

What's in the Box?

Evolution in gearbox technology and lubrication practices

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Robust and reliable, most gearboxes/reducers are designed to provide many years/cycles of service with typically very limited maintenance requirements. Recent trends in equipment design require them to operate with increased power requirements, higher speeds and higher stress values that put an added emphasis on initial equipment set-up, maintaining operating conditions, and the quality and performance of the lubricant to ensure reliable operation. While incorrect operating temperatures, misalignment and resonant vibrations typically provide a slow path of component degradation, lubrication condition and lubricant contamination will lead to rapid and unnecessary wear generation and the eventual failure of the unit itself.

Introduction

Powerful computer systems optimizing finite element analysis, logarithmic contact profiles of bearing roller and raceways and gearing sets have been combined with improved quality of materials and finish which has resulted in the reduction of gear size while increasing gearbox efficiency. These changes are translated into higher power requirements, higher speeds, and higher stresses, all relying on the quality and performance of the lubricant. Lubricant suppliers continually meet the upcoming design changes of equipment by improving base stock quality and performance coupled with the addition of sophisticated new additive packages.

It is unfortunate, that with all the effort and expense to achieve reduced size, increased reliability, speed of operation, efficiency and safety, that component and lubricant failure due to fluid contamination and/or the loss of essential lubricating properties still remains the leading cause of premature failure of most gearboxes. It is inevitable that rotating components in the gearboxes will eventually fail. Numerous documented studies by both end users and the equipment manufacturers have shown that efforts to maintain the physical and chemical properties of the lubricant while reducing contaminant levels will greatly increase the reliability and the service life of the components.

Lubrication

Equipment designers/manufacturers (OEM) and operating manuals reflect the minimum lubricant requirements for operating their equipment. These requirements include the type of oil, the oil's specifications and typical operating temperatures. These requirements vary based on the three major classes of gears:

- Spur, bevel, helical, herringbone and spiral
- Worm
- Hypoid

The differences in gear teeth actions and materials influence the formulation and properties of the lubricants required but the size, speed, load, and temperature of the bearings typically determine the viscosity requirements. During operation, the heat generated by metallic friction between the tooth surfaces and by fluid friction of the oil, will cause the temperature of the oil to rise. The final operating temperature is a function of both this temperature rise in the oil and the ambient temperature surrounding the gear case. Thus, a temperature rise of 90°F (50°C) and an ambient temperature of 60°F (15.6°C) will produce an operating temperature of 150°F (66°C). The same temperature rise at an ambient of 100°F (38°C) will produce an operating temperature of 198°F (88°C). For gear sets equipped with heat exchangers in the oil system, both the ambient temperature and the temperature rise are less important since the operating temperature of the oil can be adjusted by varying the amount of heating or cooling.

The lubricant is thrown from the gear teeth and shafts in the form of a mist or spray. In this atomized condition, it is exposed to the oxidizing effect of air. Bearing operating temperatures may be increased above normal by heat conducted to the bearing from a hot shaft, or spindle, or by heat radiated to the housing from a hot surrounding atmosphere. This high temperature will also increase the rate of deterioration due to oxidation. Sludge or deposits formed as a result of oil oxidation, can restrict oil flow or result in an insulating deposit on the internal surface of the gear case to decrease cooling and cause further increases in the rate of oxidation. Allowing the gear case to become covered in cement dust, wood chips, debris, or even multiple layers of paint will create an insulating effect allowing the internal temperatures to rise well above the OEM planned range.



Figure 1

The viscosity of the lubricant decreases drastically with this increasing temperature. Even though the lower viscosity reduces somewhat the churning losses, it also decreases the ability of the lubricant to fulfill its main function, namely separate the components in contact by building an Elasto-Hydrodynamic (EDH) film. Without this separating film the components would score, wear out, pit and fail within a short period.

Temperature Control

OEM's recommend an optimum operating viscosity for their equipment in order to perform and operate within the original design parameters. Maintaining an operating temperature that achieves the OEM recommended viscosity becomes in many cases the responsibility of the end user. The temperature of a gearbox in operation will increase until the heat balance of the internally generated heat plus the external imposed heat reaches equilibrium with the dissipated heat. If this heat cannot be dissipated by radiation through the gearbox housing surfaces and through convection to the surrounding air, surrounding structures and components, then an alternate cooling system (heat dissipation) should be considered.

Heaters and/or coolers remain the standard methods of maintaining the designed system operating temperature of the lubricants. However, many gearbox/reducer manufacturers do not install them on the units as standard equipment. If supplied, heaters with regulating valves in water/oil heat exchanger and temperature switches for air/oil system components are used to control the operating temperature range of the lubricant. After initial set-up of these components, the condition can be monitored effectively for operation by the ability to maintain the correct operating temperature settings. Regulators that are not operating correctly or improperly set will result in an unacceptable operating viscosity range.

