Going Synthetic – Boosting Performance of Small Gearboxes

By Jeffrey Lay

Autotrol Corporation of Crystal Lake, Ill., wanted to introduce their new Model 150 Class N fractional horsepower gear motor to the appliance marketplace. Their admission ticket: perfluoropolyether-polytetrafluoroethylene (PFPE/PTFE) grease.

Class N motors automatically lock oven doors during self-cleaning cycles when the temperature hits 232°C and unlock the doors during cool-down. Autotrol had selected a high-temperature, engineered plastic for the gearing. However, the gears did not meet the customer's 6,000-cycle wear requirement, which meant an external lubricant was needed. The only logical choice was a PFPE/PTFE grease, a synthetic lubricant made by combining a fluorinated oil (PFPE) and a fluorinated thickener (PTFE). PFPEs survive 250°C for extended periods; plus, they pose no compatibility problems when applied to plastics, elastomers, or metals. When tested under load in a heated environment with the PFPE/PTFE grease, Autotrol's Class N Motor still worked like new after 6,000 cycles, which far surpasses UL requirements as well as the typical life expectancy of a range. Though the price tag on PFPE/PTFE grease can exceed $100/lb. (it's one of the most expensive synthetic greases), a little goes a long way. For Autotrol, four cents worth of grease in each gear motor was all it took to exceed customer specifications — and earn a reputation for high-quality Class N motors in the appliance marketplace.

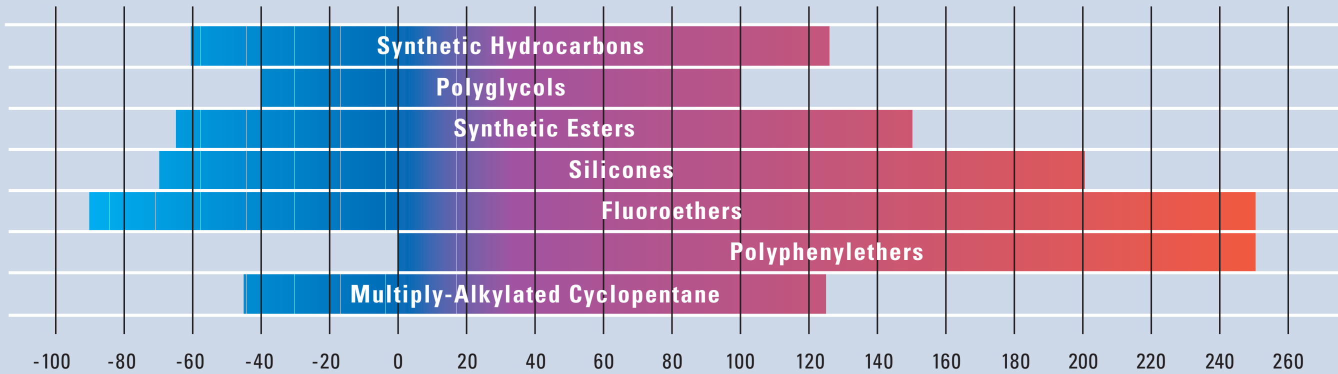
A Class N gear motor by Autotrol Corporation uses a perfluoropolyether grease by Nye Lubricants, Inc., to meet its customers' 6,000 wear-cycle and 232°C temperature requirements.

The Autotrol story is not unique. While petroleum-based lubricants are still the standard for most gearing applications, more and more OEMs are discovering, often out of necessity, the benefits synthetic lubricants bring to gear designs.

MORE THAN BROAD TEMPERATURES

As components get smaller and faster, they also get hotter — sometimes too hot for petroleum. In fact, extreme operating temperature is why most OEMs step into the world of synthetic lubricants. Petroleum begins to degrade at or before 100°C and it becomes intractable at -18°C. In either case, it won't lubricate. In contrast, synthetic hydrocarbons function at 130°C;

Table 1 **Lubricant Temperature Ranges**



esters, at 175°C; silicones, at 200°C; and PFPEs at 250°C or higher. Most synthetics also take the cold. Polyglycols stay lubricious at -40°C; synthetic hydrocarbons, at -60°C; synthetic esters, at -65°C; silicones, at -70°C; and some PFPEs, at -90°C (*See Table 1, "Lubricant Temperature Ranges"*)

Even when temperatures don't call for synthetic lubricants, more and more design engineers are relying on synthetics for a performance edge. Unlike petroleum, synthetic oils are manipulated at the molecular level to change and improve lubrication characteristics. These rigidly controlled chemical procedures produce oil molecules that are much more homogeneous than the molecules of even super-refined petroleum. Assuming similar operating environments and oil viscosities, this "molecular homogeneity" gives synthetics several advantages over petroleum lubricants. For example, synthetics offer better thermo-oxidative stability. Oxidation not only depletes lubricant supply, it creates abrasive oxides, which hastens component failure. Synthetic lubricants are less volatile at elevated temperatures than petroleum-based products even without the presence of oxygen. Synthetics also offer better film strength than petroleum. It's the "film" of lubricant on a sliding or rotating part that reduces friction and prevents wear. If the film is weak and ruptures under load, wear is accelerated. Synthetics have higher "viscosity indices," that is, the viscosity of the base oil remains more constant as temperatures change. In general, a synthetic lubricant will last three to five times longer than a petroleum product of equal viscosity. And because there is less evaporative loss, you use less synthetic lubricant per part.

