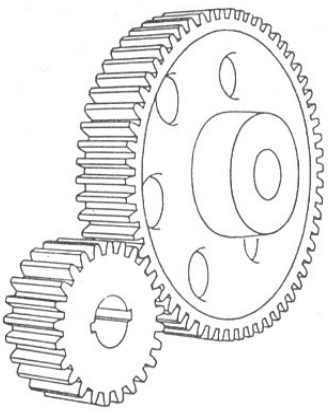
Techni-Tips 110

A Publication of the Lubrication Engineers Technical Department

Gears and Gear Lubrication

Modern gears are performing heavier work and carrying greater loads than ever before. Gear manufacturers are redesigning, modernizing and using finer steels to produce precision gears that will give better performance. Production demands are forcing the user to raise production above rated machine capacity. Many times this is done deliberately, with the knowledge that gear life will be reduced, but that the increased cost will be offset by increased production.

In the automotive, aviation and marine areas, as well as in industry, there is an increasing demand for more power in smaller packages. Gears are used to transmit this power and the same squeeze is on the gearbox, so a means must be found for increasing the load capacity of gears.



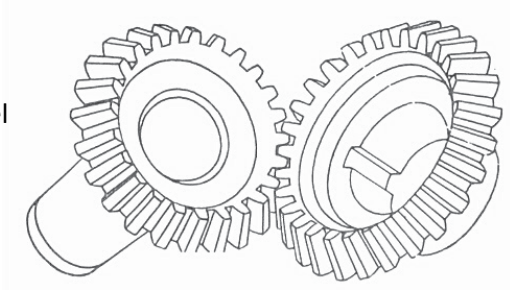
The Spur Gear

Lubricant manufacturers have helped in addressing this need by developing better gear oils to help safely carry these increased loads. Lubrication Engineers continues – with extensive research and testing programs – to produce tougher lubricants to stay ahead of the increasing demands of industry.

Types of Gears

Spur

The spur gear is a cylinder. The teeth are cut parallel with the axis on the surface of the cylinder. Spur gears are most commonly found on industrial machinery working under ordinary conditions at moderate speeds and tooth pressures.



The Bevel Gear

Bevel

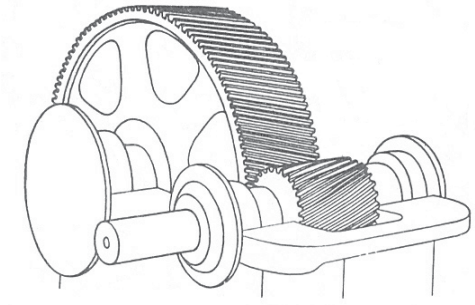
The bevel gear has teeth cut on an angular surface, like a section of a cone. Bevel gears are used for the transmission of motion between shafts with intersecting center lines. This is usually 90 degrees.

Spiral Bevel

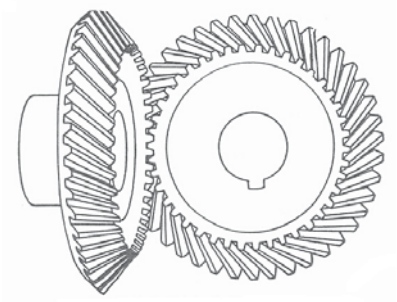
The spiral bevel gear represents cone surfaces, as does the bevel, but with the teeth spiraling around the cone. It is also applicable to nonparallel shafting, where it is usually termed an angle drive.

Helical

The helical gear resembles the spur gear in that the teeth are cut on a cylinder. The teeth on the helical gear, however, spiral around the cylinder rather than being cut parallel to the gear axis. The helix provides smoothness of operation.