A critical link in maintaining lubricant and equipment health requires temperatures of the lubricant be monitored, recorded and trended. If the gearbox is not thermo-coupled to a display panel or computer system, then a permanently installed thermometer or a non-contact temperature measurement can be obtained by using a portable "Raytek" style IR instrument. To assist in monitoring peak temperature measurements, tell-tale temperature strips can also be used to record temperature extremes. (See figure 1)

Lubrication Volume

Typical design methods for applying lubrication to the system components application systems depend mainly on the running speed of the bearing. These methods can vary but usually follow the following guidelines:

- Oil Bath and splash systems - low and medium speeds
- Circulation systems - medium speeds
- Spray or mist - high speeds

In oil bath or splash systems, the oil level in the gearbox is maintained so that the teeth of the bottom gear just dips into the oil. Alternatively a pressure circulating system may be used in which oil is sprayed on the teeth close to the point of engagement and is re-circulated either directly from the bottom of the gearbox or by the way of the oil tank.

In an oil bath or splash system, overfilling a gearbox sump can be just as damaging as under-filling. Overfilling may cause air entrainment and foam, overheated oil and leakage due to overflow. Over time oxidation may occur due to increased temperatures and exposure to air. Marginal lubrication can also result in pitting because oil film does not spread the contact (cushion) over a sufficiently wide area. This can result in metal-to-metal contact in the load zone.

Level gauges and viewing windows allow for visual inspection of the fluid levels and oil condition (cloudy, dark, foaming etc.) and should be recorded and trended along with top-up activities. These results can be used to determine changing conditions and increased or decreased monitoring / testing activities.

Contamination Control

A contaminant is any substance that enters a system and affects or interferes with the function of the system's fluid and/or the operation of its components. Solids, water and various gases (primarily air) entering or existing in a system can have mechanical or chemical interactions on the oil and/or the equipment. Fluids must be protected and monitored from such contaminants by a comprehensive contamination-control program incorporating prevention of fluid contamination, removal of contaminants, and fluid-system condition monitoring.

Knowing the contaminants and their origin will provide clues as to how they might be excluded, removed, or their effects neutralized. Contaminants can be built-in due to manufacturing/maintenance processes, or they may enter a system while parts of it are open during construction or repair. Also, they can be internally generated as a result of system operation, such as wear debris, compounds of chemical reactions, or substances resulting from decomposition of the fluid or its additives. The most common entrance of contaminants from the atmosphere is either through breather caps, imperfect seals, or other unplanned openings during normal operation of the equipment. This would include the addition of fluid during initial fills or top-ups.

OEMs will provide their own equipment specific requirements for targets and limits of contamination in their maintenance manuals or service bulletins. In most cases, the end user will not obtain these targets unless a further investment into contamination control equipment is provided.

TYPICAL GEARBOX / REDUCER (OEM) REQUIREMENTS

	Gearbox (OEM)	Bearing (OEM)
Filtration (ISO 4572)	β25 =200	β 6 = 200
ISO Particle Count (ISO 4406)	Max 21/15	Max 14/11
Water Contamination	Max 0.05% (500 ppm)	Max 0.05% (500 ppm)

Breathers

As system temperatures or environmental temperatures change, the gearbox or bearing housings will have a movement of air. Whether the housing is inhaling or exhaling, the movement of air is always trying to equalize the temperature difference from the inside to the outside of the housing or in reverse direction. Exhaling in many cases carries a fine oil mist to the outside environment, while inhaling carries the industrial environment along with nature's environment into the gearbox

or bearing housing. The area above the lubricant level but inside the housing is classed, as “Headspace” and managing the quality of the environment in this headspace is one step in controlling the contaminants entering the lubricant.



Figure 2

Countless articles have been published, and new research and oil testing techniques are always trying to prove the effects and the destructive nature of contamination on lubricants. Controlling contamination that enters the headspace environment can reduce and in some cases eliminate many of the potential root causes of lubricant failure. Most housings have a planned method or location for breathing; otherwise a build up of pressure would cause seals to fail resulting in external leakage of the lubricant. Since many of the breather systems on gearbox housings are either just a small hole in the cap or a very poor quality strainer style breather, they typically will not prevent the required contaminants from entering the system to maintain the OEM fluid requirements.

