often due to contact (surface) fatigue aided by mild sliding contact (traction). Particles may appear peeled from delamination. Many have smooth surfaces (face side) with irregular edges. They may appear thin and platelet-shaped — similar to laminar particles but without the flattened over-rolled appearance.

Figure 2 Gears often form a network of deep checkered cracks across or near the pitch line. When they get deep enough and converge, small pieces are pulled out by sliding traction to form chunklike particles, leaving spalled surface damage behind.

Rolling Traction Fatigue. This results from a combination of rolling and sliding under elasto-hydrodynamic lubrication (EHL) conditions. Cyclic Hertzian loads radiate downward, which propagates crack formation and subsurface fatigue from repeated flexing. Combined sliding produces traction forces, dislocating particles from the socket of the bruised area. Subsequent rolling contact produces downward flaking at edges, causing the damaged area to spall-out further.

Premature fatigue often occurs due to the over-rolling of hard contaminant particles (e.g., silica), which induces surface indentations and berms (stress risers). These are initiation sites for cracking, flaking and spall-out conditions.

Chunklike particles from rolling traction fatigue typically exhibit fractured or torn surfaces and edges. Some may show a less chunky appearance, such as a thick platelet with varying shapes and profiles.

Fatigue particles generated by a ball bearing may resemble a rose petal shape. Torn or feathered edges are common. They are frequently subjected to over-rolling (rework), which alters appearance, producing a more laminar shape.

The particle's face may have striations or the appearance of adhesion (micro welding). Heat-tinting from friction/adhesion may exhibit colors from straw to brown to blue.

Sliding Wear (Abrasion/Adhesion). Often occurs in high slide-to-roll or slide-only frictional zones. Boundary lubrication conditions from highly-loaded, low-speed conditions where only anti-scuff/AW additives play a role in mitigating friction and wear. More pronounced from longer sliding planes/tracks (e.g., large gear teeth), high traction forces due to boundary conditions and sliding serve to lift and dislodge fragments producing surface spalls. In gearing, the condition may be more pronounced across the dedendum zone of the gear tooth flank (below pitch line towards the root).

Large particles with long straight edges and rectangular shapes are common. Otherwise, particles may have highly irregular shapes, and their edges may appear sharp or jagged. The base surface (opposite particle face) will appear torn or fractured.

Evidence of abrasion, scoring or adhesion on the particle face is common. Deep striations may crisscross, travel the length of the particle (in the direction of elongation) or converge to the central region. Heat-tinting from friction may leave colors from straw to brown to blue.

Black Oxides. Black iron oxides are typically clusters of small pebble-like particles. Dark-metallo oxides may be larger, possessing the shape and size of rolling traction fatigue or adhesive wear particles. Most will have a free metal core with an oxide shell. Particles are very dark or black in appearance but may have small blue and orange dots near the lower limit of an optical microscope. Edges will transmit some light. Black oxides are associated with poor lubrication and steel-on-steel contact.

Particle Size and Count

The WCPD Table in Table 3 has been re-casted to show images of example particles corresponding to the cells' failure modes. Note, there is no reference (or scale) related to particle size. The purpose of the table is to emphasize and distinguish characteristic visual features of particle shape and texture. These features provide important clues related to wear modes and wear location.

It is widely known that particle size generally correlates to failure stage or severity. For instance, particles on the left side of the table are distinctly larger (>50 microns) than those on the right side of the table (<15 microns). Large particles are even more pronounced in the cells in the upper-

CONTACT DYNAMIC		WEAR PROTECTION				
		Film Strength Influence by ZN/P and Additives				
Rolling Contact	Sliding Contact	None	Low	Mild	Moderate	High
100%	0%	K-K	K	F-F	B,D,F	A
75%	25%	E,H	D,E	C,D	B,D	A
50%	50%	H-H	E,H	C-C,D,G	B-B	A
25%	75%	H,J,L	H,I	E,G	C,D	B
0%	100%	J-J, L	J,L	I	C	B

A. No wear/no contact

B. Normal rubbing wear
B-B = Normal to moderate rubbing

C. Mild Adhesive Wear
C-C = Moderate

D. Micropitting

E. Macropitting

F. Fatigue platelets
F-F = Severe platelets

G. Mild rolling traction fatigue

H. Severe rolling traction fatigue
H-H = Extremely severe

I. Sliding wear/J-body abrasion

J. Severe sliding/adhesive wear
J-J = Extremely severe

K. Severe rolling contact fatigue
K-K = Extremely severe

L. Black Iron Oxides

Table 2 The Wear Particle Contact Dynamics (WPCD) Table. The letters under the Wear Protection columns are described in the legend at the bottom of the table.

left zone of the table. Fatigue particles frequently produce larger particles (at advanced wear stages) than those produced from two-body abrasion, scuffing and adhesive wear.

The population of wear particles at different sizes and shapes is important too and can help estimate the particle generation rate related to the precipitous state of the failure. However, particle concentrations are influenced by other factors too, including:

- Where and how samples are taken
- Fluid turbulence and sedimentation
- Filtration (micron size and capture efficiency)
- Age of the oil

Because of this added complexity, it is often better to view the particle size distribution in terms of rate-of-change and size ratios (or percent large particles). If both increase significantly, the machine could be approaching an end-of-life condition.

Work Backwards

The best approach is to use the ASTM D7684 Classification Grid and the WPCD Table together. A careful examination of particle size, shape, edge detail and texture reveals much about contact dynamics and surface protection (position on the Stribeck curve). From there, you can work backward to better understand and report condition monitoring information and prescriptive response:

- What is happening: wear modes
- Where it's happening: slide/roll features, composition, etc.
- Why it's happening: location on the Stribeck Curve
- Severity: remaining useful life related to particle size, shape and concentration

Include relevant facts and data from inspection and other condition monitoring tests.

The potential for deciphering the hidden messages in wear particles depends heavily on training and practice. Over time, wear debris analysis can and should become a far more powerful early-detection condition monitoring tool. ***ML***

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 books. He serves as a U.S. delegate to the ISO tribology and oil analysis working group. Since 2000, 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.

CONTACT DYNAMIC		WEAR PROTECTION				
Rolling Con-tact	Sliding Contact	Film Strength Influence by ZN/P and Additives				
		No Protection	Low	Mild	Moderate	High
100%	0%					
75%	25%					
50%	50%					
25%	75%					
0%	100%					

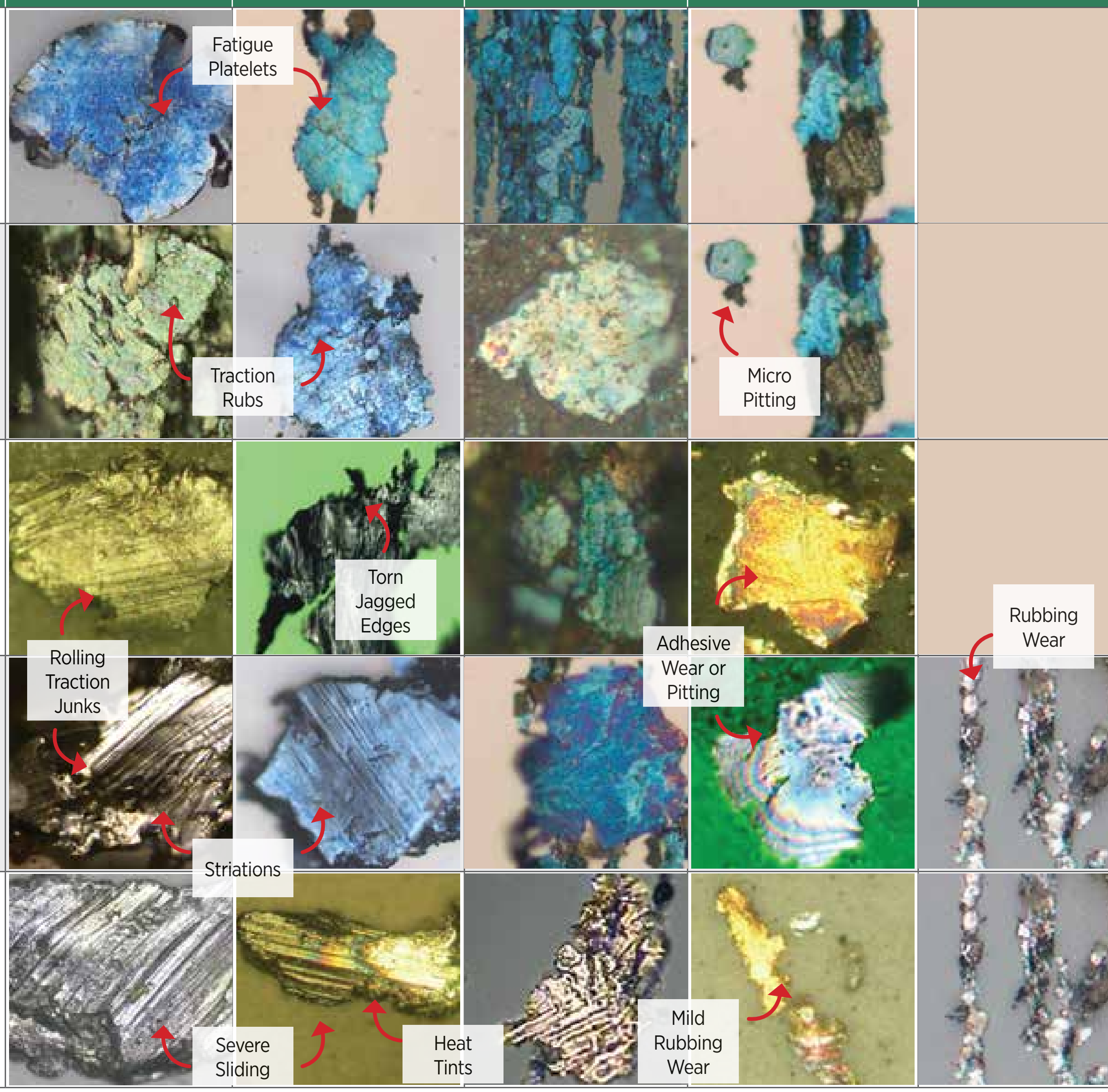

Table 3 This version of the WPCD Table replaces the cell wear mode designations with example particle images.

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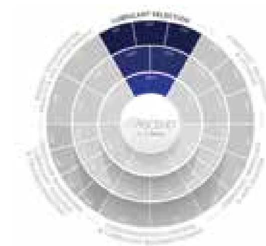

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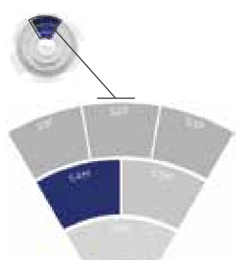

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Tribology is derived from the Greek root "τριβ" meaning "I rub," which describes the science of rubbing when followed by the Greek suffix "-ology." Today, this term simply refers to the study of lubrication, friction and wear. Friction should be treated as an enemy when it comes to machine reliability. When friction occurs, the mechanical energy is converted into heat. This heat, when combined with mechanical interactions, leads to wear, vibration and noise. These symptoms should be monitored on a daily basis, as they are the reason why we utilize friction modifier additives in our lubricants. This article dives into the different types of friction along with the role of friction modifiers to help you determine if they are right for your lubrication needs.

Types Of Friction

Leonardo da Vinci, a tribology pioneer, first discovered the basic laws of sliding friction back in 1493. These are the four types of friction he studied:

1. Sliding

a) For example, simply rubbing your palms together is sliding friction.

b) In industrial settings, we see sliding friction in Journal Bearings, Slideways, Gates, etc.

2. Rolling

a) A heavy ball rolling across the floor will create rolling friction.

b) Rolling element bearings, one of the most common mechanical designs, can experience rolling friction.

3. Static

a) Pushing up against a heavy desk before it begins to slide is static friction.

b) Similar to sliding friction, static friction is the force that holds the object at rest until the force of static friction is overcome and the object starts to move.

4. Fluid

a) The resistance felt when stirring

a fluid or a boat pushing its way through the water, is called fluid friction or sometimes called "Viscous Resistance."

b) Fluid Friction is a common type of friction often found in industrial machines that require lubrication.


A microscopic view of these surfaces in relative motion reminds us, no matter how well-machined, that each surface contains tiny, jagged asperities.

Asperities

Asperities are the rough, microscopic peaks on what is otherwise seemingly smooth surface. Even if the surface has been machined to a mirror finish, it will still have asperities. This is the exact point that friction and wear begin. When the asperities on each surface contact each other, friction is created. This is also the point where fluid friction comes into play in the form of good old lubrication.

