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High Performance Industrial Gear Lubricants for Optimal Reliability

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

In recent years gearbox technology has advanced and Original Equipment Manufacturers (OEM) have required gear oils to meet the lubrication requirements of these new designs. Modern gearboxes operate under severe conditions and maintain their reliability to ensure end-user productivity. The latest generation of industrial gear lubricants can provide enhanced performance even under extreme operating conditions for optimal reliability and reduced cost of operation.

This paper describes how gear lubricants function in gearboxes and discusses the facts vs. myths of industrial gear lubricants. The paper will show how advanced gear lubricant technology can optimize the life of the gears, bearings and seals, resulting in reduced cost of operation. Opportunities to use advanced synthetic gear lubricants to achieve operational benefits in the areas of improved energy efficiency, wider operating temperature ranges, extended oil drain intervals and equipment life will be discussed.

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Types of lubricating film classifications

Knowledge of the types of lubricating film will assist in understanding the formulation and application of gear lubricants.

The two types of lubricating film relevant to gear lubrication are boundary and elastohydrodynamic (EHL). Understanding the characteristics of each of these is important in order to understanding the lubricant performance requirements.

Figure 1 shows that boundary lubrication exists during sliding motion where metal to metal contact occurs between the two surfaces. The coefficient of friction ranges from 0.1 to 0.15 between the metal surfaces in this lubrication region. In the absence of specialized antiwear additive technology increased wear rates will occur during boundary lubrication. The amount of wear will depend on temperature, speed, surface finishes, material, lubricant viscosity and effectiveness of the additives. Gears operate with combined sliding and rolling motion above and below the pitch line. Under low speed and high temperature conditions the EHL film will be relatively thin and boundary conditions will dominate (see figure 2).

Elastohydrodynamic lubrication (EHL) occurs when the lubricant film thickness reduces metal to metal contact and local contact pressure between the surfaces is high enough to cause elastic deformation. This creates a small but finite area of contact often referred to as the Hertzian contact zone. The high contact pressure also acts to increase the lubricant

viscosity as it is drawn into the contact zone. This increase in viscosity helps generate the lubricant film that maintains the separation of the two surfaces. With this high viscosity and the short time in the contact area, the lubricant cannot escape and separation of the surfaces is achieved. The film thickness generated in EHL contacts of this type is very thin and is typically between 0.1 to 0.5 micro meters. Film thickness is a function of temperature, speed, load, geometric conformity of the surfaces, initial lubricant viscosity and the rate at which viscosity increases with pressure. This last characteristic is often quantified by the pressure-viscosity coefficient of the lubricant and varies with its composition.

Surface finish also influences the state of lubrication between two surfaces. The more polished the surface, the lower the lubricant film thickness that is required to achieve separation between the contacting surfaces. This is often quantified in the Lambda value or specific film thickness. This is merely the ratio of the EHL film thickness to a measure of the combined surface roughness. Thus a high specific film thickness indicates that the surfaces are well separated. Conversely a low specific film thickness indicates poorer surface separation which may result in higher friction and potentially increased rates of wear.

Two examples of EHL lubrication classification are when gear teeth mesh at the pitch line and in the load zone of anti-friction bearings (see Figures 3 and 4).

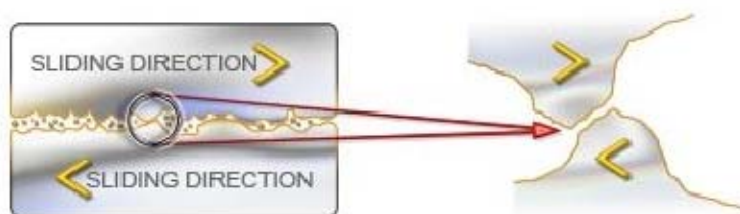


Figure 1. Boundary lubrication

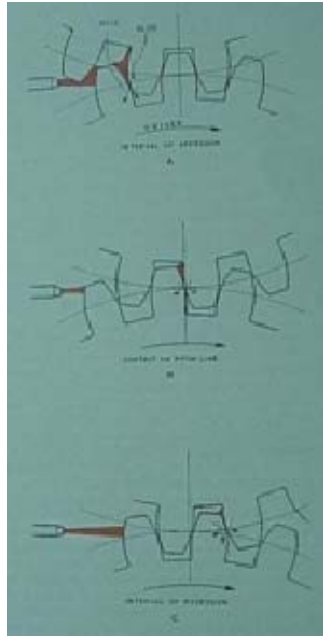


Figure 2. Gear rolling and sliding lubrication

Gear lubricant requirements

The lubricant formulator must consider many factors and components in developing a proper lubricant for an enclosed gearbox. The most important components are the gears (i.e. gear teeth), bearings and seals. The factors influencing the lubricant and the reliability of the gears, bearings and seals are;

- Gear type
- Gear speed
- Reduction ratios
- Operating temperatures
- Filterability
- Input power
- Load characteristics
 - Shock in a steel mill
 - Steady in a power plant cooling tower

