PRECISION LUBRICATION FOR INDUSTRIAL GEARS

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INTRO TO GEARBOX LUBRICATION

THE PROBLEM

Gears are commonplace in many different industries. From high speed gearing found in turbo-machinery to slow speed gear reducers found across a multitude of manufacturing and process industries, gears are the workhorses of industry. Yet despite their widespread use, gears are perhaps the least maintained of all lubricated components. This can result in poor reliability, excessive maintenance and repair costs, and unscheduled production downtime.

The problem has become even more pronounced in the last decade. While many years ago gears were oversized and capable of withstanding a degree of use and abuse, today's gear drives are precision components with higher power densities requiring a greater focus on lubrication.

In this white paper, we'll examine the factors that impact precision lubrication; including lubricant selection, application and contamination control, as well as how to develop precision lubrication practices for enclosed gears.



GEAR DRIVE LUBRICATION FUNDAMENTALS

GEARS AND FRICTION

From a lubrication perspective, gears can be categorized based on their design (gear geometry), speed and load. For high-speed gearing, surfaces are separated by a full oil film (hydrodynamic or elasto-hydrodynamic lubrication). Slow turning and/or heavily-loaded gear drives tend toward boundary lubrication where point loading can result in surface separation between gear teeth that is equal to or less than the mean surface roughness of the mating gears (boundary lubrication). Table 1 gives a general overview of common gear types and the type of lubrication film expected under different loads and speed.

Gear type	Dominant Frictional Force	Low Speed (<100 RPM)		High Speed (>1000 RPM)		
		Pitch line	Tip/Root	Pitch line	Tip/Root	
Spur	↑	Boundary	Boundary	Elastohydrodynamic	Hydro dynamic	
Straight Bevel		Boundary	Boundary	Elastohydrodynamic	Hydrodynamic	
Herringbone	يو بو	Boundary	Boundary	Elastohydrodynamic	Hydro dynamic	
Helical	re Rolli re Slidi	Boundary	Boundary	Elastohydrodynamic/ Hydrodynamic	Hydrodynamic	
Spiral Bevel	°₩ °₩	Boundary	Boundary	Elasto hydro dynamic/ Hydro dynamic	Hydrodynamic	
Hypoid		Boundary	Boundary	Elastohydrodynamic	Hydrodynamic	
Worm	•	Boundary	Boundary	Elastohydrodynamic	Hydrodynamic	

Table 1: Typical lubrication regimes found in gears

In most gears, the frictional force between the gear teeth is typically a combination of sliding and rolling friction. The degree of sliding versus rolling friction, in conjunction with the speed of rotation and applied load, all factor into how the meshing surfaces engage and ultimately how effective the lubricant is in reducing mechanical wear.



GEAR DRIVE LUBRICATION FUNDAMENTALS

To illustrate this point, consider one of the simplest of all gear designs: a spur gear with involute gear tooth profile (Figure 1). For the sake of discussion, we can consider two points of interaction between the meshing gear teeth: the tip to root contact and the pitch line contact.



In an involute spur gear design, such as that shown in Figure 1, the contact at the pitch line on each gear set is almost exclusively rolling friction. Rolling friction is defined by two surfaces that approach each other in a perpendicular direction (Figure 2a). Under rolling contact conditions, separation between the moving surfaces will depend on the applied load and speed. At higher speeds, the increased pressure on the lubricant under load causes a rapid increase in viscosity of the fluid. With sufficient pressure, the lubricant can undergo an instantaneous phase change from liquid to solid, which, in turn, can result in an elastic deformation of the mating machine surfaces. Elastic surface deformation results in the load being dissipated

across a larger surface area, allowing the gears to transmit the applied load without mechanical wear as the surfaces are separated by a full oil film. This is an effect referred to as elastohydrodynamic lubrication (EHL). The key to effective elastohydrodynamic lubrication is having a lubricant with sufficient viscosity and a high-viscosity pressure coefficient. Having too low a viscosity or poor viscosity pressure coefficient can result in metal-to-metal contact, dramatically reducing the life expectancy of the gears.