In industrial lubrication, we pay a lot of attention to fluid friction, but, believe it or not, we deal with all four types of friction on an almost daily basis. We simply may not see it because it is happening within a component — like ball bearings rolling inside of the race in their housings or sliding friction at the pitch line in the gear teeth of your gearboxes. As friction continues, some asperities become dislodged and tumble in the gaps between surfaces, creating a third body. This gives way to a term known as "three-body abrasion." This third body represents the aggregate of all particles between the two moving surfaces and with a relative motion of its own.

Friction Factors

Friction modifiers are mild wear and friction control additives that work at the beginning of mixed-film lubrication. There are many factors that go into deciding to use friction modifiers in addition to extreme pressure (EP) or anti-wear (AW) additives.

Temperature, for example, is a very critical data field to consider when optimizing lubricants. Operational temperature and ambient temperature both affect friction and are very important for specific applications. Two of the biggest factors referenced when selecting the right lubricants are the speed and load of the application. The higher the speed, the more fluid friction. Therefore, the lower your viscosity should be in the lubricant to avoid unnecessary fluid friction. That is one reason why a lot of higher speed pumps and blowers use lubricants with an ISO 46 or 68 Viscosity Grade.

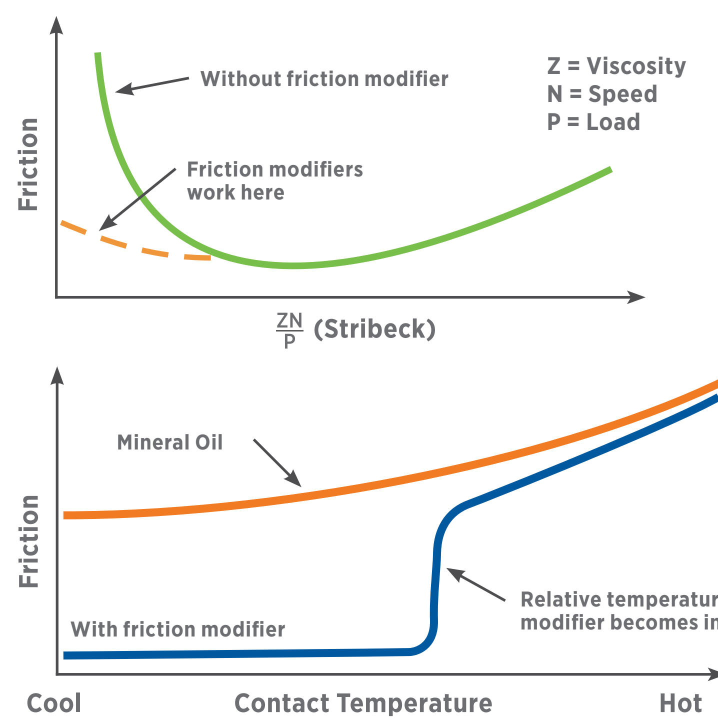
The next big factor that affects friction is load characteristics, including operational load and shock loads. If the load exceeds the recommended capacity of the component, then boundary conditions will result, and friction will occur. Also, the type of relative motion that interacts between the surface asperities plays a role, such as rolling surface on a ball bearing or sliding surface on a journal bearing. Lastly, the characteristics of the lubricant (base oil viscosity, base oil type and what additives are in the lubricant) can all affect friction or the coefficient of friction. The challenge when it comes to lubrication is to reduce the friction as much as possible by either eliminating the factors that negatively affect the surface in relative motion or at least attempting to control as many of those factors as possible. Viscosity of the oil is the primary influencer of this, while friction modifiers and other wear and friction control additives help when ideal load, speed and temperature conditions are not met, such as during machine start-ups.

Friction Modifying Additives

1. Organic Friction Modifiers (OFMs)

a) OFMs are amphiphilic surfactants, like fatty acids, often produced as a byproduct of fats and vegetable oils.

b) OFMs are common and important additives in engine oils today.



Friction Modifiers lower friction, reduce energy consumption and prevent stick-slip oscillation noise. They reduce friction regardless of whether wear is involved.

c) They adsorb on metal surfaces to form incompressible layers (monolayers) which prevent asperity contact and reduce friction and wear.

2. Oil-Soluble Organomolybdenum Additives

a) Originally developed for use as anti-wear (AW) additives.
b) Commonly utilized as gear oil.

3. Functionalized Polymers

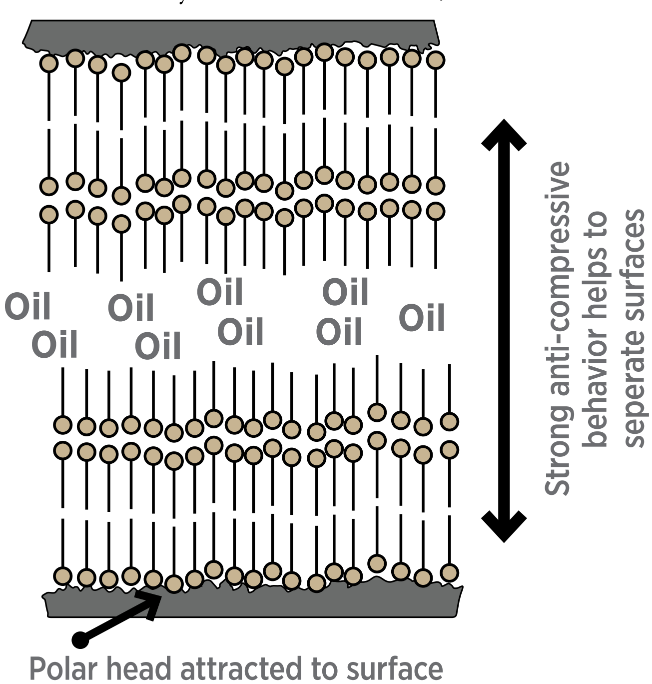
a) Found to adsorb specifically on polar surfaces.
b) Shown to significantly reduce wear and friction.

4. (Honorable Mention) Dispersed Nanoparticles

a) Honorable mention because it isn't widely or commonly used in the industrial theater yet.
b) Has been shown to reduce boundary friction, which occurs when a surface is at least partially lubricated, but not so much that there is no direct friction between the two surfaces.

Friction Modifiers

What are friction modifiers? Sometimes called boundary lubrication additives, friction modifiers are additives such as Molybdenum Dithiocarbamate, a common Extreme Pressure (EP) additive, as well as Zinc Dialkyldithiophosphate (ZDDP), a common Anti-Wear (AW) additive. Don't let the long, goofy words intimidate you — they are commonly referred to as Moly and ZDDP. As a matter of fact, those two perform quite well in conjunction within the same lubricant and increase the efficiency and performance of both the machinery and lubricants.



Friction Modifiers are additives that also increase the energy efficiency of machines. There are three primary types of friction modifier additives as mentioned in our list: oil-soluble organomolybdenum friction modifiers, organic friction modifiers and functionalized polymers. Functionalized polymers are the most beneficial to elastohydrodynamic and hydrodynamic lubricating films (i.e. moderate rolling and sliding applications). However, the oil-soluble organomolybdenum friction modifiers work best in severe hydrodynamic conditions such as a journal bearing's heavy sliding contact points. A recent study done by a leading tribology lab lends merit to ZDDP and Moly being among the most common friction-modifying additive packages. The ZDDP has AW or anti-wear properties and is considered a functionalized polymer in relation to the Molybdenum Dithiocarbamate.

What is it about these additives that make them "friction modifiers?" Well, the friction modifiers are kind of like lubrication for the lubrication. They create a smooth path for the bulk of the lubricant to flow through the top and bottom surfaces, which is called anti-compressive behavior, which does exactly what you would expect: it creates the opposite effect of compression by utilizing polarity in the lubricant. Think of it like two magnets' like poles resisting each other, just not as strong. Instead of sucking the surfaces closer together, friction modifiers assist in keeping the surfaces apart. You would be much better off using a good quality, properly formulated and balanced lubricant from the start. One of the first steps in accomplishing this is to make sure the lubricant has the proper viscosity and load-carrying capabilities. Remember, it is better to have your equipment operating with a full fluid film separating its moving parts rather than relying on a friction barrier under boundary conditions. So, in the end, are friction modifiers right for your lubrication needs? You now have the knowledge to help make that decision for your application. ***ML***

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About the Author

Paul Farless is an industrial service technician for Noria Corporation. His duties include collecting data and preparing reports for the engineering team. Prior to joining Noria, Paul worked as an automotive maintenance technician for an auto-repair service company. He also served four years in the U.S. Navy as a gunner's mate third-class petty officer and as a seaman deckhand, where he was responsible for the troubleshooting and maintenance of electromechanical and hydraulic systems. A detail-oriented team player, Paul works well in fast-paced environments and uses his military background to excel and maximize efficiency.

Improving Wind Turbine Fleet Management with In-line Wear Debris Detection

Martin Vincent, Cogentrix Energy | Stephen Steen, Poseidon Systems, LLC

Wind turbines are notoriously difficult to monitor due to several environmental and mechanical factors. First, the drivetrain consists of elements that change load, speed and torque quickly and continuously as the winds change speed and direction. The gearbox internal elements range from 18 rpm planetary gears to 1400 rpm helical gears. In addition to the turbine mechanics themselves, the distributed nature of wind farms, along with the 250-foot (or higher) climb to access the system, makes remote monitoring an efficient choice.

Early wind turbines had no diagnostic systems included by Original Equipment Manufacturers (OEMs). It is now common to rely on annual or semi-annual oil samples from the gearbox sump using

> " The chances of sampling the turbine at the optimum time to detect a problem are unlikely. "

spectrographic iron analysis to alert operators of developing problems. This periodic monitoring is not always successful at avoiding problems, though. The chances of sampling the turbine at the optimum time to detect a problem are unlikely.

The Need for Continuous Condition Monitoring

The costly repairs and potential for significant downtime associated with interval-based monitoring are both excellent reasons for considering a continuous condition monitoring system in this application. The turbines already had a data network for monitoring their basic status, power output and temperatures. These networks could easily be leveraged to add additional sensor technologies to continuously monitor drivetrain health and condition. To introduce continuous condition-monitoring to the process, two basic technology types were considered: vibration-based systems and wear debris technology.

Option 1: Vibration

Since many wind operators had roots in the conventional power plant space, vibration-based systems were familiar to operators and many fleets were retrofitted with vibration-based systems already. These systems were sometimes very adept at finding problems in the high-speed, helical portion of the gearbox as well as the generator, which ran at even higher speeds. Another key advantage the vibration system touted was the ability to pinpoint the source of the issue based on the frequency signature. However, the vibration systems often struggle to identify planetary defects in these gearboxes with their lower speeds. Mounting accelerometers where they could effectively monitor these planetary sections is also difficult. Vibration systems require many accelerometers to monitor the drivetrain, which can make installation expensive. Furthermore, a trained individual is often required to review and interpret data from these systems in order to obtain maximum benefit.

Option 2: Wear Debris Detection

Wear debris technology, on the other hand, has only one sensor and can be easily positioned as a sidestream loop on a variety of gearbox technologies, resulting in lower purchase and installation costs. Aside from being a more economical choice, wear debris systems provide a range of usability benefits. These systems are highly capable of detecting any flaw that liberates ferrous or non-ferrous debris anywhere in the gearbox. The wind turbine operator's own staff can interpret results with ease and not only determine the existence of a problem, but also the rate and extent at which it is progressing. This can be extremely valuable, especially in planning for wind turbine repairs, which commonly require an expensive heavy lift crane with 300+ foot boom. Bundling multiple repairs together is a huge advantage when maintaining these systems.

Assessment of Wind Turbine Gearbox Planetary

A manufacturer of wind turbine gearboxes had a failure mode characterized by the outboard mounted planet bearing races spalling and cracking on a certain gearbox model. One of these gearboxes was found to have some steel debris on the filter during maintenance, but a borescope inspection couldn't identify the damaged bearing due to a small clearance between the races. No other damage was evident, and planet bearing damage was a known failure mode for this type of gearbox. Initially, this failure mode was thought to fall in the "run to failure" mode. To mitigate risks while a gearbox replacement plan was being formulated, a Poseidon wear debris sensor was sourced to monitor the debris generation within the gearbox. Low levels of debris generation were immediately evident. Debris generation was proportional to higher wind events and remained quite low during the summer seasons. Given the ability to continuously monitor the gearbox and the high-quality data recorded from the wear debris monitor, it was decided to continue to run the defect to capture the failure "signature." This could then be used to gauge the degree of damage progression in other gearboxes with the same failure mode. During the monitoring of this gearbox, another gearbox was diagnosed in the extreme early stages of the same failure with a few particles on the oil filter.

