Lubricant Selection: What every design engineer needs to know

Simply stated, lubrication refers to the age-old science of friction reduction. People have been using lubricants for thousands of years, experimenting with waxes and oils from vegetables, fish, and animals to move heavy materials with equipment designed to gain mechanical advantage. In more recent years, the discovery of petroleum oil in the 1800s ushered in a new era of lubrication developments as people learned how to refine this oil and use it for a variety of purposes. Machinery could now be developed to operate faster and under heavier loads by using lubricants to create a barrier that eliminates friction and metal-on-metal contact.

Today, proper machine lubrication is vital to the health of automated equipment operating at ever-greater speeds and loads. Although some design engineers believe that lubrication is strictly a maintenance issue and task, the truth is that lubrication is everybody’s business — beginning with the original equipment manufacturer (OEM) design team.

Specifying the right oil or grease for the application requires some education on the part of design engineers, as not all lubricants are created equal. Gaining a basic understanding of lubrication types and failure modes can help designers narrow down the best oil or grease for the job and help end users avoid costly equipment downtime and repairs.

Choosing the right lubricant

Beyond reducing friction between moving surfaces, lubricants also serve to transport foreign particles and distribute heat. Typical lubricants often consist of 90% base oil — usually petroleum fractions called mineral oils — and 10% or fewer additives. Synthetic liquids or vegetable oils are sometimes used as base oils as well. Additives perform a variety of functions, such as reducing wear and friction, increasing viscosity and improving the viscosity index, protecting against rust and corrosion, and reducing contamination. Included in the non-liquid lubricant family are greases, powders, air cushions, and other specialized products. Dry lubricants such as graphite are sometimes used to provide lubrication at temperatures higher than oil-based lubricants can withstand. In any form, the key tasks of lubricants include keeping moving parts separated, reducing friction, transferring heat, carrying away particles and contaminants, transmitting power, and protecting against wear and corrosion.

The most common method of keeping moving parts separated is by forming a physical barrier, such as a thin layer of lubricant between parts, which is referred to as hydrodynamic lubrication. However, with high surface pressures or elevated temperatures, the fluid film may become too thin to fully prevent surfaces from coming into contact with each other. With regard to debris and contaminants generated by moving parts, lubrication circulation systems can carry particles to filters for removal, or in the case of...
a closed system like a gearbox, a magnet may also be used to catch metal particles.

All lubricants work to prevent wear by keeping moving parts separated from each other, though some also include special anti-wear or extreme-pressure additives for additional performance benefits. For example, to combat corrosion, high-quality lubricants employ additives that form chemical bonds with surfaces to keep out moisture and prevent oxidation or rust.

The American Petroleum Institute (API) categorizes mineral-oil-based lubricants into different groups, based on their composition and viscosity index. They may also be categorized by their main compositions as paraffinic, naphthenic, and aromatic. Design engineers should be aware that although it is beneficial for lubricants to include high-quality base oil, it is just as important to use the correct additives for the intended application. For example, PTFE (Teflon) is a useful additive in specialty greases because it operates in temperatures to 662° F and is chemically inert.

Greases are semisolid lubricants often made up of a soap (as a thickener) that is emulsified with mineral or vegetable oil, though non-soap greases are also available for specialty applications, such as extreme temperatures. The defining feature of grease is high initial viscosity, which then drops to act as an oil-lubricated bearing once shear is applied. This change in viscosity — called thixotropy — drops to roughly the same viscosity as the base oil used, making the base oil one of the most important considerations in grease specification.

Greases are often applied to machinery and mechanisms that will only be lubricated infrequently or not at all, as well as places where lubricating oil would not remain in place. Grease also helps to prevent water and moisture ingress. Lithium-based greases are the most widely used type, although their maximum operating temperature is 248° F, making them unsuitable in more demanding applications.

**Understanding lubrication failure**

Being aware of lubrication failure modes is the first step in avoiding the most common pitfalls and keeping machines up and running. Among the main causes of lubrication failure are contamination by particles or moisture, degraded oil or grease, and choice of the wrong lubricant for the application. While some failures can be tracked to poor maintenance, design engineers can have a significant impact on machine uptime by initially specifying and selecting the proper lubricant and designing parts and equipment for maintainability and reliability.