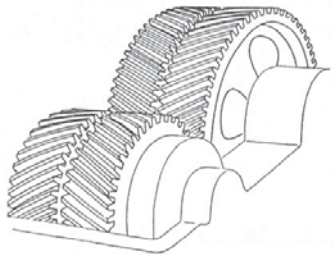


The Helical Gear



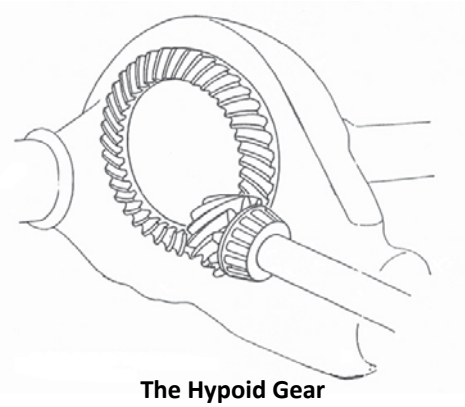
The Spiral Bevel Gear

Herringbone
The herringbone gear is similar to two helical gears having reversed directions of spiral. They are placed side by side so that the teeth come together to form a chevron pattern. Spiraling the teeth in both directions neutralizes end thrust.



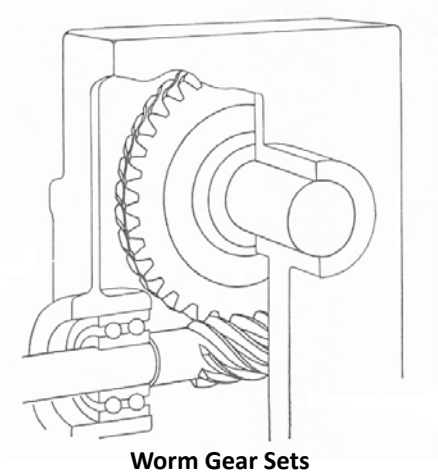
The Herringbone Gear

Hypoid
The hypoid gear is a spiral bevel with the pinion lowered below the center line of the driven gear. It is this design feature that led to its early use in automobile rear axles, because by lowering the propeller shaft it was possible to lower the car. The hypoid gear develops a longitudinal sliding motion between the teeth of the gears in contrast to the conventional spiral bevel gear where motion is predominately rolling. This greater sliding action between the teeth creates a wiping effect, along with high tooth pressures. The hypoid gear is being used more and more in trucks because the pinion is larger and stronger than a corresponding bevel pinion. So far, industrial applications have been limited.



The Hypoid Gear

Worm
The two members of a worm gear set are known as the worm and worm wheel or gear. The worm resembles a screw, although it is really a special form of helical gear and its teeth are referred to as threads. The worm is usually made of hard wear-resistant steel. The worm wheel, which resembles a helical gear, should be of a good bearing bronze. The worm wheel is throated or curved on the face to partially envelop the driver and its action in the worm gear is similar to the action of a screw on a nut. Due to the wedge-like action of the worm thread on the gear tooth, the set is relatively quiet in operation. It also provides a very wide range of speed reduction.



Worm Gear Sets

Other
These sketches and descriptions cover the basic types of gearing. In addition, various manufacturers have patented unusual gear designs, most of which are variations on the basic types. These unusual designs are usually for a specific purpose, such as limited space for extremely heavy loads, ultra-precision power transfer, and very high reductions. Care should be taken in lubrication recommendations for these unusual units.

Difficult-to-Lubricate Gear Types

Most of the gears pictured can be lubricated with a reasonable amount of care and intelligence, but two of them are quite difficult to lubricate. These are the hypoid gears and the worm gears.

Hypoid Gears

With hypoid gears, it is a necessity for a delicate balance between two important properties: film strength and anti-weld protection. This balance must be maintained to minimize wear, retard surface fatigue, and prevent scoring under a variety of conditions.

At lower speeds the load on hypoid gears is usually very high, and rubbing speeds are relatively low. At higher speeds, the tooth loads tend to decrease, but rubbing speeds are high. However, sudden clutch engagement can produce abnormally high tooth loads.