The Cost-Saving Solution

A repair on the early-stage gearbox in which the planet bearings were successfully exchanged while the gearbox remained in the tower was made. A much smaller crane was used, and the repair cost was 25% of the cost of complete gearbox replacement. This cheaper repair made early detection of the failure mode a critical component of proper maintenance. This method was even more economical when the work could be grouped to utilize the same crane and traveling crew on several repairs in succession. The wear debris monitors allow operators to scan for a rapid increase in debris generation, signaling a significant change in machine condition has occurred.

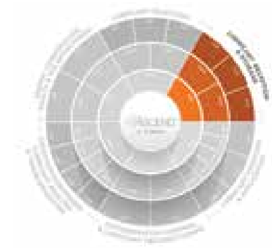
The combined benefits of early detection, avoided O&M costs, logistics planning, accurate budgeting and risk management have led Cogentrix Energy Power Management to invest in more Poseidon particle counters outfitting groups of gearboxes that share common failure modes.

This continuous window into the machine condition reassures the operator that continued safe operation of the machine is possible until a step change in debris generation is observed. Even when a step change in particle generation is noticed, the blade pitch schedules can be altered on the turbine to effectively lower the stresses on the gearbox, reducing particle liberation. Particle generation feedback was used to find the optimum pitch schedule to maximize production while minimizing bearing damage. Once particle generation becomes severe, the unit can be secured to prevent the gearbox from seizing.

Measurable Results

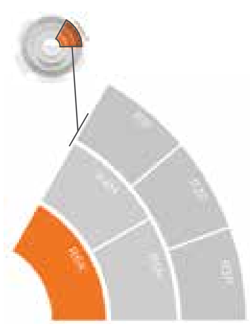
The "run to failure" unit, as shown in the graph below, was run for 2.5 years before particle generation reached extreme levels. The wear debris monitor showed increasing levels of wear debris generation each year before exhibiting a step change, presumably when the bearing race experienced a through crack. Although the unit was slated to receive a complete gearbox exchange, the planet bearings were exchanged using the "uptower" method at a significant savings. Once disassembly was complete, it could be seen that 2 of the 6 planet bearing races exhibited massive spalling and through cracks. Since bearing replacement, this unit has run an additional 3.5 years on the replacement bearings. The Poseidon units have helped manage 9 additional bearing replacements and become a valuable tool in mitigation of this failure mode. ***ML***

Travis Richardson | Noria Corporation



Keeping Score of Your Lubricant Reception and Storage Process

More about this
ASCEND™ Factor



Factor:
R6K—Reception And Storage KPIs

Level:
KPI (K)

Stage:
Lubricant Reception And Storage

About:
Proper reception and storage of lubricants affects many other aspects of lubrication. Reception and storage KPIs help track performance in this area.

Learn More:
noria.com/ascend/

If you have ever invested money in a 401K or the stock market, you might have received a letter in the mail showing your quarterly updates. Personally, I like to skip through all the text and legal script and go straight to a page with a lot of numbers, charts and graphs. These details are important to me as they let me know how certain markets are performing, and they can help predict where things will be in the future. The same thing can be seen if you watch the sports broadcast on the news — they will generally show you the highlights of the game, then throw lots of numbers on the screen such as total rushing yards, total passing yards or how many tackles a player had during the game. These numbers are just like the KPIs (Key Performance Indicators) that we use in the industry. In short, KPIs score how a program is performing and, if plotted out, can show if a program is headed in the right direction. We're a data-driven society, and if you want to get people's attention in 2021, show them the facts in numbers.

Keep Track of KPIs

Whether you are just getting a lube program started or you are striving for a fully-implemented lubrication program, there are many notable KPIs to be tracked regarding lubricant reception and storage. Receiving and storing lubricants is a critical part of the lubricant life cycle, and if certain tasks are not being performed properly (or at all), the entire program could suffer. For instance, if lubricants are routinely delivered to a site without meeting plant cleanliness targets, some remediation with the supplier, or even a supplier change, will be required. If we know oil is delivered dirty and nothing is done about it, these lubricants could slip through the receiving department and end up in a critical machine. Three areas to consider when building lubricant reception KPIs are New Lubricant Deliveries, Lubricant Inventory Rotation and Safety Incidents.

New Lubricant Deliveries

From a lubrication standpoint, one of the best things you can do to maximize machine life is to ensure that you are always using clean lubricants. Some things need to be measured to check the overall effectiveness of the lubricant receiving process. A few of these measurements relate to the cleanliness and dryness of the lubricant. Cleanliness is measured using a particle counter and then reported based on the ISO 4406 standard, which is the reporting standard for fluid cleanliness. We can use this standard to establish cleanliness targets, which can help create a benchmark for how clean various lubricants need to be for their applications. The same principle is used with dryness targets where the maximum amount of water is reported in parts per million (PPM). An example of this might be that all incoming gearbox oils should have an ISO 4406 Cleanliness Code under 17/14/12 and should have less than 300 PPM of water. The data that needs to be collected for a KPI is the number of lubricants delivered that meet the targets vs. those that do not. If targets are being met on a regular basis, all is well. If they are not meeting targets, a call with the supplier might be in store. A key aspect of this process is sampling incoming lubricants to ensure they are free of contaminants — a step that is often overlooked or neglected. Introducing heavily contaminated lubricants to equipment is an example of a root cause of premature equipment and lubricant failure. Setting a metric around this will help ensure it is tracked.

Lubricant Inventory Rotation

More often than not, as I am doing an assessment I will find at least one outdated lubricant. Lubricants, like many other items, do not last forever. A starting point for setting a lubricant's shelf-life is to use information provided by the manufacturer. It is important to remember that when the manufacturer gives suggestions, they assume that the lubricants are being stored in a clean, dry and temperature-controlled environment. Stock rotation systems such as FIFO (First in First Out) ensure that older lubricants are used before more recently delivered lubricants. KPIs can help a program manager know if FIFO and other inventory management systems are working correctly. Making sure that the minimum and maximum amounts of lubricants are being kept in stock is critical. If too many lubricants are being procured and not used, lubricants start to stockpile and can even "spoil" in the lube room. On the other hand, it is an issue if too few lubricants are being stored, and you constantly have to procure on-demand and wait for lubricants to arrive. To track this, you can measure the amount of a particular lubricant that is being stored vs. the amount going into machines every month. If a thousand gallons are being stored and only two hundred gallons are going out every month, the maximum amount held might need to be adjusted. There are a few other variables to consider when determining how much lubricant to store, such as how long it takes the supplier to deliver lubricants or if a high-volume machine needs a change in lubricant during an upcoming shutdown.

Another easy KPI to track over time is the number of lubricants that are rarely or never used. Often, when a new lubricant brand is implemented, the old brand of lubricant is shoved to the back of the lube room. There are different reasons that old lubricants might be kept around; for instance, if a machine is under warranty and is required to use the old lubricant. Another way to achieve an optimized lubricant inventory is with consolidation effort. When there are fewer types of lubricants to manage, they will spend less time in storage. Performing periodic audits of the lube room and stored lubricants should involve taking note of any stock rotation discrepancies for inventory levels. Based on the data, you can then identify areas for improvement.

Safety Incidents

One of the biggest topics in the industry today, and rightfully so, is safety. Many sites have new hire safety training, contractor safety training and occasionally refresher training. With safety being a top priority, KPIs in this area are crucial. Keeping track of accidents and near-misses can help a program see gaps in safety procedures. Injuries are more likely to occur when moving lubricants around the site and can range from back injuries to forklift collisions.

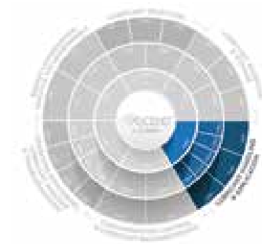
There are also many dangers when performing lubrication activities themselves, such as lubricating running equipment. Equipment can be complex and have many moving components that serve as pinch or nip points. Lubrication equipment can also pose a risk in the form of high-pressure injection injuries. The records for all safety training for lubrication practices given to employees should be readily accessible. If your safety records can segment out lubrication-related safety issues, it provides more insight into these practices rather than just a general safety score.

How does your lubrication program score when it comes to Lubricant Reception and Storage? Are you tracking KPIs to see if your program is moving forward or backward? The key to both is measuring the correct data and putting it into a format that is easy to track from month to month. What Pete Drucker said many years ago is still applicable today: "Only what gets measured gets managed." If you are striving for a better program, the key to success is in the numbers. *ML*

About the Author

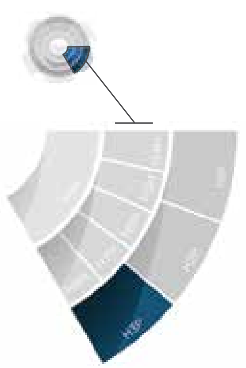
Travis Richardson is a technical consultant for Noria Corporation. He holds a Level II Machine Lubrication Technician (MLT) certification and a Level III Machine Lubricant Analyst (MLA) certification through the International Council for Machinery Lubrication (ICML). Contact Travis at trichardson@noria.com.

Matt Adams | Noria Corporation



Three Examples of Lubricant Handling Device Best Practice Advancements

More about this **ASCEND™ Factor**



Factor:
H3P – Handling and Application Devices

Level:
Platform (P)

Stage:
Lubricant Handling & Application

About:
Mishandled lubricants can become damaged or contaminated, negatively affecting performance and protective properties.

Learn More:
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Where to Begin

Almost all sites understand that there is a need for sustainability and advancement within their lubrication program. They often struggle with the questions of how, when and where their programs can be improved. Upon taking over a site lubrication initiative, recognizing how to build the program can sometimes seem like an M.C. Escher "Relativity" print — one can be pulled in so many different directions, and the overlap between specific subject matter can be somewhat confusing.

While teaching my first few lubrication classes — which included aspects of program development — I would often have trainees question the need for the extensive level of detail in each section and commonly heard, "we will never exercise those practices at our plant because … ." While some of these topics go into great detail, the premise is to ensure that the trainee understands what best practice looks like.

After a couple of these comments, it became apparent that bridging the gap between what world-class standards look like and the reality of trainees' work sites was imperative. There might not be a direct jump, and the final implementation goal might not necessarily be world-class for all tasks at each site. Prior to getting into the weeds in day-one training sections, I spend at least a few minutes going over what I generally call the lubrication development staircase — discussing how this relates to the upcoming classroom training material as well as lubrication program development aspects at their sites.

This staircase exercise is a simple illustration that I request the class use as guidance over the upcoming three or four days during the training session as we shift from one topic to another. I simply draw a staircase between 2-10 steps high and note the bottom step as the worst-case practice. Next, I begin to add notable upgrades on each proceeding step until I reach the final improvement option, which is the world-class step. We then identify which step the site is currently at based on the specific, noted lubrication topic and determine how much money, time and effort the site has to reach any additional steps towards world-class practices.

As there are capital and labor constraints, it is routinely improbable to plan for all topics to become world-class. Some topics may stay on the same step or only move up one or two steps, but to advance properly across the program, we need to know each step and what perfection within each specific topic looks like. Finally, it is worth noting that during implementation, these steps can be carried out progressively or in one swift action, depending on logic, cost and the specific need or desire of the site. This activity can be carried out across all lubrication topics and then finally reviewed together to see if any amendments are necessary.

After these actions are illustrated over a number of topics throughout the class, the trainees will begin to have a better understanding of each section we cover, where their sites are in the grand staircase scheme of things, what world-class practices look like and how their sites should advance accordingly. I urge trainees to continue this staircase exercise as they return to their sites and to identify the how, when and where of the current and future state of their lubrication programs.

Now that this staircase practice has been reviewed, let's take a look into a couple of examples within the Ascend Chart's **Lubricant Handling and Application Devices — H3P** section to determine exactly what this looks like with regard to grease gun development, oil transfer, and bulk oil filtration.