When a lubricant fails, it is important for all parties involved — including design and maintenance teams — to find the root cause of failure. Beyond analyzing symptoms such as excessive vibration, pitting, abrasive wear, and noise, engineers should strive to discover the underlying cause. For example, was the wrong grease selected, perhaps one not meant for temperature extremes? Did machinery imbalance or misalignment cause damaging vibration levels? Were moving parts subjected to contaminated air or high moisture levels? Once a thorough failure analysis is done, engineers can ensure that a more suitable lubricant is chosen to keep machinery running cool, clean, dry, properly aligned, and well oiled.
Some components, systems, and industries are more heavily impacted by lubrication failures and maintenance issues than others. That said, lubrication is important for all types of machines and systems with moving and mating parts. For example, according to industry analysts, the percentage of all employees working in maintenance in the petrochemical industry is close to 20%, while the steel industry has almost 30% of its employees performing maintenance tasks. Regarding component types, one recent report puts the percentage of gearbox failures caused by lubrication-related issues at nearly 65%. Worse yet, one top gear supplier estimates that more than 90% of all gear coupling failure is related to lubrication. Considering that the cost of equipment downtime and maintenance greatly exceeds the initial cost of lubricants, it makes fiscal sense for engineers to specify the correct oil or grease during the design stage of moving equipment.

**Magnalube-G PTFE grease handles high loads, extreme temperatures**

One example of high-performance grease designed specifically for high temperatures, high loads, and extended operating life is Magnalube-G from Magnalube Inc. This specialized formula is a non-soap elastomer/PTFE lubricating grease made of superior raw materials, including a base fluid of highly refined paraffinic mineral oil. The unique formula molecularly binds PTFE with polyurea for long-life performance in a range of industries and applications, lasting for more than 10 years in many sealed-for-life applications. Magnalube-G is widely specified in construction, industrial, and medical equipment, as well as computer components, robotics, electric motors, air cylinders, and hydraulic machinery, among many other uses.

This specialized grease is fortified with several additives that inhibit rust and oxidation and resist extreme pressure. It performs well in harsh environments, achieving excellent test results regarding water washout, salt spray, and boiling water immersion. In addition to superior performance in high-temperature environments, Magnalube-G also features excellent thermal stability and consistent performance across a wide temperature range of -40° to 530° F. The waterproof formula does not contain any metals, yet it outperforms traditional soap-based greases, such as lithium grease. It also exhibits high mechanical stability, keeping its consistency and not hardening or softening as many other types of grease do when subjected to various forces. High dielectric strength is another key feature of Magnalube-G, as it is nonconductive and offers dielectric properties similar to those of silicone greases.

**Best of both worlds: Hydrodynamic and boundary lubrication**

While many lubricating oils and greases employ hydrodynamic lubrication to separate surfaces by creating a very thin oil film between moving parts, Magnalube-G uses both hydrodynamic and boundary lubrication to avoid metal-on-metal contact. This dual approach to lubrication is especially important in applications that generate high loads and slow speeds, because a true hydrodynamic fluid wedge cannot be maintained in these conditions: The oil film will either be squeezed out due to pressure, or the sliding motion will not be fast enough to maintain the lubricating film. Magnalube-G uses boundary lubricant materials made of polyamidcarbonyl solids, specifically PTFE polyurea — an extreme pressure boundary lubricant that can handle 10,000 lb per square inch in pure powder form. These solids, carried within the petroleum base oil, form a mechanical barrier that drastically reduces contact between moving parts. Therefore, the petroleum oil performs double duty as a carrier for the boundary lubricant, while also lubricating under the mathematical principle of hydrodynamic lubrication. Magnalube-G continues to lubricate machinery with a fine microscopic film even after the grease has extruded away.

When selecting the correct lubricant for an application, design engineers should be familiar with common lubrication failure modes and take steps to avoid these common pitfalls:

- **Temperature-related failure** comes from overloading, overgreasing, high or wrong viscosity, poor lube circulation, improper cooling, ambient temperature, and thermal conditions.
- **Moisture-related failure** stems from ambient conditions (humidity, rain), washdown practices, hot operation then shutoff, improper seals, additive depletion, improper venting, and leaking cooling systems.
- **Foreign matter failure** arises from ambient conditions, contaminated oil or grease, component wear particles, lubrication practices, combustion, poor lube storage and practices.
- **Viscosity failure** is caused by oxidation, contamination, moisture and chemicals, poor additives, temperature, and substandard lube practices.
- **Contamination failures** result from environmental conditions, poor lube practices, leaking coils, lube vendor errors, and dirty storage areas.