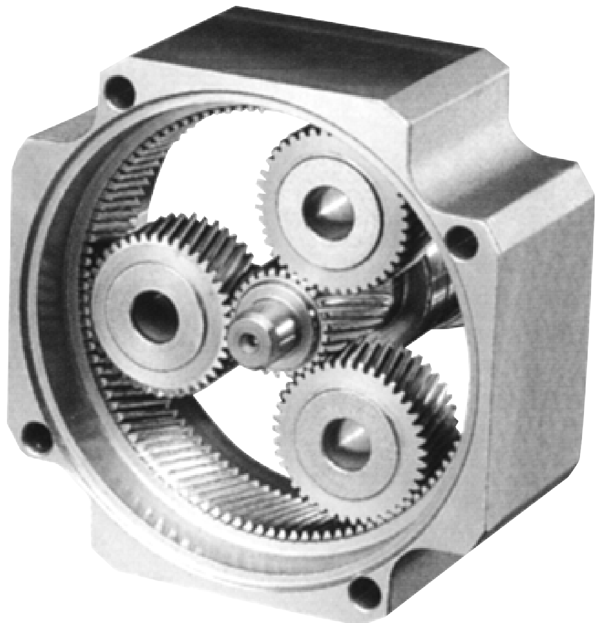
OIL MEETS GEAR

Lubricants make gears run smoother and last longer. Mechanically, a lubricant forms a protective film between the mating gear teeth, broadening the line of contact. Broader contact increases the area that supports the load, reducing pressure on the teeth and retarding wear.

Choosing the right oil is the key to getting the best lubricant for a specific gearing application. Each family of synthetic oils — there are six of them — has its own unique, designed-in qualities. Synthetic hydrocarbons are the most widely used synthetic lubricant for gears and gearboxes. They offer excellent cold-temperature performance to -60°C and good oxidative stability. Synthetic hydrocarbons are compatible with many plastics and, compared with other synthetic fluids, are relatively inexpensive.

Synthetic esters are ideal for cut-metal and powdered-metal gearing, if proper seals are used. Due to their affinity for metal, especially steel and iron, esters provide maximum wear protection. They have become the clear choice for automotive supercharger gearing and other severe-duty applications because they withstand temperatures as high as 180°C. Like esters, polyglycols have an affinity for specific metals, such as brass or phosphate bronze. Therefore, they are frequently used in worm gear applications to reduce friction and improve efficiency.

Silicones and PFPEs are compatible with nearly all gearing plastics. Both are suitable for broad temperature applications and have shown exceptional, low-temperature torque characteristics. PFPEs are also resistant to chemically aggressive environments. They are unaffected by sulfuric acid, hydrochloric



Bayside Motion Group, Port Washington, N.Y., designed a unique family of all-helical planetary gearheads which can see input speeds up to 10,000 RPM. A precision gear set designed for servo motors, even a film of lubricant can potentially be thick enough to cause a positioning error. Engineers at Nye Lubricants, Inc., formulated a very light, thixotropic, synthetic grease that helped the gear teeth retained their original profile after a full-load, 300 hour/3,000 RPM life test — without causing positioning errors. In addition, the grease was credited with reducing gearhead's operating temperature by 5 degrees.

acid, alkalis, halogens, and petroleum solvents. In addition, some PFPEs have very low vapor pressure, which is essential for vacuum chamber and aerospace applications where out gassing can be problematic.

Polyphenylethers (PPEs) are not widely used in gear applications. However, these synthetic oils resist radiation, which makes them good candidates for gearing in medical or dental applications, where radiation sterilization is mandatory. (Note: because of their radiation resistance they can not be exported to some countries for security reasons)

OIL OR GREASE?

Choosing the right oil is essential even when specifying a grease for gearing. Lubricant behavior depends on the type of oil in the grease. Greases are made by mixing a powdered material or thickener with a base oil. Thickeners includes soaps, like lithium, salts, clays, and synthetic materials like PTFE. Greases can be thought of as a "sponge of oil," where moving parts, such as gear teeth, squeeze oil out of the matrix to prevent friction and wear.

While oils have been the norm in gearing, they do raise design concerns, including leakage and increased cost. By choosing grease, an engineer can often reduce cost by eliminating oil seals and seal design. In most gear applications soft greases — those designed specifically for gears, not bearings — offer the best of both worlds. Soft greases will slump or flow back into the gear-teeth mesh like an oil, while remaining gel-like to reduce leakage common with oil lubrication.