Grease Gun Application Development

Reviewing and understanding the advancement of grease gun development at a site is a great example to begin with, as there are noticeable specific changes from one stage, or stair-step, to the next. As we begin to break this topic down, we can see there are about five specific steps to look at:

1. Random grease guns with no dedication
2. Standardization of grease guns
3. Standardization and dedication of grease guns
4. Standardization, dedication and coding
5. Standardization, dedication, coding and calibration

Generally, the worst-case situation involved in grease gun ownership at a site is observing the use of a homogenous mixture of different varieties of grease guns with no rhyme or reason for how they arrived at this state. Often, the first step in development will be the standardization of grease guns; this is commonly executed by minimizing grease gun types down to a single brand/type of pistol or lever gun and a single brand/model of pneumatic or battery-style grease gun. This step provides visual change management for the site, sets the tone for advancement and aids in the progression of normalizing the "shot" amount of grease per application.

Following standardization, the dedication of grease guns often takes place. This step allows the site to stipulate certain grease guns for each type of lubricant used onsite, minimizing the concern for cross-contamination and providing further visual detail. Coding — the development of a color, shape and code for each dedicated grease gun type — follows the dedication step procedure very closely but provides even further advancement with regards to management. This step is imperative if sites have several team members from one or more departments involved in re-lubrication tasks.

The final step is the calibration of the grease guns themselves. I use this term broadly as there are several options at this juncture. The use of ultrasound-aided implementation, grease volume meters or the actual calibration of grease guns using a weighted average can all suffice. Over the years of traveling from site to site, I have noted all levels of grease gun development, and it is worth stating that this is a basic practice that most lubrication program owners should consider fully implementing, especially if it is a larger site with multiple team members.

Oil Replenishment and Transfer Development

Another great example of this practice can be completed in the advancement of oil transfer. Just as we covered grease replenishment through the use of a grease gun, oil replenishment — while often automated — is also carried out through manual practice. Developmental steps for oil transfer often look like the following:

1. Plastic funnel
2. Dedicated funnels sealed after use
3. Paper one-time use funnels
4. Sealable containers with correct size spouts
5. Sealable containers with quick disconnects

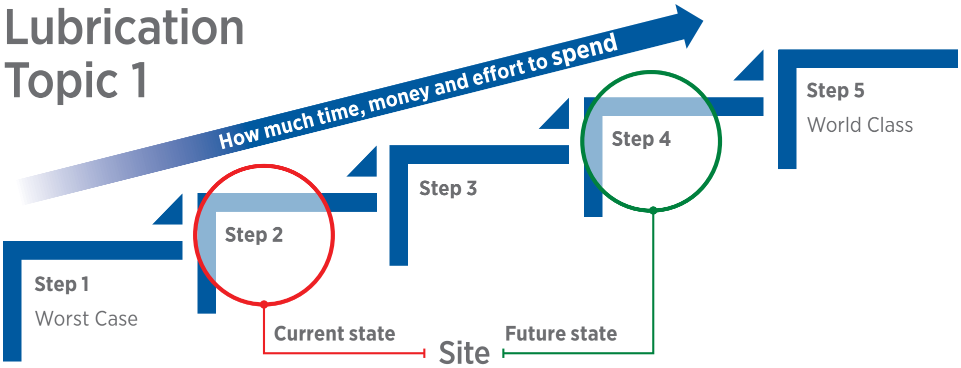
It is very common to see plastic funnels in use at sites within the lubrication program. While containing spills is paramount regarding costs and environmental implications, there are better options available if the program is open to positive change. Often times I find plastic funnels randomly stored on the top of cabinets or, even worse, directly below "bad actor" components that are prone to leaks or top-offs. While logistically leaving these funnels nearby makes topping up components easier for the lubrication technician or operator, this is poor practice due to the level of contaminants adhering to the funnel while not in use.

The first simple step to improve this action is introducing the use of plastic bags to store the funnels and dedicating the funnels to specific oil types. These actions minimize the concern for debris accumulation and, through dedication, minimize the potential for cross-contamination of other lubricants. The next step while inhibiting an increase in consumables is the consideration of paper one-time use funnels. Paper funnels have improved greatly over the years and provide a means to address the repetitive use of plastic funnels onsite for different oil transfer applications and lubricants.

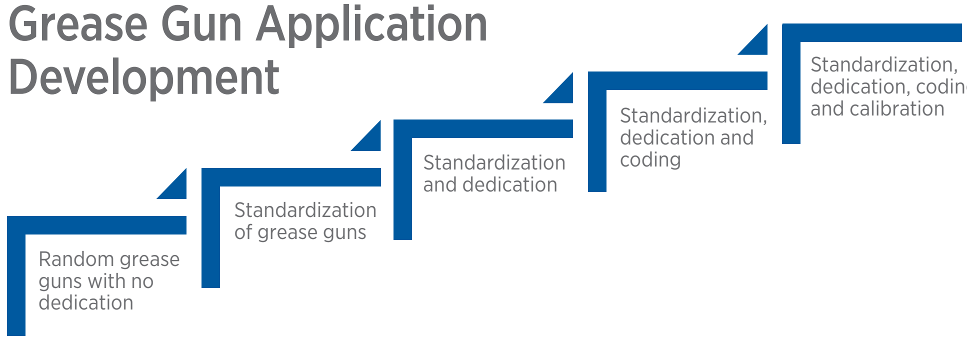
With any sound, lean improvement development, the goal is always to minimize and simplify steps. With this being the case, if dedicated sealable top-up containers have correctly sized spouts for most applications, the obligation of a funnel is no longer a necessity. Several sites have begun to implement these sealable containers, but we must note it is imperative that when purchasing, an audit of fill port sizes needs to be completed to properly identify and minimize the use of funnels in the future.

The final step to consider during oil transfer is the addition of quick disconnects to the sealable containers and mating components in the field. The implementation of this practice essentially eliminates any potential for foreign contaminants to gain access to the system.

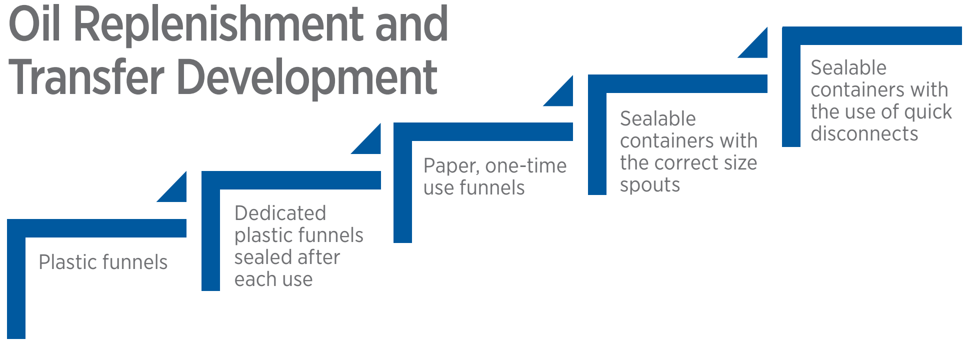
Lubrication Topic 1



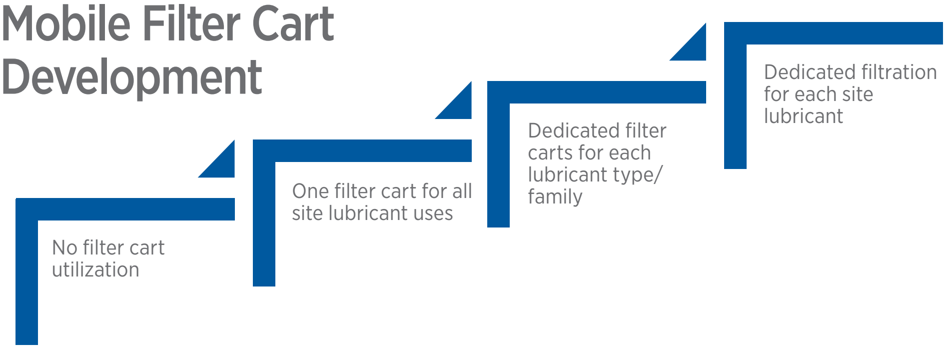
Grease Gun Application Development



Oil Replenishment and Transfer Development



Mobile Filter Cart Development



Mobile Filter Cart Development

One final but important example that will be discussed within the **Lubricant Handling and Application Devices — H3P** arena for staircase development is the deployment of mobile filter carts. Portable filtration units are a lubrication swiss army knife of sorts. They provide the ability to transfer lubricant, act as flushing and draining devices and provide online and offline filtration — depending on the system designs across an array of equipment in the plant. These carts are becoming more of a standard at sites daily, but prior to acquiring these units, it is important to understand the site's current lubricants (i.e., a lubricant list), the total charge volume of the lubricants, the usage by asset or component and what budget is available to better outline a game plan for portable filtration. Below is an example of step-by-step advancements:

1. No filter cart utilization
2. One filter cart for all site lubricant uses
3. Dedicated filter carts for each lubricant type/family
4. Dedicated filtration for each site lubricant

As one would expect, the bottom step, or worst-case option, regarding mobile filter cart development would be the absence of filter carts onsite. While some sites may not merit the use of filter carts (i.e., all site sumps or reservoirs less than a few gallons), smaller mobile handheld filter options are another avenue to consider. Beyond this advancement, it is often seen where sites utilize one filter cart for all portable filtration across the site. While there is improvement with this step, it is highly recommended to flush the line between uses of the same lubricant and filters between types/families. This step is commonly overlooked and, as such, can create the potential for cross-contamination.

Transitioning forward, the next advancement to consider is often the most practical, and that is dedicating filter carts for each site based on the lubricant type and family. An example of this practice is dedicating all family gear oils to one cart, all family turbine oils to another, and so on. While this process reduces the concern for noteworthy cross-contamination of other lubricants, some unease is still present within the families since cross-contamination within families can still impair viscosity.

The last significant step to mention is the dedication of filter carts to each lubricant type merited based on use, volume and criticality. Although the upfront cost of acquiring these carts may provide a hit against capital, there can be significant returns on investment. Other prominent areas of improvement within mobile filter carts are tagging and labeling — allowing for stronger visual change management — and the advancement of filtration options between micron rating, beta ratios and filter types.

Wrapping Things Up

It is universally understood that most sites genuinely have the desire to improve their lubrication programs. While this task can be somewhat daunting, identifying and understanding the developmental steps of each lubrication-related task will greatly aid in how much time, money and effort should be provided to each one. The practice of walking through these simple steps in each of your lubrication areas may seem pedantic, but doing the little things right systematically aids in addressing overlooked or underemphasized aspects of a site's program. Hopefully, a review of a few examples inside the Ascend Chart's **Lubricant Handling and Application Devices — H3P** section on exactly what this practice looks like regarding grease gun development, oil transfer and bulk oil filtration will encourage and support you in all of your future machinery lubrication endeavors. ***ML***

About the Author

Matt Adams is a technical consultant for Noria Corporation, concentrating in the field of predictive maintenance. He has experience in multiple condition-based maintenance technologies and focuses the majority of his attention on lubrication program development, training and general consulting. Matt holds Machinery Lubrication Engineer certification (MLE) a Machine Lubricant Analyst (MLA) Level III certification and a Machinery Lubrication Technician (MLT) Level I certification through the International Council for Machinery Lubrication (ICML). Contact Matt at madams@noria.com to find out how Noria can help you maintain the compressors at your facility.

When Alright Is Not All Right
Give Your Lubrication Program a Critical Exam

> " We do assessments, because even if you know where you're going, you're still lost if you don't know where you are. "

Charles Darwin once stated that for a species to advance and survive, they (the species) had to adapt to compensate for the changing environment. The change, he advised, had to occur incrementally, organically and with purpose. Consider the magnifying results of small change over time, demonstrated by the math equation in Figure 1. We need this kind of change in our workplace in order to compensate for the changing environment in our global workplaces. We need our processes and practices to change to remain relevant in a shrinking world if we want to survive and thrive.

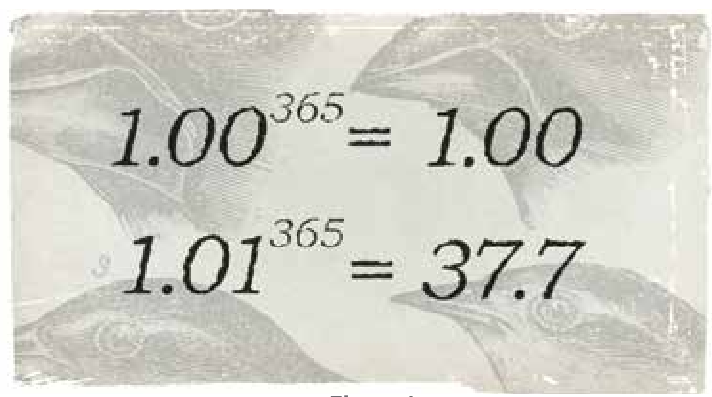


Figure 1

Allow me a few words to put the need into the context of having a lubrication program that is good enough. In fact, you might say that it's 'alright.'