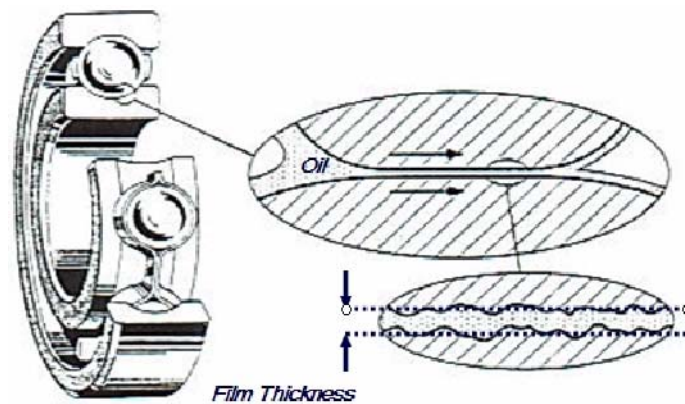


Figure 3. EHL in bearing

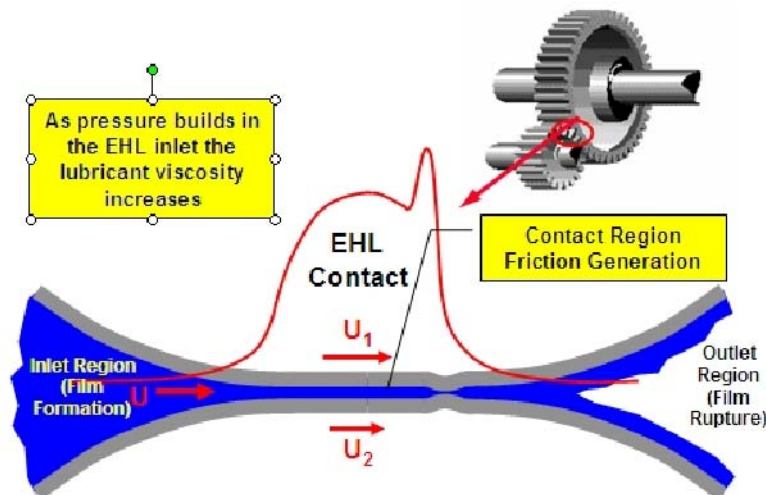


Figure 4. EHL in gears

- Drive type
- Application method
- Water contamination
- Ambient conditions
 - Arctic temperatures below -20°F
 - Tropical – high humidity temperatures above 100°F
- Maintenance access
 - Easy access – walk up to the gearbox
 - Located under an evaporative type cooling tower
 - Located above the ground in a wind turbine or overhead crane
- Industrial specifications
 - AGMA (American Gear Manufacturing Association)
 - DIN (Deutsches Institut für Normung)
- Original equipment manufacturers (OEM) specifications

The goal is to develop a lubricant that uses high performance base stocks balanced with the proper additive technology to achieve the optimum performance and reliability of the gearbox.

When gearbox operating conditions are severe, such as extreme temperatures, loads, and speeds, synthetic lubricants may be necessary for reliable operations. A synthetic lubricant that offers extended drain interval may also be desirable where equipment is not readily accessible. An example of an application that meets the preceding criteria would be gearboxes in wind turbines.

Gear lubricant characteristics

The necessary characteristics for gear lubricant can be stated as:

- Correct viscosity at operating temperatures to assure distribution of the lubricant to all contact surfaces and formation of an EHL film over the range of operating speeds and loads.
- Adequate low temperature fluidity to permit circulation at the lowest expected start-up temperature.
- Chemical stability to minimize oxidation under elevated temperatures and agitation in the pres-

ence of air and to provide the desired lubricant life for the maintenance service intervals.

- Good demulsibility to permit water separation for removal.
- Good antiwear performance to protect against wear under boundary lubrication
- Extreme pressure additives to minimize welding of metals under excessive loads.
- Low traction to control operating temperatures under severe service.
- Anti-rust properties to protect gears and bearing surfaces from rusting.
- Non-corrosive so that gears and bearings will not be subjected to chemical attack by the lubricant.
- Foam resistant to allow entrained air to separate from the lubricant.
- Compatible with commonly used seals.

A properly enclosed gear lubricant is a balanced formulation that will provide gear protection, bearing protection, corrosion/rust resistance, seal compatibility, filterability, oxidation resistance and anti-foam/air release (see figure 5).

Gear protection

The gear lubricant functions are to cool, to reduce wear, and to assist in sealing for optimal protection of the gearbox components. An area of concern for lubricant gear protection is excessive wear. Several types of wear might take place including pitting, micropitting, and scuffing.

Pitting can be in the form of micropitting or macropitting. Micropitting is surface metal fatigue that causes the tooth profile shape deviations which can reduce gearbox efficiency, increase noise, and vibrations. Two commonly used terms to describe micropitting are "grey staining" or "frosting" of the gear tooth face. Contact stresses located below the pitch line (dedendum) of the driving gear tooth are higher because of the shorter radii of the tooth curvature (see figure 6).

Gears that are overloaded for any reason will develop fatigue failure and pitting of surface metal will occur in the dedendum area after long periods of time. As the pitting increase it can be called macropitting. If an overload is great enough this type of fatigue failure could occur in a relatively short period of time (see figure 7).