The lubrication of hypoid gears is almost entirely under boundary conditions, i.e., there is not a full fluid film between the teeth, and intermittent metal-to-metal contact exists. It is essential that the axle lubricant has high film strength and high anti-weld value. If the lubricant does not have sufficient anti-welding properties, the teeth actually weld together, tearing away and scoring the surfaces. The effect is the same as if the gears were run with no lubrication.

If the film strength is insufficient, but the lubricant is adequate in anti-welding properties, the force gradually distorts the metal permanently. This results in rippling or fish scaling of the tooth surfaces. Actually, this is metal corrosion as well as metal fatigue. The metal begins to pit, then forms small irregular cavities, and this is followed by extended flaking and complete breakdown of the tooth surfaces.

Worm Gears

Worm gears have a great deal of rubbing, and therefore require more than straight mineral oils for lubrication. For many years the typical worm gear lubricant was a steam cylinder oil containing 5 to 10 percent of animal oil such as acid-less tallow. This is enough to increase the film strength or oiliness so that it will support moderate loads. Some modern oils will accomplish the same purpose and stand up much better in service. Since the worm is usually steel and the worm wheel is bronze, there is little welding effect between the two, so that lubricants with high chemical activity are not really necessary.

Most applications involving the other types of gearing previously displayed can be handled by a straight mineral oil, although it should be remembered that much equipment is extended beyond normal conditions. When extending beyond normal conditions, an extreme pressure (EP) gear oil may be very important. While the gears to be lubricated are the primary point of concern in any gearbox, there are usually anti-friction bearings included in the gearbox. While actual lubrication of these bearings is simple, they may be more susceptible to failure caused by dirt, low oil level or wear metal.

When gear sets are initially placed in operation, they should be operated for brief periods of time and with no load, or with a light load, if possible. This applies to trucks and mobile equipment as well as industrial gears. After the initial drain, an optimum drain period should be established with careful monitoring. This drain period will be influenced by operating temperatures, loading, possible contamination and any other applicable conditions. Under extreme conditions, the drain period should always be reduced. With new equipment still under warranty, you should adhere to the manufacturers' recommendations. Any time drain intervals are extended past manufacturer recommendations, the extended interval must be supported by oil analysis results confirming suitability for further service.

Gear Oil Selection

In selecting gear oil for a particular application, there are many ways to reduce the risk of failure. Of primary importance is thorough attention to detail. It is easy to accept the OEM recommendation word for word. The manufacturer makes either the most complete or the simplest recommendation, according to policy, but the manufacturer cannot anticipate all conditions under which the machine may operate. The manufacturer's recommendation, therefore, must be considered a guideline and not the final word. Operating conditions must be determined in order to make the best possible recommendation. Many other considerations may come to mind and can affect the operation of any machine, but attention to the following should help in making specific lubricant recommendations.

Considerations in Selecting the Right Gear Oil

- Location – If machine is out of the way or difficult to get to, it may not be lubricated as often as it should.
- Environment – Heat, dust, moisture, chemical vapors, and other conditions surrounding the machine may affect lubrication.
- Housekeeping – Are there accumulations of dirt and other indications of poor maintenance?
- Overloading – Are there visible indications of operation above rated speeds?
- History – What previous difficulties have existed? Has the machine been overhauled? What lubricants have been and are being used?
- Machine Performance – Is the machine performing properly?
- Modifications – Has the machine been changed in any way since being installed? What effects do these modifications have?
- Maintenance – What is the present maintenance interval and what is done to the machine?
- Lubrication – What is the current lubricant in use and what is the OEM lubricant recommendation? What is the current lubrication interval and what is the OEM-recommended interval? What is the consumption rate? Is there any leakage?

Failure and Wear Analysis

No discussion of gears and gear lubrication would be complete without some dealings with failure and wear analysis. During the first inspection of a set of gears that are properly installed and lubricated, the combined action of rolling and sliding will smooth the working surfaces of the teeth and give them a highly polished look. Under continued operation, trouble may occur that will show up as a breakdown of the tooth surface. The type of failure will often indicate the reason and proper remedy. Listed below are the ordinary types of wear and failure of gears.