For lower speed gears under rolling friction, the rate at which the two surfaces approach is too slow to allow the EHL film to form. Under these conditions, boundary lubrication will occur, requiring the use of extreme pressure and anti-fatigue additives to prevent wear from occurring.





GEAR DRIVE LUBRICATION FUNDAMENTALS

By contrast, at the tip to root of an involute gear tooth profile (Figure 1) and in many other gear geometries, sliding friction is the dominant frictional force. Sliding friction involves surface motion in a parallel direction (Figure 2b). In high speed gearing, the speed relative to the load is typically high enough that moving surfaces are separated by a full film of oil. However, unlike rolling friction where elastohydrodynamic lubrication is the norm, high speed sliding friction results in hydrodynamic separation between the moving surfaces, an effect akin to a water skier experiencing "lift" once the tow boat speed is high enough for the applied load (weight of the skier and water ski dimensions). Hydrodynamic lubrication requires the oil to have sufficient viscosity for the applied load and speed, both of which have an impact on oil film thickness.

For slower turning gears, such as the low speed gear in a gear reducer, the viscosity of oil necessary for hydrodynamic lift is too high compared to the ability of the oil to flow into the load zone. As a result, a hydrodynamic oil film cannot be maintained and, once again, boundary lubrication conditions dominate. Where boundary lubrication occurs in conjunction with sliding motion, severe sliding wear - sometimes referred to as adhesive wear, galling, or scuffing - can occur. In an involute gear geometry, this typically occurs just above and below the pitch line and frictional forces transition from pure rolling to sliding friction.

Sliding motion also results in higher localized temperatures, which causes a reduction in the oil's viscosity and can also cause the oil to be wiped away from the converging gear surfaces, further inhibiting the formation of an oil film. Under these circumstances, the meshing gears will be under boundary lubrication conditions. Where boundary lubrication is anticipated, special wear prevention additives must be used to protect gear teeth.



GEAR LUBRICANT SELECTION

LUBRICATING YOUR GEARS

Lubricants used in gearing come in three basic classes:

- Rust and oxidation (R&O) inhibited oils
- Extreme pressure (EP) oils
- Compounded (COMP) oils, sometimes referred to as cylinder oils

The type of lubricant used will depend on the type of lubrication regime (hydrodynamic, elastohydrodynamic, boundary, etc.) and the type of gear set. For higher speed application where fullfilm conditions exist, simple rust and oxidation inhibited oils are used. Aside from their lubricating properties, these oils need to exhibit good oxidation resistance to counter the effects of the heat generated and good corrosion resistance to counteract the effects of any ambient moisture ingress and protect any yellow metals that may be present.

For slower speed or higher loaded gears where full-film separation is simply not possible, extreme pressure additized gear oils should be used. There are several different types of EP additives, from chemical films that react with and coat the gear surfaces to solid suspensions that improve lubricity under sliding contacts. However, all have the same basic function: to reduce the coefficient of friction under boundary lubricating conditions.



GEAR LUBRICANT SELECTION

For worm gears in particular, it is often recommended to use a compounded oil rather than an EP additized oil. The reasons for this are twofold. First, some chemically active EP additives can be corrosive to yellow metals (brass, bronze, etc.), which are commonly used for the ring gear in worm drives or in bearing cages. Second, compounded oils contain lubricity agents based on fatty materials that do a better job of reducing the coefficient of sliding friction, the dominant frictional force in most worm drives. For gears containing yellow metals, chemically active EP additives are not recommended at elevated temperatures (140 F-150 F and higher).

Like any other lubricant application, viscosity is the single most important decision when selecting a gear oil. Viscosity is selected based on the speed and size of the gears by calculating the pitch line velocity and the ambient operating temperatures. While this is a good starting point, other variables, such as shock loading or cold ambient start-up conditions, also must be factored in for an optimized lubricant selection. Viscosity mismatch is one of the most common errors with gearbox lubrication. Table 2 provides some good general guidelines on viscosity selection.

Oftentimes, OEM recommendations are adopted in selecting the correct gear lubricant. While this is an excellent practice in many applications, where extreme conditions, such as high or low operating temperatures or shock loading, are present, OEM guidelines should be considered as just a starting point and should be adjusted up or down depending on the application.