There is a very famous man in the world of maintenance and reliability by the name of Earl Porter. Earl was an early pioneer of what is now known as the Computerized Maintenance Management System (CMMS). Earl said one of his most well-known idioms to me years ago, and I wrote it down.

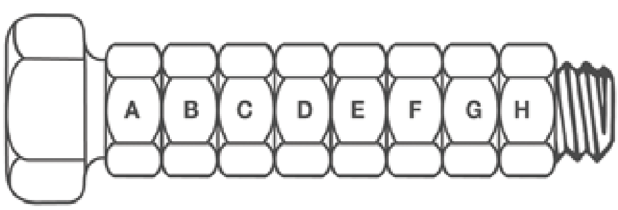
We were assigned to work together to conduct a preventive maintenance assessment at a cheese factory in Wisconsin. Upon arriving at the plant, Earl asked, "John, do you know why we do assessments?" Now, I know why we do assessments — I've assessed every aspect of maintenance and reliability in almost every industry on almost every continent.

"We do assessments, John, because even if you know where you're going, you're still lost if you don't know where you are."

That message had a tremendous effect on me. My assessments going forward had purpose now, and I had a renewed obligation to lift the scales from my clients' eyes to help them see — no, to make them see — where they were and which way to go from there. You see, if we don't know where we are, we are lost. That doesn't mean just pointing at a map (figuratively) and saying, "I'm here." Rather it means "owning" where you are. If we don't accept that we are lost, don't accept where we are currently, it is highly unlikely that we'll have the motivation or the driving force to improve.

When I conduct a maintenance or storeroom audit or assessment, the lubrication program (specifically, the lube storage area) is on my checklist. I believe that I can surmise the quality of the maintenance (or storeroom) service I'm likely to measure by the condition and orderliness of the lubrication storage room. A well-kept lube storage area denotes an organized, well-documented and disciplined maintenance and storeroom operation. The opposite of that tells me that I might need to consider buying a house near that plant — I'm going to be there awhile.

Metaphorically, get on the bathroom scale. What do you weigh? Where are you? "Own" that weight and do something about it. Even if you know where you're going, you're still lost if you don't know where you are. If you don't accept where you are, you, my new friends, are lost.



Consider this humble graphic. Simply a bolt with eight nuts. Each nut is individually labeled to infer that they should run down the bolt in order and sequence. I have not checked the math on this, but I'd stake my good name that it is correct (or really, really close). Accordingly, there is exactly one way to take this assembly apart. But, as the math goes, there are approximately 40,000+ ways to reassemble it. Ostensibly, someone could assemble it wrong with the nuts in the wrong order.

Keep in mind — the "right" way refers to the process that produces the optimum result. This will look different for every machine and all its individual parts.

If you were given the task of assembling the system as intended without an instructor, or worse, bad instructions, what are the chances that the result would be optimal? Or the result would be acceptable, or the time to complete the task acceptable, or the quality of the work well within tolerance, all with a favorable review from the customer? Not good, I'd venture.

I want to interject a little literary license here and mention that I might use "chances," "probability," "likelihood" and "odds" as synonyms.

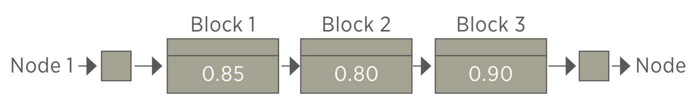
A little projection is necessary for this next bit: imagine you are responsible for all aspects of machine lubrication, starting (as it always does) with lubrication selection and storage. In your new role, you are pleased to find that you actually have a dedicated oiler. We'll call him Leroy (note to the reader, Leroy was my very first dedicated oiler in my career). Although he's hard-working and well-intended, he's also poorly trained.

You ask Leroy to take over full ownership of the lubrication program — from selection to storage to application. If he needs you, tell him you'll likely be in a meeting (high probability), but you'll get back with him when you can.

You just gave Leroy a bolt and eight nuts and told him, "Good luck."

In his best-selling work "Maintenance and Reliability Best Practices," Ramesh Gulati introduces us to the concept of Reliability Block Diagrams, or RBD. Ramesh offers some graduate-level insight on how to calculate an asset's reliability, but for shop-floor practitioners such as us, it's really the RBD idea that we need to know for this discussion.

Here is a simple, series arrangement of assets, with each machine's reliability value shown in the blocks:

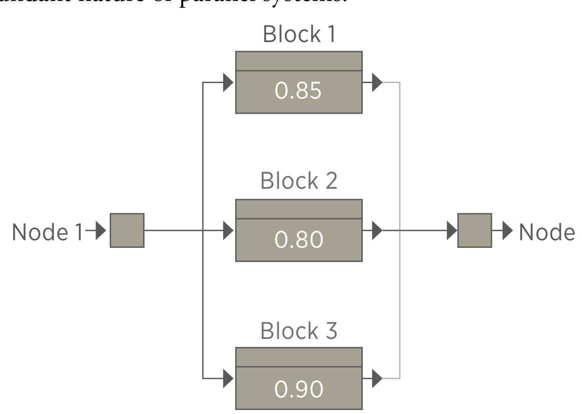


Mr. Gulati tells us that the overall system reliability for a series configuration can be calculated as:

R1 X R2 X R3

The result for our example is: 0.612 or 61.2%

Here is a slightly more complex example, taking into account the redundant nature of parallel systems:

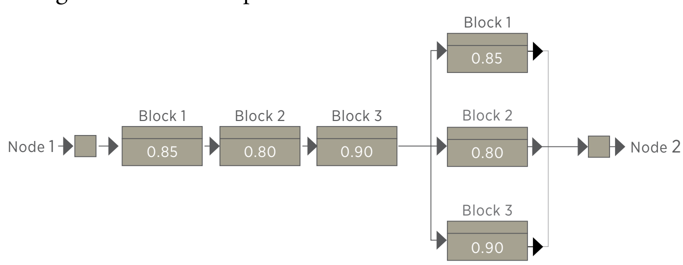


The overall system reliability for this parallel arrangement is calculated as:

1-[(1-R1) X (1-R2) X (1-R3)]

The result for our example is: 0.997 or 99.7%

Upping our education just a few notches more, and we can calculate the overall system reliability for a very complex (series and parallel) arrangement. For example:



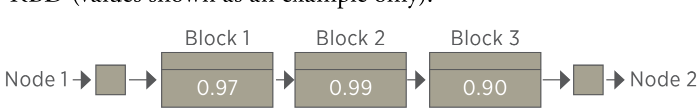
Hint: solve the parallel system first and then put the result in series with the other blocks.

The result for this example is an overall system reliability of 0.61 or 61%

It would be very fair for you to ask at this point, "What in the world has this got to do with lubrication? Or anything for that matter?" Fair enough. I believe that the same reliability block diagram can be used to calculate the overall reliability for all systems, not just for machines connected together.

Take this modest motor-coupling-pump skid assembly:

As a system, it can be re-shown as a block diagram, such as this RBD (values shown as an example only):



With an overall system reliability of 0.864 or 86.4%

Do you recall our oiler, Leroy? And do you recall I took some literary license and made reliability, probability, chances and odds synonymous? Here is the payoff.

What I'm reprinting here is the exact text from an actual PM work order — this is from a multi-billion-dollar company:

"Apply 4 grams of grease to the bearing."

For Leroy, the system he just entered reads in his mind like this, "Leroy, get a grease gun, go to the press, locate the bearing grease fitting, shoot in 4 grams of grease, document that activity (optional — as usual), put the grease gun away."

Or,

R1 X R2 X R3 X R4 X R5 X R6

For us to ponder:
R1 = Which grease gun? Which grease? How clean is it? Does it have the right additives?

R2 = Which press?

R3 = Which grease fitting? Is there a grease line, or is it direct application?

R4 = How much really is 4 grams? Is the grease gun calibrated? How do we know how much one pump puts out?

R5 = Document what, the number of grams, the number of strokes, the type of grease and the condition of the bearing?

R6 = Where do I put the grease gun, on the back of my cart, in my tool box or back in the crib?

To easily make the calculation of Leroy's work, which is a system of related activities, let's agree to use the U.S. Department of Education's commonly known standard that you only need a 70% to pass a class. That results in the following overall system calculation for Leroy's effort, if all of his activities are at least at a passing level:

70% X 70% X 70% X 70% X 70% X 70% = 11.7%

Leroy can perform every single individual task we have assigned him with remarkably steady reliability of 70%. There is a probability that he will perform every function to a satisfactory and, therefore passing, score. Yet, our system has failed. If you make an 11.7% on your test, there is a good chance that you'll be repeating that subject.

Now, let's approach this as a system and recognize that, with honest ownership of where we are now, a strategically laid out path, skill-based and objective training, a better PM description and discipline to the task, we can net a significantly different result with modest, incremental improvements.

Here is the new PM task that Leroy himself helped to write:

Leroy is our point person for all aspects of the lubrication program. He adds to the improvement efforts by not only detailing the work order tasks, but also by organizing the lubrication storage area. He consolidates the lubricants to what is absolutely required in the facility. Those lubricants are stored in a manner that guards the inherent reliability of the oils and greases. A solid lube route is developed and covers all the lubrication points in the plant. His overall performance contributes to the system advancement. Leroy makes small yet incremental improvements in a relatively short time. His numbers today:

95% X 95% X 95% X 90% X 85% X 95% = 62.3%

And there is still so much more to do. Leroy didn't settle for a lubrication system that was just alright; he rose to the occasion to ensure that it was all (done) right.

Once you and I begin to look at maintenance tasks as individual components that make up a bigger system, we can make the small, organic changes that are force multipliers.

As leaders, we are challenged to find these opportunities to make real change. In the latest calculation for Leroy's work above, I increased the first value (R1) from 70% to 95%. This can be achieved through the process of lubricant consolidation, lube storage organization and a little training. It had a major impact on this one application. Imagine that single improvement being multiplied by the number of machines that would benefit from organized and properly stored lubricants.

It's my hope that this short article gives you the motivations to determine where you are on the road to having an exceptional lubrication program. If you don't "own" where you are, you are still lost. It is okay to be at the beginning of the road to world-class. You have lots of company and lots of help. It is a journey we've all taken at some point.

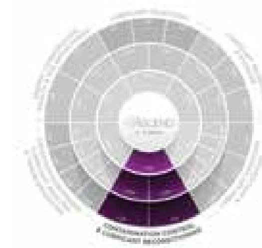
Having a lubrication program that is just alright is far from one that is all right. ***ML***

About the Author

John Ross has been a practitioner of maintenance and reliability for over three decades. A former Captain in the United States Air Force, he has been recognized as a distinguished public speaker, technical writer, and presenter. He is a certified Lean Manufacturing facilitator, Process Safety Management SME, and a CMRP.

David Dise | Noria Corporation

Factor: C3M



Why Gearboxes **Hate Water Contamination**

More about this **ASCEND™ Factor**

Factor:
C3M – Contamination Control Objectives

Level:
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Stage:
Contamination Control & Lubricant Reconditioning

About:
Implementing contamination control objectives and goals increases machine reliability. More stringent objectives should be set for machines with high criticality.

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Water is the second most destructive contaminant and is often ignored as the primary root cause of gearbox failure. The metal parts inside the gearbox will always be susceptible to rusting and varnish when water is present. When you add a slight amount of heat, air and water together, you will have oxidation, acid numbers will rise and rust will start forming, causing a plethora of other problems. As the additives in the oil start working in overdrive to combat the water contamination, they get consumed or used up. Additive polarity is defined as the natural directional attraction of additive molecules to other polar materials in contact with the oil. These polar materials include water, sponges, glass, dirt, metal surfaces and wood pulp. In effect, additives hitch a ride on particles or water droplets. Over time the oil loses its ability to protect metal surfaces, viscosity changes and eventually failure will occur.

Let's talk about the three different states, or phases, of water contamination you might see inside a gear-box oil reservoir. You can have dissolved water, free water or emulsified water. It is important to know the different states of water contamination and what they look like to not only determine how bad a problem is, but to identify what action needs to be taken to fix it. When talking about gearbox reservoirs, all three states of water can cause serious damage. Free water and emulsified water specifically are the most harmful states in any lubricated system.

