Getting a Grip on Big-Gear Lubrication

Jack McGuinn, Senior Editor

In the wide, wide world of moving parts, the gears required for the big jobs—the *really* big jobs—often experience big problems. Proper lubrication of these gears is paramount in industrial applications such as wind turbines, kilns, sugar mills, crushers, heavy construction, offshore drilling rigs, mining and quarrying. Scuffing, extreme friction, edge-loading, micropitting, misalignment and, of course, harsh environment issues—all are potential troublemakers. This is particularly true for large, slow-running, open gear drives where high torques are transmitted.

For perspective, consider this: damaged tooth flanks (due in part to an underperforming lubricant) are the reason for about 60 percent of gear drive defects.

It therefore follows that proper lubrication of these gears is paramount—especially when one considers that many big-gear applications directly involve public safety and failure is not an option.

Nevertheless, stuff happens. And when it does, the most common lubricant-specific causes for big-gear application breakdowns include inadequate film viscosity, incorrect lubricant specified, nozzle clogging (sprayability), bearing-lubricant issues, contamination and, of course, failure to withstand harsh environment effects such as dust, salt water, heat and cold.

Conversely, these problems can be addressed, if not completely avoided, with the use of lubricants that will reduce friction, heat, wear, operating temperatures, downtime and maintenance. And, valuable environmental upgrades are part of the mix as well. Bottom line, the use of high-performance gear oils, further boosted with newly advanced additives, can prevent or stop such problems as the above-mentioned skewed tolerances, high-friction-related heat and wear, extreme pressure, etc. This is typically achieved by:

- Improving overall tribological properties of the metal surfaces
- Returning efficiency and previously wasted energy to the system for increased power
- Improving physical surface improvement, which steps up oil flow and increases oil film strength
- Improving the shear strength of the base lubricant
- The overall reduction in friction and friction-related wear
- Protecting against rust by forming a continuous film of lubricant that excludes water from gear tooth surfaces
- Resisting flaking from gears at low temperatures, thereby maintaining full protection against wear and scuffing

But given that many of these issues also apply to smaller gear sets, why does size matter?

And what constitutes a "big" gear? Are its dimensions etched in stone? Depends who you ask.

"Gears for mill and kiln service start at about 20 feet in diameter," says Frank C. Uherek, manager of mill products engineering and inside sales for the Rexnord Gear Group, Rexnord Industries LLC. "Big gears would be considered over 24 feet in diameter up to 46 feet. The dividing line is based on the number of manufacturers available to make gears in this size range. (Anything) much over 35, feet the number of manufactures is limited to five."

"With our research activities in wind turbine gearboxes, we con-

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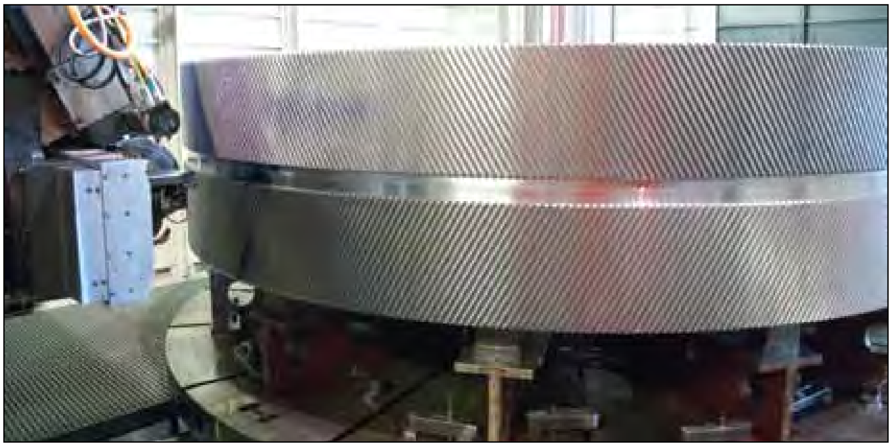


The correct lubrication choice for big gears—like this double-helical gear from HMC—takes on added significance when public safety concerns are part of the application (courtesy HMC Inc.).

sider gears (ring gears) up to several feet in diameter (to be large)," says Dr. Aaron Greco of Argonne National Laboratory, currently on assignment with the Wind and Water Power Program/Technology Development and Testing Team for the U.S. Department of Energy in Washington, DC.

We also put the question to Rob Ferguson, a gear engineer for Indiana-based HMC, Inc, who replies, "The term 'big gear' is relative but I consider big gears (to be) over 120" in diameter."