Normal Wear
Normal wear is the loss of metal from both surfaces from unavoidable abrasion. This does not prevent the gear from performing satisfactorily during its expected life.

Initial Pitting
Initial pitting may occur when gears start working and may continue only to the stage where local high spots have been reduced so that there is sufficient contact area to carry the load without further surface damage. Occasionally this type of pitting will heal over. When pitting continues and becomes progressively worse, the unpitted areas are insufficient to carry the load and rapid destruction may occur. In some cases, load reduction will prevent further destruction. The lubricant should not be expected to eliminate pitting, although in some cases very mild pitting may be improved by using a heavier oil.

Abrasion
Abrasion is characterized by many fine scratches on a tooth surface. It is damage caused by gritty material introduced into the gear case. Wear takes place uniformly across the teeth. The wear may be rapid and destroy not only the surface but the shape of the tooth. Abrasion can be prevented by more frequent changing of the oil to remove foreign abrasives, or better protection of the gear case from contamination.

Galling
Galling removes metal from tooth surfaces. Initially it may be referred to as scoring. Galling is due to the failure of the oil film to carry the load, because operating conditions are abnormally severe or because the incorrect oil was used. Metal-to-metal contact occurs, and tooth surfaces are worn or torn. Excessive wear results, and the surfaces are usually very rough. Occasionally metal is dragged over the tooth edges, creating a feathery appearance. Because of the metal wiping action, a ridge may develop at the pitch line of the driven gear and a groove at the pitch line of the driving gear.

Spalling
Spalling is the abnormal loading of tooth surfaces. This overstresses the subsurface metal until large chips or flakes break way from the teeth. This condition starts at the base of the tooth. Small flat flakes of metal may be visible in the oil.

Major Operating Criteria for Rear Axle Performance

Through years of building and servicing truck axles, Eaton Manufacturing Company has come to the conclusion that lubrication, loads, operation (terrain), and driver are the four major operating criteria that must be considered to assure satisfactory rear axle performance. Eaton makes the following suggestions for each of these criteria:

Lubrication
Using proper gear oil helps to lengthen axle life. Gear and bearing life is always improved by the use of EP lubricants containing the proper additives. These lubricants are designed to carry heavier loads than straight mineral oils. Also, correct viscosity is important, particularly in extremely hot or cold weather because of the heavy loading on rear axles.

Dirt and debris in the housing is a serious problem in lubrication. More dirt accumulates during break-in, and this is one of the most critical periods in the life of an axle. The factory lubricant should be changed at low mileage or hours, and then a periodic check should be made of the lubricant level on a regular, frequent basis. Lubricants can be run fairly long under normal or average conditions, but the drain period should be reduced under high speed or heavy operating conditions.

Loads
Loading has a definite effect on axle life. Loads will affect both the housing and the differential assembly. An axle housing can take some bending and still spring back to its original shape. Shock loading, hitting a stump or rock, and other types of abuse can bend a housing past the yield point and cause extensive damage to axle components. Overloading will also reduce axle life.

Operation (Terrain)
Continuous operation in mountains causes axles to operate at or near maximum torque loads for long periods of time and reduces the axle life. Off-highway applications such as logging and mining are strenuous operations for any axle. To ensure economical operation, it may be advisable to select an axle one size larger than standard.

Driver
The driver of the vehicle is as important a factor in the life of an axle as any other. Correct operation of the axle, as well as other components, are the direct result of driver performance. Trained drivers will improve any operation.

LE Proprietary Additives

Each of LE's gear oils contains one of LE's proprietary additives. To varying degrees, these additives help reduce gearbox temperatures, improve film strength and reduce friction.