Tomo	Pitch line velocity, m/s ³⁾								
°C	1.0 - 2.5	2.5	5.0	10.0	15.0	20.0	25.0	30.0	
10	32								
15	46	32							
20	68	46	32						
25	68	46	32						
30	100	68	46	32					
35	100	100	68	46	32				
40	150	100	68	46	32	32	32		
45	220	150	100	68	46	46	32	32	
50	320	220	150	100	46	46	46	32	
55	460	220	150	100	68	68	68	46	
60	460	320	220	150	68	68	68	46	
65	680	460	320	220	150	100	100	68	
70	1000	680	320	220	150	100	100	68	
75	1500	680	460	320	220	150	150	100	
80	2200	1000	680	460	220	220	220	150	
85	3200	1500	1000	460	320	220	220	150	
90	3200	2200	1000	680	460	320	320	220	
95		3200	1500	1000	460	460	320	220	
100		3200	2200	1000	680	460	460	320	

Table 2: Recommended viscosity grade for enclosed gears based on the pitch line velocity of the slower speed gear and operating temperature



GEAR LUBRICANT SELECTION

In some instances, such as high or low operating temperatures or the desire to extend oil drain intervals, the use of high performance gear oils, including synthetics, is recommended. Where their usage can be financially justified, these lubricants offer significant benefits in low temperature start-up, high temperature thermal and oxidative stability, and improvements in film strength. Although there are several different types of synthetic gear oil, the two most common are polyalpha-olefin (PAO) and poly-alkylene glycol (PAG). Both have their relative merits, but their use should be considered judicially since the cost of switching to a synthetic gear oil can often far outweigh the benefits. When selecting synthetic gear oil, it's not uncommon to drop down one ISO viscosity grade from the OEM recommendation since the effective viscosity of a synthetic gear oil at elevated operating temperatures often matches that of the OEM recommended mineral oil grade due to the higher viscosity index of synthetic fluids.

Increasingly, PAG fluids are being used in gearboxes, including initial factory fill. While these types of lubricants offer some distinct advantages, including lower coefficients of sliding friction and better deposit control, care must be exercised when using PAG fluids since they are chemically incompatible with hydrocarbon fluids, including conventional mineral-based gear oils and PAO synthetics.



CONTAMINANTS IN GEARBOXES

COMPREHENSIVE CONTAMINATION CONTROL

Most contamination control strategies for gear drives focus too much on the dirt you can see, but the dirt we are most concerned with we cannot see. The particles that do the most damage are in the 2-5 micron range. This is the range of clearance in many sensitive components including servo valves, bearings and the pitch line of gear teeth.

To put that in perspective, a human hair averages 60 microns in diameter and the extent of human vision is approximately a 40 micron black dot on a white background.

To illustrate the effect of silt-sized contaminants, consider the graph shown in Figure 1 that shows the effects of fluid cleanliness on gearbox life expectancy. For many industrial gear drives running in typical plant environments with no silt control, the level of fluid cleanliness is often 22/20/17 (c) or dirtier. Based on the data presented in Figure 3, by maintaining fluid cleanliness at or below the optimum levels of ISO 18/16/13 (c) or cleaner, the life expectancy of the gears and other oil wetted components of the gear drive should be at least twice as long.



CONTAMINANTS IN GEARBOXES



Table 2: Recommended viscosity grade for enclosed gears based on the pitch line velocity of the slower speed gear and operating temperature

For water, a similar relationship holds between the level of contamination and the mean time between failures (MTBF). While the hygroscopic nature of oil makes it next to impossible to keep gear oil completely free from water, keeping water at or below the saturation point is the key. For many conventional gear oils, the saturation point of the oil at typical gearbox operating temperatures ranges around 400 ppm-600 ppm of water (0.04%-0.06% by volume). For a gearbox that holds approximately five gallons (20 liters) of oil, that equates to as little as 1½ teaspoons of water. Once the saturation point is exceeded, water will come out of solution into either the free or emulsified state. In this condition, the deleterious effects of water, which include loss of film strength, rust and corrosion, increase exponentially, seriously impacting equipment life.