Upgrading breathers that control contaminant ingress starts with understanding the environment around the housing. An effort to stop the ingress of water in a continuous hot dry environment will result in an investment, which would not have any financial return on that investment. Stopping only water ingress in an environment of high humidity and excessive airborne contamination will not successfully stop the ingress of the destructive powers of the airborne contamination. Oil sampling and testing, coupled with investigating the surrounding environment should provide a direction in selecting the correct contamination retention method, a method that provides the most economical and effective retention of the known contaminants from reaching the headspace of a specific piece of equipment. In cases of extreme environmental contaminants or considerable air movement within the housing, there could be a need for an external bladder system (See figure 2). The attached chart lists some of the breather exclusion methods along with the contaminants that they restrict from entering the housing headspace.

METHODS OF EXCLUSION	CONTAMINANTS EXCLUDED				
	Solid Particles >50 Microns	Solid Particles <10 Microns	Solid Particles <5 Microns	Airborne Water	Fumes / Odor
Open Vent					
Metal Screen	X				
Cellulose Filter	X	X			
Filter Pads	X	X			
Microglass Filter	X	X	X		
Desiccant Silica Gel				X	
3m Filter / Desiccant Silica Gel	X	X	X	X	
Activated Carbon					X
Activated Carbon / 3m Filter	X	X	X		X
3m Filter / Silica Gel / Activated Carbon	X	X	X	X	X
Expansion Bladder Systems	X	X	X	X	X

At some point, all styles of breathers that are not maintained will become plugged with debris resulting in an increase of internal pressure of the housing and the ultimate failure of the seals. Leaking seals in gearbox housings have become a common complaint in industry and the end result is typically the rework of the shafting material and the replacement of the seals due to the hard aggressive wear created by the abrasive particles attracted to the leaking lubricant. In too many cases the root cause (blocked or plugged breather) is not identified as the condition of the breather and is not monitored or replaced on a planned maintenance schedule.

Filtration

Once contaminants are in the fluid, settling, filtration/separation and fluid replacement may reduce contamination. For settling to occur, a contaminant must have a density greater than the fluid transporting it. The lower the density of a contaminant particle, the more buoyant it will be in a fluid. Many gearbox manufacturers have designed the gearbox housing to allow the

contaminants to settle out in areas that will not allow them to be redistributed into the system. Removal of these contaminants requires thorough flushing of the housing during the replacement of the lubricant. The best way to flush is to use compatible low-viscosity base oil, or a low-viscosity variation of the service oil that can be applied in a method that ensures that all the dead zones are cleaned and any debris is dislodged.

Maintaining the lubricant throughout its in-service life requires some form of filtration for the removal of accumulated contaminants. A properly designed high viscosity filtration system must be utilized that will supply the correct flow rate to perform the function of removing the targeted contaminants in a reasonable time frame. Re-circulating, kidney loop or auxiliary filtration, consists of a pump, filter, motor, cooler (if required) and appropriate hardware connections. Fluid is continuously pumped out of the reservoir, through the filtration system, through an incorporated temperature regulating system (if required), and back to the reservoir ensuring fluid conditioning regardless of the operating condition of the main system. These systems can be either portable or permanently retrofitted to the gearbox/reducer housing. The choice comes down to criticality of production (the need for reliability), safety and severity/penalty of failure.



Figure 3

Smaller, portable filter carts, and hand-held pump/motor/filter units are ideal for pre-filtering, flushing or transferring fluids into reservoirs. These off-line portable carts can be adapted to service many different gearbox/reducer housing in the same family of lubricants by adapting quick-connect self sealing fittings on the drain and fill ports (See figure 3). Care must be taken in selecting the right pump flow rate, filters, and conductor sizes to operate at higher viscosity gear oils. A properly designed filtration system will minimize operating costs by reducing lubricant and equipment damaging contaminants while assisting in extending lubricant life and ultimately the mean time between failures.

To measure and trend the contaminants and the effectiveness of the filtration system, an oil analysis program should be incorporated into the planned maintenance program. To initiate this program, strategically located test ports should be installed to provide trouble-free, repetitive and representative sampling of the lubricant contaminants along with consideration of monitoring the health of the equipment. This sampling method should allow the equipment to be tested under its typical operating condition while being non-obtrusive and maintaining a safe sampling method for the technician.

Summary

Temperature, pressure, contaminants, aeration, water, metal particles, and agitation all help to accelerate the oxidation process (destruction) of the lubricant. Combine that with the destructive nature of solid particles trapped between rolling elements, raceways and gear teeth, and emulsions created (lack of lubricating properties) by ingested water will ultimately result in the sacrifice of equipment performance and reliability.

Lubrication Management for Gearboxes/Reducers combines:

- Maintaining heaspace quality
- Operating within the designed operating conditions
- Use a dedicated and/or portable filtration for contamination control
- A competent oil analysis program for maintaining the specific physical, chemical and cleanliness standards throughout the life of the lubricant

The end result will be increased company profits by maintaining the functionality of the equipment for production.