• **Duolec®** dual-acting additive imparts synergistic properties to lubricants, providing both wear-reducing and EP protection. The result of revolutionary technology designed specifically for use in LE gear lubricants, Duolec increases oil film strength and is temperature-activated to provide a protective layer that smooths metal surfaces and minimizes the effects of any contact, thereby reducing friction and preventing surface wear.

• **Almasol®** solid wear-reducing additive is able to withstand extremely heavy loads, chemical attack and temperatures up to 1,038°C (1,900°F). It is attracted to metal surfaces, forming a microscopic layer but not building on itself or affecting clearances. Almasol minimizes metal-to-metal contact and the resulting friction, heat and wear.

• **Monolec®** wear-reducing additive creates a single molecular lubricating film on metal surfaces, vastly increasing oil film strength without affecting clearances. An invaluable component in LE's engine oils, industrial oils and many of its other lubricants, Monolec allows opposing surfaces to slide by one another, greatly reducing friction, heat and wear.

• **Quinplex®** impact-resistant additive contributes to outstanding water resistance, tackiness and enhanced mechanical stability, and helps to form a barrier against corrosion.

LE Gear Oils

Lubrication Engineers manufactures a variety of mineral oil-based and synthetic gear oils to more closely meet the requirements for different applications. The quality and performance of LE's gear oils ensure greater productivity, extended equipment life, reduced maintenance needs, and decreased downtime – all of which contribute to a healthier bottom line for any organization.

Mineral Oil-Based Gear Oils

Almasol Pure Mineral Gear Lubricant (401) provides exceptional wear reduction and long service life in all applications requiring a straight mineral gear lubricant. It is a balanced formulation of mineral base oils, R & O inhibitors, wear-reducing and other additives – including Almasol, LE's exclusive wear-reducing additive – that provide the highest level of wear reduction possible without the use of a chemically active EP agent (as specified by some manufacturers of transmissions and gearboxes.)

Almasol Worm Gear Lubricant (460, 680) is formulated with mineral oils blended with stable lubricity additives and Almasol, LE's exclusive wear-reducing additive, to provide protection in a wide temperature range. It protects bronze bull gears from excessive wear in enclosed worm gearboxes. It provides superior oxidation resistance in high-temperature applications where EP gear lubricants cannot be used. It reduces friction in high sliding worm gear applications due to formulation with stable compounding and lubricity additives.

Duolec Vari-Purpose Gear Lubricant (1601-1610, 1302, 1304) is a high-performance industrial and automotive gear oil with ISO grades ranging from ISO VG 46 to 1500. Designed for use in any industrial gear or bearing application that requires a thermally stable, EP lubricant, it maintains performance even after filtration. It also meets the requirements for many hypoid and planetary gears in more heavy-duty mobile equipment, as well as differentials in over-the-road vehicles. It contains Duolec, LE's exclusive dual-acting additive, and is fortified with a shear stable tackifier to provide adhesion to metal during use.

H1 Quinplex White Gear Lubricant (4090-4250) is recommended for a variety of gearboxes and other critical applications in food and beverage manufacturing facilities. It is NSF H1 registered for incidental food contact and was formulated to withstand severe loading conditions and prevent rust and corrosion. It contains a carefully selected blend of pure mineral and synthetic base stocks to provide superior protection at a wide range of operating temperatures. It also offers anti-wear protection, differentiating it from many other white oils on the market. To ensure good metal adhesion, it contains a shear stable polymeric tackifier system including Quinplex, LE's proprietary impact-resistant additive.

Monolec Gear Lubricant (703-704) offers the versatility of one product that meets the demanding fleet requirements of all types of differentials (including limited slip) and transmissions, as well as most industrial enclosed gearboxes. A multiviscosity EP gear oil, it was formulated to achieve the proper balance between load-carrying capacity, film strength and lubricity. It contains Monolec, LE's exclusive wear-reducing additive.