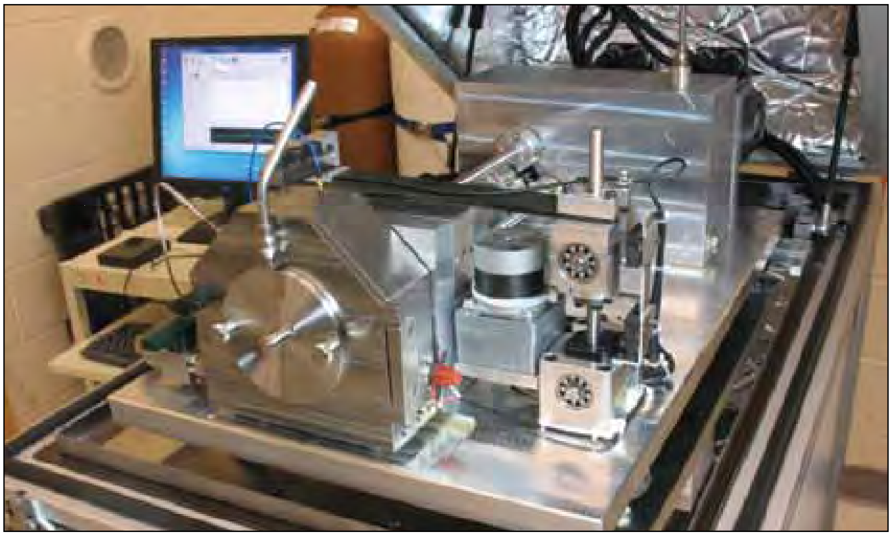
We then asked the group to offer their own list of what they considered the primary issues in the big-gear realm relative to lubrication.

"Big gears operate at relatively low speed," says Ferguson. "At these low speeds it is very difficult to maintain an adequate oil film thickness. Many large gears also operate in outdoor environments with large temperature swings throughout the year. They are also exposed to contaminants that can be come entrapped in the lubricant and entrained in the gear mesh."

Uherek weighs in with "(What's important) is ensuring that adequate lubricant is supplied to the mesh, both in terms of viscosity and amount. Significant wear can occur due to plugged spray nozzles. In addition, the lubricant must be pump-able at low temperatures. Contamination control is also critical."

"The general difference between large-diameter gears and small is that the rotation speed is slower and torque is higher for large gears," says Greco. "These operating conditions relate to slower pitch velocity affecting the entraining velocity and higher contact pressures (especially if there is misalignment and edge loading issues). Lubricants used for these applications therefore can consider EP and wetting behavior. Some common failures observed in wind turbine gears include scuffing, micropitting and macropitting."

A kiln gear set showing distress due to insufficient viscosity (courtesy Rexnord Gear Group/Rexnord Industries LLC).



This ring-on-roller, bench-top test rig from PCS Instruments is used at Argonne National Laboratories for testing lubricants (courtesy Argonne National Laboratories).

And, Ferguson explains, "Big gears operate at relatively low speed. At these low speeds it is very difficult to maintain an adequate oil film thickness. Many large gears also operate in outdoor environments with large temperature swings throughout the year. They are also exposed to contaminants that can become entrapped in the lubricant and entrained in the gear mesh."

Identifying and qualifying a specific lubricant for big-gear applications is crucial. We asked two of our experts to explain why that's the case and how it is done.

For Uherek, "The best source of information is a manufacturer's recommendations based on ambient temperatures, speed of the gear and application (e.g., mill or kiln). If these are not available, the AGMA 9005 Industrial Gear Lubrication standard offers guidance on lubricant types and spray intervals. Another source is the AGMA 6014 Gear Power Rating for cylindrical shell and trunnion-supported equipment that has an extensive discussion in the annex covering types of lubricants and options."

And HMC's Ferguson states that "The selection of an adequate lubricant can be complex if you encounter challenging operating environments. It is important to know the operating speed, the environmental conditions—such as ambient temperature, operating temperature, duty cycle, type of enclosure if any—and how the lubricant will be applied."

One factor perhaps not readily apparent in specifying a lubricant for a big-gear application is the need—more accurately, the lack of—a test rig sufficient in size to do the job. Just how problematic is that?

"To my knowledge there are no test rigs that can test gears at the size of wind turbines (besides full-scale dynamometers)," says Argonne's Greco. "However, the operating contact conditions of large gears can be replicated by more versatile ring-on-roller benchtop test rigs that are commercially available."

"Yes, most R&D is done on gears that are (already) in service," says HMC's Ferguson. "Most end users are not willing to experiment on their large gears due to the high cost."

"Many existing lubricant tests do not (even) involve gears," says Uherek, pointing out that "4-ball testing, or the FZG load test, use gears meshing on a ~4 inch center distance. Although gear teeth are involved, the ability to scale up the test results to 257-inch centers and the use of intermittent spray applications are limited. In many cases lubricant suppliers test on a few real-world mills as they estimate performance and balance additive packages. This type of testing is the most accurate, but comes at substantial cost. Therefore, future lubricant advances are limited."

A huge component of big-gear-related lubricants is additives; typically synthetic, they are that "something special" that greases the grease, you might say.