Dissolved Water

Dissolved water is like humidity in the air. The water or moisture is present but dispersed throughout the oil, molecule by molecule, making it almost impossible to detect with the human eye. You can have a high concentration of dissolved water without being able to see it with the naked eye. With a high concentration of dissolved water, you might see condensation start to build. Having a high concentration of water and adding heat will make it react like when you leave a water bottle almost empty in the sun.

The heat pulls the moisture out of the oil in a fog or cloud and sticks the moisture to the inside walls of the reservoir not being splashed with oil. As the saturation level goes up, condensation builds and eventually forms into a condensation droplet waiting to become heavy enough to slide or drip into the oil. Dissolved water is what causes any part not coated in oil to start rusting, promoting further oxidation and contamination down the road. As the concentration or saturation of dissolved water builds, it will turn into free water or emulsify with the oil. You can have both free and emulsified water in the same sump.

Free Water

We all know water and oil do not mix well together. Water is usually heavier than oil and will sometimes settle out in the bottom of the sump. This is what we refer to as free water. Free water is usually in high concentration because of a shaft seal leak or some other source of outside water ingression. Free water is also hard to identify in small concentrations unless we have a window or some way to see the oil inside the sump.

If caught early enough, free water is the easiest form to remove from a sump or reservoir. Installing a bottom sediment and water bowl or column sight glass on the drain port is a good way to keep a constant eye on water contamination. Free water buildup can cause serious problems, with oil levels eventually filling up and either overflowing or causing the gears to now operate with water and oil causing emulsification. If water is allowed to mix around in the oil, it can cause foam and become suspended within the oil, emulsifying and causing serious viscosity changes which then results in boundary conditions and eventual machine failure.

Emulsified Water

Water/oil emulsification occurs when free water and hot oil are agitated together. The oil and water become mixed, leading to increased viscosity, loss of film strength, additive washout and lubricant failure. Viscosity is the most important physical characteristic of an oil. When free water is allowed to become emulsified, the viscosity will go up and machines will start working harder, become hotter and machine parts will fail.

Emulsified water is almost impossible to fight with filtration. It is important to catch the problem during the free state to prevent emulsification. Failure due to water contamination may be catastrophic, but it may not be immediate. Many failures blamed on lubrication are truly caused by excess water contamination.

Some of the effects of water on gearboxes:

- Shorter component life due to rust and corrosion (gears and bearings).
- Water etching caused by the generation of hydrogen sulfide and sulfuric acid from water.
- Erosion caused by free water flashing onto hot metal surfaces and causing pitting.
- Hydrogen embrittlement happens when water invades microscopic cracks in the metal surfaces. Under extreme pressure, water decomposes into its components and releases hydrogen. This explosion forces the crack to become wider and deeper, leading to spalling.
- Film strength loss — the pitch line of a gear tooth is protected because oil viscosity increases as pressure increases due to the oil's pressure/viscosity coefficient. Water does not possess this property. Its viscosity remains constant (or drops slightly) as pressure increases. As a result, water contamination increases the likelihood of contact fatigue (spalling failure).

Some of the effects of water on gearbox oil:

- Water accelerates oxidation of the oil.
- Water depletes additives like oxidation inhibitors and demulsifiers.
- Water causes ZDDP anti-wear additives to destabilize over 180°F.
- Competes with polar additives for metal surfaces.

Water can lead to soot agglomeration, wax curd and even sludge by mopping polar impurities. Chemically, it can cause additive depletion and oxidation of the lubricant while also forming acid and rust. Physically, it can alter the viscosity of the lubricant. Now that we know all about how water affects gearboxes and the damage it can cause, let's talk about how to solve the problem and keep it from happening again.

The most common cause of water ingression or contamination is through open ports/hatches, shaft seals, flange fittings and cooling systems. Water is used in every industry and is therefore the leading cause of machine failures. Water contamination is a silent killer. It can take a long time to cause noticeable damage, but when the signs do appear, it is usually too late.

However, all oils will have a traceable amount of water in them. It is important to test new oil coming in, so you have a baseline or starting point — something to use as a reference if a problem does arise.

Some of the ways to monitor water in oil are:

- The use of sight glasses (column sight glass & BS&W bowl) for a quick visual indication. Moisture sensors attached to the oil reservoir.
- Moisture sensors can be installed to measure the moisture in the headspace of the reservoir as well as moisture in the oil.
- Oil analysis is another way to monitor the amount of water in the oil. For the most accurate results, I recommend using an oil analysis lab.
- A convenient way to determine water concentration in the field is by using a calcium hydride test kit. Water reacts with solid calcium hydride to produce

hydrogen gas, which is directly proportional to the amount of water present in the sample. The water content of the sample is meas-ured by the increase in pressure in a sealed container. These test kits are reported to be accurate down to 50 ppm free or emulsified water. The calcium hydride test is a great starting point, letting you know immediately that a water problem exists.
- Another way to monitor for water contamination is by suspending a metal rod inside the reser-voir's headspace. Over time, if water is present, the metal rod starting to rust will let you know that water contamination is an issue.

Controlling water contamination can be accomplished in a variety of different ways:

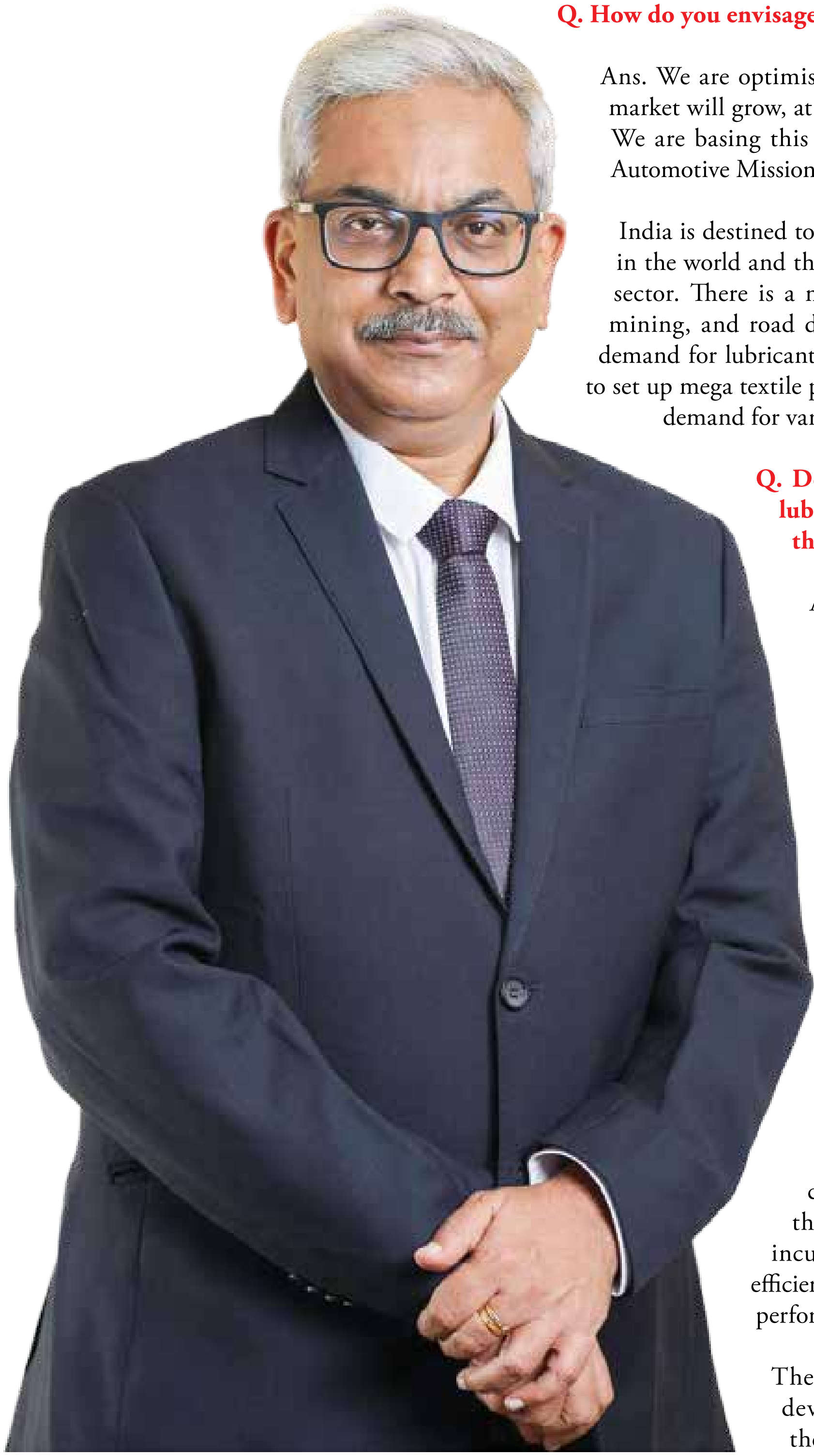
- A simple desiccant breather mounted on the headspace. Desiccant breathers allow the air entering equipment to flow through the desiccant media, stripping out any moisture and trapping it in the desiccant media before entering equipment.
- On medium size reservoirs, you can attach filters with water capturing capabilities. On large reservoirs, I would recommend using a vacuum dehydrator for removing and monitoring water.
- You can utilize heat to flash off any water in the oil. I personally avoid recommending such methods because I do not like taking the risk of adding unnecessary heat to a system.

The cheapest and most effective method of controlling water is simply stopping water from entering machines or making contact with machine surfaces. Invest in splash guards around equipment, making sure ports and hatches are sealed tight and training people on how to carefully spray down and clean equipment with high pressure. It is also helpful to inspect shaft seals for damage and replace damaged seals as needed. If equipment is outside, building rain covers or redirecting the drain water away from equipment can also help mitigate water contamination problems. It will be much cheaper and easier to protect equipment from water ingression than to remove water after it's inside the system.

Gearboxes are expensive but built to last — if maintained correctly. Controlling contamination is a full-time job. Not only are we fighting against something we cannot see most of the time, but we are also dealing with a problem that could fluctuate by the hour. Water is something we cannot ever completely get rid of, but it is something we can control. Start a "No Water Contact" initiative at your plant. Work on training people on the proper ways of spraying down machine parts without causing damage. Modify and safeguard equipment against water contact in any way you can. By taking the right steps and thinking through the problem carefully, we can help control water and reduce how much of it is entering our equipment. ***ML***

About the Author

David Dise is an to Associate Technical Consultant for Noria Corporation. He works closely with plant managers and reliability engineers to develop lubrication and reliability programs. His goal is to help plants become world class. David has been certified as a Level II Machine Lubricant Analyst and a Level I Machine Lubrication Technician by the International Council for Machinery Lubrication. Before joining Noria, he worked as a flowback operator at 1st Rate Energy Services, traveling to several different locations around the United States.



Q. How do you envisage the growth of industrial lubricants?

Ans. We are optimistic and despite COVID-19, the industrial lubricant market will grow, at an approximate CAGR of 2.5% between 2021-2026. We are basing this on the demand for industrial lubricants for India's Automotive Mission Plans (AMP).

India is destined to be amongst the top automobile manufacturing hubs in the world and this will also provide an impetus to the manufacturing sector. There is a massive push by the government on infrastructure, mining, and road development, and that too is bound to increase the demand for lubricants. We are also hopeful about the government's plans to set up mega textile parks and food parks, which will definitely add to the demand for various industrial-grade lubricants.

Q. Do you think synthetic lubricant, energy-efficient lubricants and eco-friendly lubricants will penetrate the Indian market?

Ans. Despite having a higher initial cost compared to conventional mineral-based lubricants, synthetic lubricants provide 3-4 times more longevity along with protection for equipment. We have reasons to believe that OEMs are driving the use of synthetic lubricants for benefits such as reduced maintenance costs, improved equipment reliability, safer operations, and suitability for emergent complex systems designs. The long drain synthetic lubricants are also gaining popularity in most of the industrial segments such as wind turbines, cement plants, textile industry, etc., due to the criticality of applications.

Another fascinating trend is the increased demand for energy-conserving lubricants. When energy consumption is optimized, equipment operating costs come down, translating into business profits. A small percentage of reduction in energy consumption can translate into significant annual returns. We find that both OEMs and consumers consider it worth incurring a little extra cost on high-quality energy-efficient lubricants as it balances out the investment vis-a-vis performance.

The demand for eco-friendly industrial lubricants, developed from biodegradable base stocks, is on the increase, as attempts are being made to reduce environmental pollution and minimize contamination of ecosystems due to the spillage or leakage of lubricants. Although bio-based lubricants currently account for a small percentage of the total demand for lubricants, it is estimated that an increase in environmental consciousness among end-users will drive demand in the near future.