Multilec Industrial Oil (6801-6807) is heavy-duty oil designed to prolong equipment life by combating the effects of high temperatures, water, contaminants and heavy loads that accelerate wear. Available in seven different viscosity grades, this multipurpose lubricant is ideally suited for use in all types of air compressors, hydraulics, oil circulating systems, industrial turbines, and R & O industrial and gear applications. This long-lasting, nonfoaming, turbine-quality oil provides superior resistance to heat, oxidation and moisture. It features a balanced blend of premium base oils and robust additive technology, including rust and oxidation inhibitors and Monolec, LE's exclusive wear-reducing additive.

Synthetic Gear Oils

Duolec PAG Gear Lubricant (9705-9707) was specially formulated for the ultimate in corrosion resistance, wear protection and thermal stability. Polyalkylene glycol (PAG) lubricants are synthetic formulations known for their high viscosity index, EP properties, and ability to handle temperature extremes. In addition to the PAG base fluid, this formulation features Duolec, LE's proprietary dual-acting additive. It is an excellent choice for lubricating a variety of bearings and gears – particularly worm gears – as well as other equipment operating under extreme conditions.

Duolec Syn Gear Lubricant (9815-9846) is formulated with 100 percent synthetic base fluid to ensure excellent high- and low-temperature performance. The synthetic base fluid also provides oxidation stability, which contributes to long lubricant life and a reduction in costly lubricant changeovers. It provides uninterrupted operation and long service life for expensive gear applications, including heavily loaded gearboxes that are exposed to temperature extremes. With its special blend of clean gear technology additives, it works to prevent deposit formations in high-temperature applications and will not break down over time. It also provides exceptional low-temperature flow properties, protecting gears during the coldest startups. It contains Duolec, LE's proprietary dual-acting additive, and is able to withstand incredible loads and stresses from heavy-duty applications such as pulverizer gear units.

H1 Quinplex Syn FG Gear Oil (4150-4460) is recommended for a variety of gearboxes and other critical applications in food and beverage manufacturing facilities. It is NSF H1 registered for incidental food contact and was formulated to withstand severe loading conditions and prevent rust and corrosion. It contains 100 percent synthetic base stock to provide superior protection in extreme high and low temperatures. It also offers great seal compatibility and excellent nonfoaming qualities. Its anti-wear capability differentiates it from many other white oils on the market. To ensure good metal adhesion, it contains a shear stable polymeric tackifier system including Quinplex, LE's proprietary impact-resistant additive.

Monolec Syn All-Climate Gear Lubricant (9919-9920) is formulated with 100 percent synthetic base fluid and a synergistic additive package, making it the ideal choice for heavy-duty rolling stock transmissions and differentials in severe service conditions. It is also recommended for some high- and low-temperature industrial gearbox applications. Its robust formula will not break down in severe service. It provides high-temperature oxidation resistance, low volatility and excellent thermal stability, allowing it to provide long-lasting protection for the application. It also retains its flow during subzero temperature conditions. The additive package includes Monolec, LE's exclusive wear-reducing additive as well as EP and anti-foaming additives.

Monolec Syn Industrial Oil (9032-9460) is designed to prolong equipment life by combating the effects of high temperatures, contamination and loads that accelerate wear. It is a versatile synthetic lubricant that meets or exceeds the requirements of non-EP gearboxes, air compressors, vacuum pumps, hydraulic systems, and roll mill bearings found in the textile, plastic, rubber and paper industries. It is formulated with high-viscosity 100 percent synthetic base oil and a specially developed additive package for applications running at extreme temperatures. The additive package – including Monolec, LE's exclusive wear-reducing additive – provides outstanding thermal stability and R & O resistance as well as wear resistance as pressures and temperatures rise. A foam suppressant completes the package. The base oil and additive formulation works synergistically to reduce wear, extend oil drain intervals, reduce oil consumption, and practically eliminate deposits and sludge formation, all while providing excellent compatibility with seals.

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