Of their usage and efficacy, Uherek says that "Depending on the application, the key issues (when using additives) are maintenance of high viscosity, achieving ease of application, and staying power between applications (10 to 20 minutes) for intermittent systems. As these are single-use lubricants, life enhancing, water and foam resistance become less of an issue than in an enclosed gear drive."

However, additives also lead to added cost, so their use must be weighed accordingly, vis`a vis good performance. Which begs the question: will synthetic additives completely replace their natural, mineral-based counterparts?

"The choice of mineral- or synthetic-based gear oils and the relative percentage split of each in the future will depend on many aspects," explains Felix Guerzoni, product application specialist and team leader at Houston-based Shell Global Solutions U.S. Inc. "There are no doubt significant benefits in moving to synthetic-based gear oils, and the lifetime cost benefit and return on investment can be quantified. One contributing factor could be the number and capacity of base oil manufacturing plants manufacturing API Grp I base oils, which are set up to manufacture more of the heavier viscosity grade base oil cuts required for industrial gear oils. No doubt the mix is moving towards more API Grp II and Grp III plants. The data reported recently (*Lubes 'n' Greases* magazine) suggested that in 1998, 56 percent of the North American base oil capacity was API Grp I, whereas in 2011 that number had dropped to 29 percent."

And yet, Rexnord's Uherek states, "Synthetic oils are not always the solution to lubricant issues. (While) they can offer advantages in lower-pour points and less viscosity change over broad temperature intervals, EHD film thickness needs to be closely monitored and application intervals need to be audited when considering a lubricant change. Given moderately high contact pressures—and when slow speed sliding occurs—residual compounds such as asphaltic still solve many problems."

And while HMC's Ferguson allows that synthetic lubricants will indeed attain greater currency, he "doubts" that the traditional lubricants will be "completely replaced." There are many traditional lubricants that have proven they can do the job and introducing new, unproven lubricants will be difficult," he says.

Returning to the here-and-now, what lubricants currently exist that serve to prevent or minimize micropitting (also known as grey staining), for example, in gear teeth and scuffing wear—just to cite two all-too-prevalent gear failure causes?

"There are several active areas of R&D for gear oils that address these issues, including engineered, nanoparticle lubricant additives, new base synthetics like PFPE (perfluoropolyether)," says Greco.

But, Uherek points out, "In large-gear applications, micropitting is not common, due to the hardness difference between the pinion and gear. It is difficult to get micropitting when running a surface-hardened pinion with a through-hardened gear.

"Micropitting is more common when both members are surface-hardened, such as in enclosed drives. Scuffing can occur on slow-speed applications such as kilns; in those cases, surface finish, viscosity and tooth geometry modifications—such as tip relief—can alleviate this issue."

Yet when considering big-gear lubrication, it is the determining of the sometimes elusive and often complex balance between correct lubricant viscosity level and gear-generated heat.

And how is that done, exactly?

In a word—"carefully"—says Greco. "Too low of a viscosity can lead to micropitting and scuffing issues; conversely, too high of a viscosity can affect efficiency and cold-start conditions. The wind turbine industry has trended to higher viscosities, commonly 320."

Aside from always consulting with the OEM of the gear for their recommended lubricant type and viscosity grade for a given gear set, says Guerzoni. "The most accurate method for determination of required viscosity for gear sets involves an elastohydrodoyanmic (EHD) calculation. These calculations require a significant level of detail, including—but not limited to—gear geometry, surface roughness, operating temperature, load and speed.

"When all of the key data required to conduct a fully detailed EHD calculation is unavailable, operators can refer to the guidelines given in AGMA industrial gear lubrication standard 9005–E02. This standard provides a set of tables with suggested viscosity grades for industrial gear drives (separated by whether helical, spur, bevel gear or worm gear) and based on a minimum data set of pitch line velocity, operating temperature and the viscosity index of the oil (which in turn indicates whether a mineral or synthetic gear oil is being used). Consideration needs to be given to the lowest and peak operating temperatures. Generally speaking, for a given temperature—the lower the pitch line velocity, the higher the viscosity of the gear oil required. For a given pitch line velocity, the higher the operating temperature, the higher the viscosity of the gear oil required."

In closing, a brief—if somewhat off-topic—look at the continuing encroachment of direct drive versus gear-drive, and how it might affect lubrication issues seems relevant. Shell's Guerzoni offers this:

"Many OEM's in the wind sector are focusing on direct-drive technology—especially for offshore turbines. Major players, including Enercon and Goldwind, have direct-drive models for onshore, while OEM's including Siemens and GE are concentrating on direct-drive technology for future offshore installations. The proposed benefit is around improved reliability for the turbine and no gear oil to change on a periodic basis. Industrial gear oils are still required for yaw and pitch drives. Greases are still required for roller and pivot bearings with specific requirements demanded for those applications."