Q.How would you rate the importance of sustainability in your company today and what is the sustainability strategy of your company for lubricants?

Ans. The importance of adopting sustainable business practices has become extremely important for corporations in the current milieu. Every lubricants company has to explore a wide variety of opportunities and agendas to sustain their business. Adopting sustainable practices can help an organization become more efficient, improve its brand value and reputation, provide a platform for innovation, achieve better growth, and strengthen stakeholder relations.

As part of our corporate strategy, we, at MAK Lubricants, are constantly improving and exploring systems and practices towards achieving sustain ability and emphasizing the importance of contributing to the betterment of the People, Planet, and Profit. Our R&D team plays a vital role in exploring various sustainable energy technologies such as:

- ❑ Eco-friendly and biodegradable lubricants, and long drain interval products, to reduce disposal and improve energy efficiency.
- ❑ Fuel economy lubricants to lower demand for energy and green house gas emissions, among other things.

Q. Market for Specialty Lubricants and MWF (metal working fluids) continues to be monopolised by MNCs. Does BPCL have plansof entering this market?

Ans. MFWs and Speciality Lubricants market is constantly evolving, wherein customers expect customized grades and total lubricant management services. MAK Lubricants has positioned itself as a challenger to the monopoly established by various MNC's in these categories. Our R&D team has the capability to develop

innovative specialty lubricant products and our technical services team is equipped to provide customer service. Customised specialty lubricants are already being supplied to auto ancillaries, textiles, steel, and sugar sectors. We are totally focussed on the sector, and we are working towards marking our presence as market leaders in the category.

Q. Do you think the introduction of EV's is likely to drastically reduce the lube market volume? How is BPCL planning to cover this reduction?

Ans. We believe that ICE (internal combustion engines) will continue to grow for some time. Global indicators suggest an increase in car parc requiring lubricants approximately by 30-40% by 2030. In addition to this, the share of battery-powered electric vehicles (BEVs) in the HDCV segment is at a nascent stage and in future the penetration of BEVs in this segment will be driven by city buses, last-mile vehicles, and off-road applications.

We find that E-mobility is being considered as the smarter and safer choice, as it also helps meet the future emission targets being introduced globally, and this is a reason for its quick and wide spread acceptance. Hybrid vehicles sales shall play a major role in the growth of e-mobility by 2030, in the light-duty vehicle (LDV) segment. As we all know hybrid vehicles use a combination of conventional hardware and electric propulsion mechanism. This means a majority of new LDVs currently, will still contain an ICE, which in most cases will be fuelled by petrol (MS). Also as per our estimates, the share of BEVs may only reach 10% of global LDV sales. OEMs are strategizing on the future of passenger car electrification and their sales projections. As e-mobility steadily becomes mainstream, OEMs are likely to further develop the propulsion systems and adopt hybrid transmission fluids. This future scenario and expected growth in the production volumes makes the formulation of hybrid-specific fluids more commercially attractive.

The requirement for industrial lubricants, which is currently more than 55% of total lubricant consumption in India, will continue to register growth in view of the large-scale industrialization, on efforts being made by the government.

For various types of EVs, we are in the process of introducing e-axle fluid and battery coolant.

Q. How can we leverage digitization in lubricants value chain? What digital initiatives has BPCL taken to stay ahead in the game?

Ans. Competitive differentiation, now more than ever, emerges from superior digital capabilities and technology endowment, more agile delivery, and a progressively more tech-savvy senior leadership. The Lubricant industry is no different and there is scope for digitization efforts across the value chain.

It can be for product application, engagement, marketing or supply chain processes. Technology can be deployed for predictive maintenance by way of real-time condition monitoring or creating digital twins. Data can be collected through sensors & software and analysed for effective lubricant consumption on customer premises.

Engagement marketing involves omni-channel enablement, demand sensing and shaping, social media analytics, and intelligent marketing. Connecting customer insights with sales, marketing, and R&D teams, by establishing a communication process, can be critical.

Supply chain management can evolve into being truly digital by making changes in decision making progress through collaborative planning, intelligent procurement, and warehouse management system.

Effective technology implementation will enhance productivity, customer relationship, and channel management. We expect that with the use of technology, employees can focus more time on customers.

At MAK Lubricants, we are in the process of implementing several digital initiatives. With the intention of developing a consolidated platform for various needs of customers, we have engaged Salesforce as a customer relationship management tool.

We have introduced instant gratification as a part of the Hello BPCL App, a single corporate app for BPCL customers across businesses wherein they can get instant credit to their linked bank accounts by scanning coupons, on a select range of MAK lubricants packs.

We are designing a track-and-trace technology through QR code implementation, which will enable us to track the movement ofthe product at all stages: from production till the end-user. This will allow for better warehouse management. We have introduced Urja Chatbot, an AI based virtual assistant to address customers' queries on all products of Bharat Petroleum.

The real benefit of any technology implementation can be experienced only when there is a high adoption rate of maximum features across users. Thus, it is vital to make people comfortable with the various digital initiatives.

Q. What was the impact of COVID-19 on lubricants business and what are the supply chain strategies that big organizations like you are implementing to handle such situations ?

Ans. The COVID-19 pandemic truly brought with it unprecedented times. It created a sudden stoppage of all industrial activities which created a cascading effect on transportation of raw material/finished goods as well as other suppliers. While the safety of our employees was of prime importance, there was little time available to prepare for this pandemic and the consequent unexpected scenarios. For first few days, it was extremely challenging as we had to ensure raw material supplies and take care of transportation of finished goods right up to our channel partners.

Along with us our raw material suppliers were also facing challenges in supplying input material to manufacturing plants while additive suppliers had to cut down on production. This coupled with restriction in movement of workers and declaration of containment zones, made operations quite challenging.

On the demand front, the erratic consumption patterns led to abuild-up of inventory at all levels. Many of our suppliers were finding it difficult in terms of maintaining cash flow to keep operations running.

The team spirit of MAK really made it possible to quickly adapt to the "new normal life" post COVID-19. Prime importance was given to taking care of health and welfare of employees. With availability of vaccines, BPCL ensured that all its employees were vaccinated at the earliest to ensure little to no disruption in operations. Standard operating Procedures were introduced on aspects of HSSE giving guidance to our suppliers and customers.

Raw material supplies, production planning and stock-management, were optimized in order to ensure least disruption during the imposition of lockdown. Logistics partners were brought in to ensure seamless movement and every plant was encouraged to share their contingency plans, to keep the plant running in case of any disruption in supplies.

Finished goods inventories for sufficient inventory days to cover, was ensured so that there was no dry out of products in the markets. We also utilised the situation to train and build competencies of our employees to facilitate micro team/ staggered working.

Q. How are customer service expectations changing and what are all the value added services provided by MAK Lubricants to industrial customers?

Ans. Customer expectations are not restricted to quality products now it has expanded much further, and hence we need to be a solution provider to their requirements. Industries and businesses expect customised products, timely supplies, and quick turnaround time.

We have an entire team dedicated to our Industrial customers, comprising Technical Services officers and Quality control professionals. We have deployed mobile quality control labs for on-site lubricant testing. Our value-added services of condition monitoring of lubricants and coolant management are very much appreciated by our customers.

Our team of professionals also impart training to Industries for effective use of lubricants for maximizing performance. Leveraging digital platforms, we have been engaging with our customers through webinars inviting experts from different industries to discuss the intricacies of lubricants application in plants and processes.

Mr. G. Krishnakumar, Executive Director - Lubes is an Electrical Engineer from Regional Engineering College (REC), Tiruchirapalli and a Master's Degree holder in Financial Management from Jamnalal Bajaj Institute of Management Studies. The success quotient in Mr. Krishnakumar's stints across Business

Units and Human Resources figure sizeably in his illustrious career, indubitably, as he is known for his valuable contributions to the pioneering loyalty programmes of BPCL viz., Petro Card and Smart Fleet, his dexterous strategies in building Brand BPCL and for reimagining the Corporate Training Centre BPLC. An avid reader, ardent quizzer, and an amicable team player , he has proven records of delivering result in challenging times.

With a masters in Financial Management, an enriched experience of Human Resource Management, leading the competitive Business of MAK Lubricants, Mr. Krishnakumar is text book definition of multi dimensional business leader!

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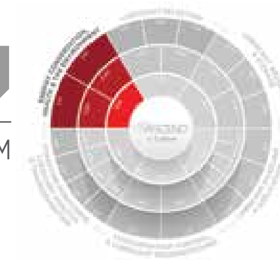
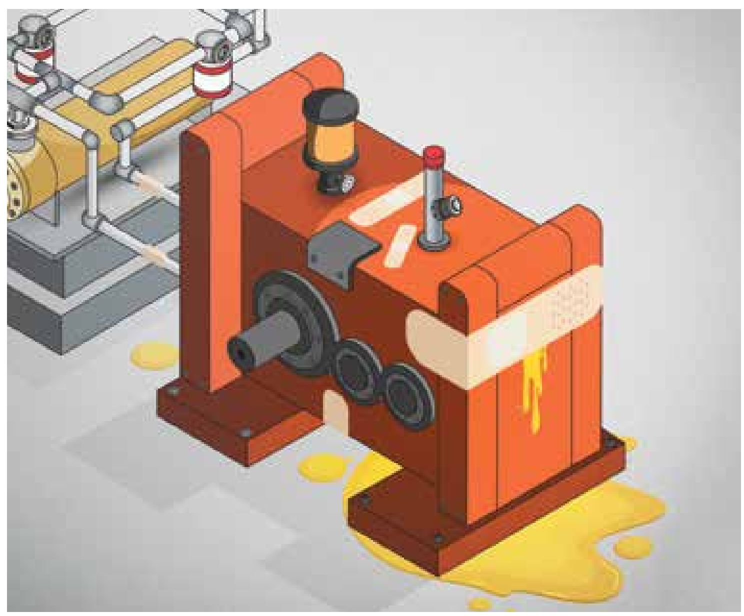


Understanding and Managing Oil Leaks

"Small leakers are often the biggest risk, simply because they are more likely to go unnoticed or without much concern afforded to them."

We all know leaks make a mess. Why do they keep happening? How do we know if a leak is something to be concerned about or if it is just commonplace for plant equipment? Well, given that rotating equipment and lubricated equipment are practically synonymous, oil leaks can be more common than we would like. Thus, understanding the risks associated with an oil leak is important. While preventing leaks all together is desirable, it's often not achievable. Therefore, we must be ready to reduce the leaks to an allowable amount based on variables of risk. For now, we'll focus on oil leaks, although much of what will be mentioned could also apply to grease leaks.



Images Courtesy of Brian Ramatally (CASL)

Any time oil escapes the lubrication system (sump, piping, etc.) and enters the external surroundings, this is an external leak. We are often aware of this, as there is visual evidence of the oil dripping out onto other components and forming a puddle on the floor. However, another type of leak occurs when unwanted oil seeps between internal chambers inside a lubrication system.

This is called an internal leak. Not many consider internal leaks at all, much less the risks associated with them. This is largely because of the lack of evidence. Unless we are monitoring pressure gauges or operational movements closely, these internal leaks may go unnoticed.

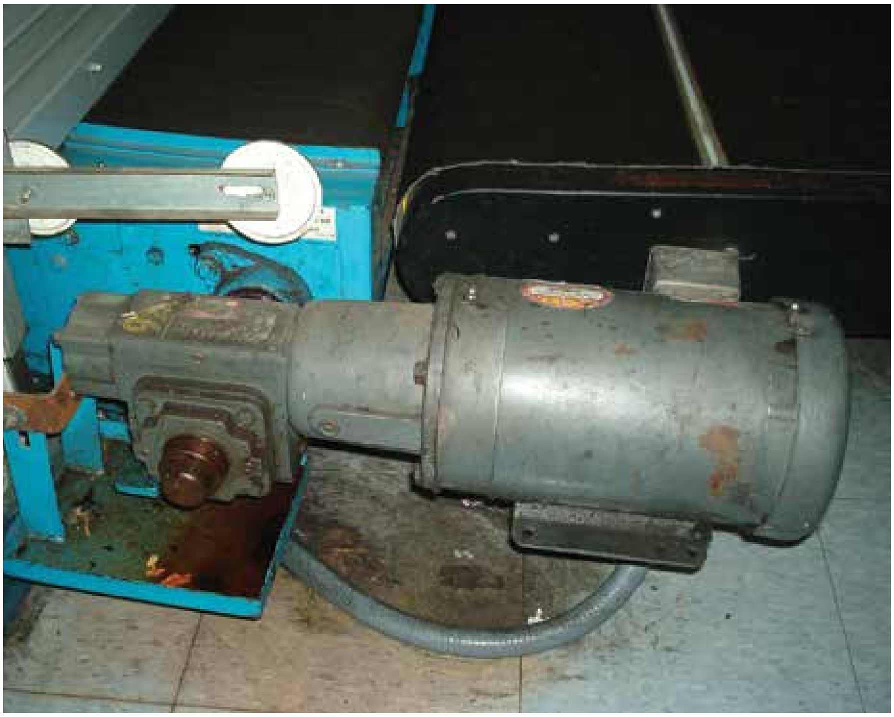
But regardless of the type of leak, what is considered normal? Is there any amount of leakage that is allowable? When should a leak be taken seriously and corrected? Is this a maintenance activity that is largely reactive or can steps to be taken to be more proactive?