This problem is most pronounced in gear drives that operate intermittently at low ambient operating temperatures. While 500 ppm of water in a gearbox operating at 140 F (60 C) typically will be all in the dissolved phase, shutting down the gearbox and allowing the oil to cool to 32 F (0 C) will cause most of the water to come out of solution.

Water also has a secondary effect on gear oils. Many of the additives used in gear oils are either water soluble or react with water. As such, whenever gear oil is left saturated with moisture due to either an extended shut down period or inappropriate new oil storage, additives can be either stripped or rendered ineffective. For most gear oils, water levels need to be kept dry enough so that any water that may be presented is completely dissolved. While not possible in some circumstances, practical limits for water in gear oils should be below 200 ppm-300 ppm (0.02%-0.03% by volume).



GEARBOX CONTAMINATION CONTROL

CONTROL YOUR CONTAMINANTS

Controlling contaminants within gear drives requires a concerted effort to assess each possible ingression source. Even something as simple as changing the oil can result in a significant amount of particle and moisture ingress unless the utmost care is taken. The first step in controlling contaminants is to review all possible ingression sources. These include both contaminants introduced from the outside, as well as contaminants created internally. Some of the more common sources include:

- Airborne dirt and moisture
- Water from wash down/sanitation
- Water from the production process
- Unfiltered new oil
- Internally generated wear debris
- Byproducts of oil degradation



GEARBOX CONTAMINATION CONTROL

With any contamination control strategy, the first place to start is to look at external sources of ingression. Most external contamination ingression in gearboxes comes from the breather/vent port. This stands to reason since many gearbox designs utilize a combination breather and fill port. Careful examination of the fill port/breather cap often reveals little more than a course sponge or wire wool/mesh to restrict contamination ingress. Wherever possible, older style breathers or combination breather/fill ports should be replaced with modern, high efficiency breathers (See Figure 4). In very low humidity environments, standard particle removing breathers should be used. These should be sized based on the anticipated air flow requirements and rated to remove silt-sized particles in the sub-five micron range. However, in most plants and industrial environments, moisture is an issue, especially since many gear oils are hygroscopic. Where airborne humidity or process water ingression is an issue, it's necessary to remove not just silt-sized particles, but also moisture from the air as it enters the gearbox headspace. This requires the use of desiccant breathers, which include both a particle removal element capable of eliminating silt-sized particles and a desiccating media, often comprised of silica gel, to remove all traces of moisture from the air as it enters the gearbox.



Figure 4: Old style breather/fill ports should be replaced with desiccant breathers to prevent particle and moisture ingress, as well as quick connects to all new oil to be added and offline filtration to be performed non-intrusively

While desiccant breathers are effective for removing particles and moisture from the air, in some environments where a lot of moisture and humidity is present, the life expectancy of the silica gel can be a little more than a matter of weeks. Under these circumstances, a more cost-effective solution may be the use of a hybrid breather that remains sealed when no air exchange is required. In this case, thermal expansion and contraction of the headspace as the gearbox

heats up or cools down is controlled through a bladder that expands or contracts to equalize pressure. If a significant pressure differential exists, for example during start-up, a series of check valves on the bottom of the breather open to equalize pressure between the gearbox headspace and the environment. Unlike standard desiccating breathers, the advantage of hybrid breathers is that the system is nominally sealed, preventing contamination ingress and preserving the life of the breather. Depending on application and environment, these so-called hybrid breathers can last as much as five to 10 times longer than the life of a conventional desiccant breather.



GEARBOX CONTAMINATION CONTROL

Having a desiccant or hybrid breather and removing other sources of contamination ingress is an excellent first step in any gearbox contamination control strategy. Eventually however, there will be a need to open up the gearbox to change oil, check oil level, etc., and in doing so, it's easy to undo all the benefits provided by high-quality breathers. To illustrate this point, consider the way oil is changed on most splash lubricated gearboxes.