Importantly, greases can be formulated light enough to accommodate even small gear motors. In fact, gear greases can be engineered soft enough to actually flow under shear and return to gel consistency when static. With their stay-in-place quality, these very light, thixotropic, synthetic greases are a viable alternative to conventional gear oils, which are often mistakenly defined as "required" for low-torque applications.

Greases can be used in both high and low-speed gearboxes as long as the housing is designed to reduce open spaces, where grease can become trapped and lead to lubricant starvation. In existing gearboxes, a "grease retrofit" is made possible by incorporating plastic baffles to reduce the amount of grease required to fill the box and to keep the grease where it is needed.

THE PLASTIC QUESTION

Plastic gears are often "designed" to operate without lubrication — and they do. In the struggle to achieve maximum operating performance and life, however, many engineers are finding external lubrication dramatically improves plastic gear designs. In fact, it can be stated without exception that lubricated gears — even lightly loaded, low-speed, plastic gearing — will last longer and run quieter than the same gear set without lubrication. So the basic question is, How long and how quietly do the gears have to operate? If the answers are "quite long" and "very quietly," grease should be considered.

When selecting a grease for plastic gears, the base oil must be compatible with the design materials. Material densities and additives have an effect on compatibility as well. While lubricants do not affect most thermoplastics, some oils can craze, crack, or embrittle a variety of plastic and elastomer components. Esters, diesters and polyesters, for example, are noted for their incompatibility with polycarbonate, PVC, polystyrene, and ABS resins. Only fluoroethers are inert enough to be safe with most every component or seal. "Compatibility charts" are available from many manufacturers, but testing is the only way to guarantee a successful material match.

An engineer also needs to consider how well the lubricant will adhere to the gears. "Tackifiers," which are additives that improve a grease's ability to adhere to gear teeth, are usually recommended for plastic gears. They reduce sling-off.

In cases where plastic gears have internal lubricants such as PTFE or silicone, the internal lubricant may interfere with the "wetting action" of some external lubricants, that is, reduce the external lubricant's ability to provide an adequate film of oil between the gear teeth. Therefore, when selecting an external lubricant for plastic gearing, engineers either should choose gears without an internal lubricant or make certain that the internal lubricant works synergistically with the base oil in the external lubricant. Typically, if an external lubricant is used, no internal lubricant is required.

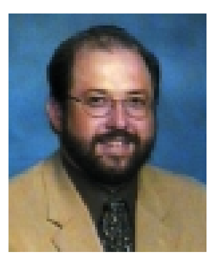
ON THE ROAD

Some gear designs, such as Visteon Automotive Systems' rack and pinion steering components, rely on mixed-film or boundary lubrication to prevent gear wear and failures.

Rack and pinion gears constantly change direction and the potential for high shock-loading puts a great deal of stress on not only the gears but the lubricant as well. Additionally, the Visteon system has a spring-loaded, yoke-to-rack mechanism which keeps the rack mated to the pinion. Under mechanical shock-load testing, simulating pot holes and railroad tracks, the rack separated from the pinion, increasing wear and causing an annoying clunking sound — surely a warranty claim in the making. Visteon engineers needed a lubricant to reduce gear wear and the level of noise transmitted through the steering column, and their petroleum grease wasn't doing the job. A newly developed, high-viscosity, synthetic base oil with a lubricious thickening agent and extreme pressure (EP) and antiwear additives was applied to the gear teeth as well as the spring-loaded, yoke-and-rack interface. It passed all gear and yoke wear tests — while imparting a smooth, quiet, quality feel to the entire steering system. Further, when Visteon switched from petroleum to synthetic grease, manufacturing costs decreased because less lubricant was needed per part.

Mallory Controls of Indianapolis, Ind., chose a low-viscosity, synthetic hydrocarbon base oil combined with a lithium-soap thickener and special lubricity and adherence additives to meet the low-temp, low start-up torque requirements of plastic gears in its Model 620 appliance timer. The grease was custom-designed by Nye Lubricants, Inc.

Petroleum or mineral oils may always have a place in the world of gearing. However, synthetics are fast gaining in popularity. For temperature extremes, they're a must. But in a marketplace where consumers expect more from appliances, power tools, automotive components, sports and recreational equipment, lawn and garden devices, and other products that rely on gearing, synthetic do more than broaden operating temperatures. They deliver a performance advantage that becomes a manufacturer's competitive edge. ■



Jeffrey Lay, Gear Industry Director at Nye Lubricants, Inc., is an active member of the American Gear Manufacturers Association (AGMA), Technical Association of Pulp & Paper Industries (TAPPI), and the Society of Mechanical Engineers (SME). Jeff can be reached at (937) 885-2312 or by E-mail at jefflay@nyelubricants.com.