Leaks are something I often inspect for and help identify through Noria's Lubrication Program Development (LPD). During the first phase of LPD, an assessment is performed and aligned to the 40 Factors of the Ascend™ methodology (see noria.com/ascend). One of these factors is **Leakage Management (E3M).** After a plant undergoes an Ascend Assessment, there is often the need to bring awareness to the abnormal state of leaks that exist. The reality of what is considered "normal" is not what should be allowable. Most leaks are manageable, and if not, the result can be excessive costs, or worse, a hazardous work environment.

The Cause of Leaks

It's easy to blame a machine that is considered "a leaker" on some error in manufacturing or on actions taken during a rebuild. Sometimes this may be true. If there is not enough attention given to the type of material used or to component assembly, then any hope of controlling leaks may be doomed from the start.

Other times, a leak is blamed on a symptom rather than root causes, like when housing corrosion or worn seals produce a leak. While these symptoms may be the source of the leak, they only failed because of something else: the root of the problem. If you're going to have any chance of preventing a leak from recurring, the root cause must be uncovered. Targeting the root cause helps make the most of the reactive nature of a leak fix by creating a more proactive and sustainable solution. In most cases, the root cause of a leak stems from either a selection decision, negligence with maintenance or improper operations.



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- **Selection** – If the machine is not selected (and sized) appropriately for the desired operating function, then leaks and other early failure modes can occur. Proper selection also includes ancillary decisions, such as choosing the right lubricants, seal materials and leak-stop agents based on physical or chemical composition. Exposing these materials to incompatible substances within the system could create leaks.
- **Maintenance** – Of all the maintenance activities, one of the most important is inspections. If conditions of the machine are not properly monitored, the root cause of leaks can prevail. This leads to the reactively fighting leaks instead of proactively preventing them. As the sayings goes, "If you don't schedule time for [proper] maintenance, your equipment will schedule it for you." This can be done with quality routine inspections and oil analysis, as well as other condition monitoring technologies that target the root causes of leaks.
- **Operation** – When machines are forced to perform work beyond their intended design, severe, unexpected leaks can occur. This certainly includes scenarios when equipment is over-pressurized, over-loaded or at higher speeds. With that being said, it can also occur when suspect conditions such as high contamination, high temperature, and abnormal vibration are ignored.

The Effect of Leaks and Overall Risk Concerns

Some leaks start small and stay small. In a perfect scenario, this would give maintenance ample time to discover the leak during routine inspections and follow up with corrective action. Other times, leaks are more significant and it's critical to act quickly. Don't be fooled by the size of the leak, as this doesn't always identify the level of risk or urgency of action. In fact, small leakers are often the biggest risk, simply because they are more likely to go unnoticed or without much concern afforded to them.

Take for example a leak with a rate of about one drop per second; it would take less than a day for a gallon of oil to leak out. That means a typical process pump would be out of oil during a single eight-hour shift. For a large oil reservoir, this could add up to more than 400 gallons of oil lost over the course of a year.

First and foremost, any leak that is not adequately contained can present dangers to the environment. Most of us are familiar with the severity of larger leaks of hazardous oils into waters or other areas with wildlife, as well as the high cost to the responsible organization in the form of fines and any environmental cleanup efforts.

Leaks can also pose a risk to our health in many ways. They can create a potential fire hazard or slip and fall opportunities. Even more dangerous is the risk of the leak finding its way into product that will eventually be consumed. While this is of more concern at food processing facilities, this type of risk can occur at any plant, especially those around waterways.

As it relates to the equipment, a leak can certainly lead to lubricant starvation issues and reduced machine performance. In the example of the process pump, it wouldn't take much oil loss to result in a lubrication issue, ultimately leading to machine failure. Larger systems such as hydraulic systems are more prone to leaks with actuators or other high-pressure areas. While some minimal amount of oil loss in these types of machines may be considered "allowable," it can still lead to reduced efficiencies, loss of control and an overall reduction in equipment reliability. These equipment effects may seem subtle and insignificant, so the cost impact often becomes evident after it's too late to avoid. Such is the case if these equipment inefficiencies lead to product damage or other deficiencies in production results.

There are many other risks that can result in both external and internal leaks. Sometimes the effects are just one link in a chain reaction of cause and effect, which can eventually lead to equipment failure. Contamination ingression, for example, which can enter at "leak point," may very well lead to a failure. This leak point could either be in the headspace or a chamber under vacuum pressure.

While the cost of the oil was briefly mentioned as a risk above, it often pales in comparison to other substantial risks presented by leaks such as the cost of labor required to handle them.

5 Steps to Managing the Leaks

1. **Recognize its presence and identify the leak source.** Once it is recognized, consider any safety concerns first. If the leak presents any immediate danger to personnel, this should be reported immediately for subsequent action. But regardless of its safety concern, all newly identified leaks should not be ignored before they are properly examined. Once a leak is known, make note of its presence with an inspection report and try to determine the source. This may require the aid of leak source detection technologies and techniques. If the exact source of the leak cannot be reasonably determined, at least identity the component or lubrication system from within which the leak is coming. This should also be tagged for further personnel awareness.
2. **Characterize the leak severity.** This will be a combination of the current state of the leak and the consequence if the leak is allowed to continue. The current state of the leak is based on characteristics such as leakage rate, current estimated volume lost, the type of fluid and the type of component. The consequence includes all known risks as discussed already. Some examples of scenarios with high consequence are those without adequate spill containment from critical systems or with high downtime concerns.
3. **Investigate the leak point and the possible root cause.** This could be obvious, or it could be difficult. The array of leakage sources is so great, and the detection techniques are so vast that there are books dedicated to them. But some immediate consideration should be given to common leak points such as seals, joints, ports, pressurized lines and any surface from a fluid containing structure. Remember, even if a leak point is known, this doesn't always point directly to the root cause. Take, for example, a leak at a dynamic seal. The reason why the seal is leaking may be largely unknown, at least until more observations can be made during disassembly. With that being said, there are some clues, like if the known seal

Images Courtesy of Alec Meinke General Mills Inc. (Blue Buffalo) material can be identified as incompatible with the lubricant in use. Oil analysis or maintenance and operations history can also provide some clues. However, at this stage, if the root cause cannot be nailed down, then at least a prognosis should be made to support the proposed corrective action decisions.

4. **Determine (and take) the necessary corrective actions.** Unless the leak can be fixed easily from the exterior, the corrective action may require a shutdown. For critical machines where this is more difficult to allow in the short term, a temporary measure may be considered as an initial mitigation step. This may include a "band-aide" solution to quickly stop the leak and provide any immediate needs to the equipment, such as an oil top-up. Leaks may be temporarily stopped externally (such as with a sealant) or internally (such as with leak-stop agents, although these should be used carefully as previously mentioned or they can exacerbate the leak). This may buy maintenance and operations some time before the proper corrective action can be made. Of course, leaks should be cleaned up promptly to avoid any further hazards. As the leak is scheduled for full repair, every effort should be made during this process to preserve the evidence and further investigate the root cause (step 5). If necessary, this may alter the corrective action during repair.
5. **Verify the root cause (follow up from step 3).** As evidence is collected during repair, a root cause analysis (RCA) should be performed. In addition to the examination of failed parts for defects and causes of failure, the analysis should include results from oil samples and filter debris. This evidence should then support a conclusion about the root cause and point to possible adjustments that will prevent a leak from returning. As we recall the common causes of leaks, this may include machine selection decisions, maintenance activities or operational factors.

Conclusion

If you work at a facility where oil leaks are commonplace, then it may be time to devote the effort needed to accomplish proper leak management. Once they are justified by the identified risks, the practical steps can be approached for each individual occurrence. Although precise and frequent inspection practices are a must for identifying leaks, don't ignore their significance once they are found. The risks can be greater than just a financial concern. Ultimately, when leaks are minimized equipment will become more reliable and working in a cleaner workplace can allow for more necessary improvements in the plant to take place. ***ML***

Reference:

Fitch, E. C. (1992). Proactive maintenance for mechanical systems. Oxford, England: Elsevier Advanced Technology.

About the Author

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EXXON MOBIL LUBRICANTS INDIA PROMOTES SPORTS IN INDIA

ExxonMobil Lubricants Pvt Ltd announced the renewal of its brand ambassador association with the Tokyo Olympics medallists - Neeraj Chopra, Mirabai Chanu, and Bajrang Punia - for Mobil India. The announcement was made during a gala felicitation ceremony atNew Delhi in the presence of the company's top retailers.

Tokyo 2020 was India's most successful Olympic campaign with a tally of seven medals. While Neeraj Chopra became the first track & field athlete and the second Indian to win an individual Gold medal, Mirabai Chanu isthe first Indian weightlifter to win a Silver. Bajrang Punia, who won a Bronze at the event, is the only Indian wrestler to win three medals at the World Wrestling Championships. A common thread among these sports persons is that they symbolize a powerful story of transformation, rising from humble beginnings to representing India at the Olympics.

Commenting on the development, Deepankar Banerjee, CEO, ExxonMobil Lubricants, said, "We feelextremely proud to renew our brand association with Neeraj Chopra, Mirabai Chanu and Bajrang Punia. Our engagement with them began before they achieved world fame,and hence it gives us immense pleasure to see them become the very best in their respective fields, winning major titles and medals at the Olympics. Like the athletes have made a difference to India and the sport they represent, we too will continue to work hard, building on Mobil's world-class brands, synthetic leadership, and scale to bring trusted, high-quality performance products and solutions to the country."

Speaking during the event, Imtiaz Ahmed,GM-Marketing Deployment, Consumer Marketing, ExxonMobil Lubricants, said, "The three champions personify Farak LaakarDekhiye, what we stand for in India, which is not only our expertise, innovation and performance but also about giving people the confidence to unlock their ambitions for tomorrow. The athletes are a natural fit for us and we couldn't be more pleased to be able to continue our association."

During the felicitation ceremony, ExxonMobil Lubricants also showcased its latest products,Mobil Super SUV Pro and the Mobil Super Moto2W engine oil upgraded range, which were recently introduced through an advertising campaign featuring Neeraj Chopra, Mirabai Chanu, and Bajrang Punia.

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Inhouse training on Practical Industrial Lubrication Orientation Training (PILOT) and Machinery Lubrication Level I training at MCPI Private Limited, Haldia, West Bengal

Lubrication Institute conducted a two-day training on **Practical Industrial Lubrication Orientation Training (PILOT)** and three days training on **Machinery Lubrication Level I** training for the Engineering team of **MCPI Private Limited, Chemical plant in Haldia, West Bengal** from 10th to 13th November, 2021

This was on-premise classroom training, fully customized and designed uniquely to support the maintenance and reliability teams in organization. This training helped them realize their full potential and achieve optimal, sustainable outcomes. There was also a post training engagement activity to ensure knowledge retention.

Arunava Das
Manager mechanical,
MCPI Private Limited

"Overall very good and knowledge enhancing training program."

Saikat Chakraborti,
Senior Executive, MCPI Private Limited

"Had a good interactive session with the trainer. It was very effective training."

Syed Faisal Hashmi
Manager, Utility,
MCPI Private Limited

"Trainer explained the things well. Had a good learning experience where we learnt equipment specific lubrication"

Somnath Adhikary
Senior Manager, MCPI Private Limited

"Very well sequenced, well explained, very informative and interactive session."

Tushar Chakraborty
Executive, Electrical,
MCPI Private Limited

"The trainer followed very good teaching procedure. One major learning was oil contamination is not good for rotary machine."