TYPICAL OIL CHANGE STRATEGY

Since the oil must be changed with the gearbox shut down, the oil inside the gearbox is typically colder than during normal operation. As the oil cools, the viscosity increases, making it difficult to drain all the old oil out of the drain port. To reduce the amount of time it takes for the oil to be drained, most mechanics are prone to removing the breather or fill port to increase the flow rate. However, by doing so, the effect on contamination control can be disastrous. Draining five gallons of oil from a gearbox requires the equivalent volume of air to enter through the open port, which in most ambient plant environments is enough to increase the effective ISO cleanliness code and moisture content within the gearbox by several orders of magnitude.



GEARBOX MAINTAINABILITY

THE SOLUTION

The solution for controlling contaminants is to configure the gearbox to remain sealed during all phases of normal operation, including routine planned maintenance such as level checks and oil changes. This can be easily achieved by modifying the drain and fill/breather ports with simple adapter kits that permit multiple access points to the gearbox without opening the gearbox sump to the environment. This kit, which is used to replace the breather/fill port, allows for the installation of a desiccant breather and quick-connect fittings to facilitate the addition of new oil without opening the gearbox. By combining this adapter with a simple quick connect fitted on the drain, this gearbox can be maintained without ever being exposed to the ambient environment.



Maintaining the correct oil level is also critically important, particularly in smaller, splashed lubricated gearboxes where an oil level variation as small as 1/2-inch can mean the difference between success or lubricant starvation. Because of this, routine oil level checks are an important part of any gearbox preventive maintenance program. To facilitate level checks, many gearboxes are equipped with a dipstick style level indicator. Although these are effective when the gearbox is shut down, they cannot be used effectively with the gearbox running and often times create an ingression source for contamination. Wherever possible, external level gauges should be used. The most common type is a brass fitting with a glass or plastic clear tube. It allows the oil level to be quickly and easily checked without pulling a dipstick or opening up the gearbox – ideally to the fill port adapter – so the system can be kept free of contamination but still read the correct level. High and low (shut down and running) levels should be marked on any level gauge to indicate the correct oil level under any operating condition.

The importance of isolating the lubricant from the ambient environment cannot be overstated. Even oil changes can be done without exposing the gearbox to the outside environment by using a filter cart with a manual filter bypass to pump the drain using the quick connect and then using the quick connect on the fill port adapter to add the new oil without removing the breather or adapter. The optimum configuration for maintaining control of contaminants is shown in Figure 5.



Even with a good quality desiccant breather, adapter kits and quality seals, gearboxes still need to be filtered to achieve optimum levels of contamination control. But while some gearboxes with circulating oil have full flow filters, most gearboxes have no permanent filtration, and even where filtration is present, most full flow gearbox filters do very little to remove siltsized particles or moisture.

For gear drives, the secret for precision contamination control is the use of supplemental offline filtration. This simple strategy, which involves taking a small amount of oil from the wet sump, passing the oil through a high efficiency filter and returning it back to the sump, has proven to be very effective at maintaining optimum levels of cleanliness in gearboxes.



The simplest is to use a permanently installed bypass filtration system. This system has a pump and two filter housings: the first housing being used either to remove water or large particles, with the second filter rated to remove silt-sized particles. Flow rates for this type of system should not exceed 10% of the total oil capacity (for example, no more than 5 GPM for a 50 gallon sump), but even with just a small amount of oil passing through the filter at any given time, these types of systems can effectively control particles and moisture to very low levels.

In some instances, installing a permanent filtration system on all critical gearboxes within a plant can be cost prohibitive. Under these circumstances, a portable filter cart can be used in conjunction with quick connects on the drain and fill port adapter to periodically decontaminate the gearbox. Just like permanent systems, flow rates should be controlled to 10% or less of the total volume to prevent foaming, aeration and oil starvation to the gearbox, while the use of two filters in sequence allows for moisture and large particle control, as well as small particle filtration. Ideally, whenever using a portable filtration system, the cart should be left connected for a sufficient time so the oil is passed through the filters at least seven and preferably ten times. For all but the largest gearboxes, this equates to a matter of hours, making the use of a single cart for a multiple gearbox highly practical. Wherever possible, a single cart should be dedicated to a single type and grade of lubricant to avoid cross-contamination.



CONTAMINATION CONTROL IS POSSIBLE

REAL-WORLD CASE

Controlling contaminants in gearboxes can be challenging, but with a concerted effort, it's possible to control particles and moisture to very low levels. Figure 6 shows the impact that 24 hours of offline filtration can have on a roll drive gearbox on a paper machine, with particle levels dropping from 24/21 (R6/ R14) to a remarkable 12/9!



Before Filtration x/24/21

After Filtration x/12/9



GEARBOX OIL ANALYSIS

THE STRATEGY

For critical assets, we all know that condition-based maintenance (CBM) is the most effective reliability strategy. But for CBM to be truly effective, we must have both predictive and proactive data. But not just any old data; the data must provide sufficient information so we can make a judgment call on whether a machine is running normally, is starting to show signs of deterioration, or is close to failure.

So what data do we need to effectively conduct CBM on gearboxes? When it comes to predictive maintenance (PdM) data, there are, of course, a number of choices, from vibration analysis to thermography to ultrasonics to oil analysis. With such a wide array of options, the most obvious question is, which one's better? The answer, of course, is it depends. It depends on the machine, the failure mode and the degree to which the failure has progressed. Take, for example, the issue of soft foot on a gearbox caused by a poor base mount.





A vibration analyst skilled in doing phase analysis can easily pick up on this problem using vibration analysis long before the problem shows up in oil analysis. But turn that around; incipient gear wear caused by lack of oil film or incorrect oil viscosity will always show up first in oil analysis. For gearboxes, like every other asset, a variety of PdM tools are required to effectively address all possible and likely failure modes.

Having said that – and here's where I admit there might be some bias – in my opinion, poundfor-pound oil analysis is a far more effective predictive tool for gearboxes than any other PdM technology. Typical for most common gearbox failures, oil analysis will identify a problem well in advance of vibration analysis. To illustrate this, I always think back to an example from early on in my career from a large Renk gearbox at a cement plant. From oil analysis, we found a slow increase in iron wear month-by-month with no apparent change in vibration signature. But fully four months to the date from when the first abnormal oil sample appeared, the vibration analyst started to pick up evidence of a cracked inner race on the input shaft bearing. Once diagnosed, the problem was corrected during the plant's annual maintenance shutdown with no unscheduled downtime.

In this example, oil analysis was what I like to call the "sharp stick." It prodded the maintenance team into action to pay more attention to this critical gearbox, while vibration analysis provided a level of diagnostic specificity – cracked inner race on the input shaft bearing – that oil analysis likely would never provide. But for oil analysis to be effective, there are certain rules we have to apply. First and foremost, we have to have a good sample. The old adage, garbage in, garbage out, certainly holds true for oil analysis. Beyond sample quality, performing the right series of test is also critical. Let's look at the critical success factors for oil analysis on gearboxes.



SAMPLING INDUSTRIAL GEARBOXES

THE STRATEGY

Gearboxes are the most common industrial component type that requires oil sampling. Unfortunately, they are also the most frequently incorrectly sampled component. The most common method by which gearboxes are sampled is to use a vacuum sampling gun and flexible plastic tube inserted through the fill port or breather port, a method often referred to as droptube sampling. Not only does this allow for the introduction of contaminants through the open port, the use of flexible tubing can also result in tremendous variation within the oil level (top, middle, bottom) and within the gearbox (bottom, gear case wall, etc.) itself.



SAMPLING INDUSTRIAL GEARBOXES



Figure 7: Ideal location for sampling a circulating wet sump gearbox

A far better option for sampling is to install a dedicated sample port in the correct location. For wet sump circulating systems, the best place for a sample port is after the oil pump, but before any full flow filters (Figure 7). Taken from this location, the maximum amount of information about the degree of wear debris, contamination and fluid condition will be obtained.

Where no oil circulation system exists and oil is distributed by internal splash, sample ports should be installed on a suitable location using an existing port. Oftentimes, the dipstick port, level port, or drain port all can be modified with suitable sampling hardware to effectively

extract a representative sample (Figure 8). Ideally, the sample tube should be installed such that the sample is being taken approximately halfway up the oil level, at least 2 inches or 5 cm away from the walls and any rotating elements within the gearbox. Once installed, the sample can be extracted using an appropriate threaded adapter coupled to a standard vacuum oil sampling gun. Facilities that have switched from drop tube sampling to the use of a dedicated sample valve often see an overall drop in baseline values for wear debris and contamination, as well as a significant reduction in sample-to-sample baseline variability (noise), significantly increasing the sensitivity of oil analysis as a diagnostic tool.

Compared to other predictive maintenance tools, such as vibration analysis and thermography, oil analysis is typically a leading indicator of a wear problem, often showing up weeks or months in advance of any significant change in vibration signature. This is especially true for low speed gears and bearings in a multi-reduction gear drive where vibration analysis is typically less sensitive due to difficulties with slow speed accelerometers. While oil analysis will typically show the problem first, vibration analysis is far better at localizing the exact component and failure mode. But, both are required for an effective predictive maintenance program.



Figure 8: Sampling a splash lubricated gearbox from the drain using an oil sample port



TEST FOR GEARBOXES

THE METHOD

Aside from sample integrity, key to oil analysis for gear drives is selecting the correct series of tests. While standard tests, such as elemental analysis and viscosity, are important, it's equally important to look at other test methods to optimize the detection capability of oil analysis. This is particularly true for wear debris detection. When gearboxes start to wear, most wear debris is in the excess of five to 10 microns in size. At this particle size, the instruments used to provide elemental wear debris analysis (e.g., ppm of iron, copper, etc.) are blind, meaning a problem may go undiagnosed. Under these circumstances, large particle tests, including ISO particle counting or ferrous density analysis, is strongly recommended. To further diagnose active wear problems, access to wear particle morphology (size, shape, color, etc.) using either analytical ferrography or automated particle shape classification (e.g., LaserNet Fines) is also highly recommended.





While an annual or semiannual oil change is fine for smaller gearboxes, it makes sense for larger gearboxes to use oil analysis for condition-based oil changes, changing the oil based on oil analysis rather than time. But for condition-based oil changes to be effective, we need to look beyond viscosity. Typically viscosity will only change when the oil is 90 percent to 95 percent degraded, which is too late to prevent deposit and other long-term problems from occurring. Instead, we should use a combination of acid number and Fourier transform infrared spectroscopy (FTIR) oxidation as an indicator of lubricant health. Since many gear oils start with high acid numbers in the 0.5 to 4.0 mg/KOH range due to the extreme pressure (EP) or anti-wear (AW) additives used in these oils, FTIR is a good backup test, provided a good new oil baseline has been taken.

For gearboxes where water is a problem, we also need to be careful about the test method used. While FTIR or a simple crackle test can be good indicators of gross water ingression, the Karl Fischer moisture method (ASTM D6304) is preferred where accurate, trendable data is required. An ideal test slate for industrial gearing should include the tests listed in Table 3.

Table 1 - Ideal test slate for industrial gear drive						
Test	Standard	Benefit				
Wear debris	ASTM D6185	Early warning of incipient wear				
PQ index or DRIII	-	Large particle ferrous wear				
Viscosity	ASTM D445	Confirmation of correct oil viscosity				
Particle Count	ISO 4406:99	Measures degree of particle contamination				
Water	ASTM D6304	Measures water content in the oil				
Acid Number	ASTM D664	Determines the rate of oil oxidation				
FTIR	-	Evaluates the degree of lubricant degradation				

Table 3: Basic Oil Analysis Test Package for Gearboxes

Sampling frequencies for gearboxes also should be considered carefully. While quarterly sampling may be adequate for slower turning gearboxes (< 50 RPM on the lowest speed shaft), for higher speed gear drives or very critical applications, monthly or even biweekly sampling is recommended. This is particularly true for newer gear drives where power densities are much higher and main gears are far more sensitive to particles, moisture and other poor lubricant conditions.



THE CONCLUSION

A SUMMARY

Gearboxes are commonplace across many different industries. Because of their size and apparent robust nature, gearboxes are often overlooked when it comes to precision lubrication. But with a little care and attention, focusing on getting the right lubricant in the right place at the right time while maintaining the oil in a clean, dry, cool condition, gear drives can provide reliable operations for many years.



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