By Mary Moon

WILL VARNISH VANISH?

It's just another day—turning off the alarm clock, turning on your television, making coffee, toast and oatmeal—provided that electricity is available to power these appliances in your household. Everyone knows that the supply of that electricity can be disrupted by a tree tumbling onto a powerline or a lightning strike destroying a transformer. But a more subtle threat consists of microscopic blobs of organic goo in lubricating oil that can form deposits called varnish on critical mechanical components and bring massive power generating and other industrial equipment to a halt.

After years of research and development, progress on several technologies shows promise for reducing varnish formation, possibly making varnish a historical footnote alongside turning a crank to start a car engine or using a waterwheel to generate electricity.

Lubricant Maintenance

Peter Dufresne of Calgary, Alberta-based EPT helps turbine and compressor users tackle varnish issues. He explained, "In-service lubricants undergo oxidation where chemical reactions create byproducts that are essentially waste molecules. These molecules normally are dissolved in hot lubricant when machinery is operating. But when machinery is shut down and the lubricant cools, this breakdown material tends to precipitate as thin films of varnish on metal surfaces and thick layers of solid or gel-like sludge at the bottoms of tanks."

There are three major lines of defense against varnish, according to Dufresne: lubricant base stocks that resist oxidation, additives that protect lubricants from oxidation, and ion exchange treatment to remove breakdown molecules before they form varnish.

"With suppliers promoting new 'low varnish' or even 'varnish-free' lubricants, there is some confusion in the industry regarding the need for lubricant conditioning systems," he said. While there is great appeal in the idea of a maintenance-free lubricant, Dufresne disagrees that the brand of lubricant used should determine the maintenance requirements, or that one brand would require no maintenance.

From an oxidation stability perspective, API Group II or Group III base oils are vastly superior to Group I. The refining process has virtually eliminated reactive species from Groups II and III, so these oils are highly resistant to oxidation, he said. "Base oils made from natural gas are starting to appear in the marketplace, and these would have excellent purity and oxidation resistance. The challenge is that varnish is not related to purity of the lubri-

Photo: INFINITY - Fotolia

cant. Rather, polar oxidation byproducts tend to precipitate in these less polar, oxidation-resistant base stocks."

Developments in lubricant additives are also impacting varnish formation and mitigation. Dufresne explained that there are two major families of antioxidant additives: amines and phenols.

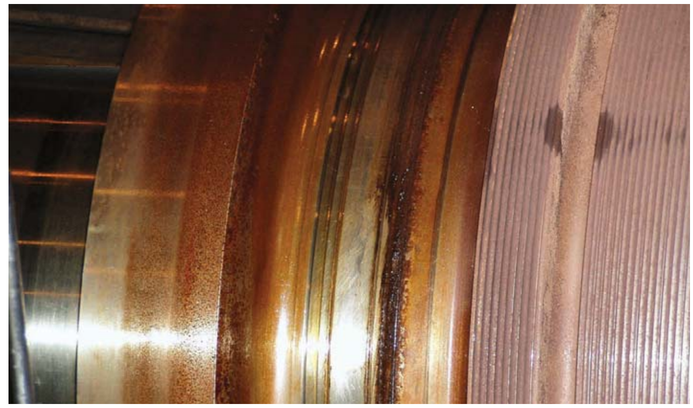
"Five years ago, some main brands of turbine/compressor oils were formulated with amines only, some with phenols only and others with both. In theory, a highly oxidation-resistant base oil may not require an amine antioxidant, while removing phenols may reduce the varnish forming tendency of some oils.

"Today, this story continues to develop in the marketplace, with common turbine lubricant brands using both amines and phenols. On the performance side, it appears that additive quality is more important than quantity."

However, Dufresne insisted, "There is no lubricant that does not require maintenance."

"Over the past 10 years, we have seen a shift in the way lubricants are used and maintained. With the use of a turbine lubricant conditioner on a quality Group II lubricant, breakdown material is removed at its earliest stage. This prevents the material from saturating the lube and precipitating to form varnish. Additive values can be maintained using annual top-up programs with the same brand of oil in the system.

"Using this approach, we have observed lubricants with no increase in acid number, with membrane patch colorimetry values of less than 2 on a consistent basis, and antioxidant consumption rates of less than 3 percent per year. To have gas turbine lubricants in this condition after nine years of continuous operation is a real game changer for the industry and offers a glimpse into the future of how lubricants will be used and maintained in turbine and compressor applications," he concluded.



Varnish formation in a power generation turbine. (Photo: EPT)

Group II Oils

Tim McKee, global brand segment manager, and Zhen Zhou, research chemist, both with Chevron in San Ramon, California, emphasized the critical importance of continuous improvements in formulation, cleanliness and in-service maintenance of industrial lubricants to reduce the risk of varnish. They state that API Group II mineral oils, which Chevron produces, are reliable base stocks with extensive track records of performance in turbines and other industrial applications.

McKee pointed out that technical advances in Group II base stocks and lubricant formulations are commercialized every few years and are compatible with prior Group II products.

According to Zhou, there are many types of varnish, depending on the presence of contaminants. For example, in steam turbines, varnish formation depends on water contamination of the lubricant as well as oxidation of the base stock. And water is less miscible with less polar base stocks than more polar oils.

Zhou recommends that end users flush lubricant tanks prior to delivery of fresh oils and maintain the cleanliness of in-service oils, by means such as filtration, to reduce the risk of varnish and resulting mechanical issues.

PAGs

Martin Greaves, research leader, lubricants with Dow Chemical Co., echoed Dufresne's comments about polarity as a contributor to varnish formation: "Multiple factors can result in varnish formation, such as thermal events and oxidation. One explanation is that as hydrocarbon oils age, base oil oxidation byproducts are more polar than their parent base oil and can become insoluble. This can lead to precipitation on surfaces and the beginning of deposit and varnish formation."

One alternative to hydrocarbon base oils is synthetic polyalkylene glycol base oils, such as those Dow produces, which are more polar. Well-formulated PAG based lubes are stable under the temperatures typically experienced in large gas turbine units, Greaves explained. Any aging that occurs through oxidation leads to polar oxidation byproducts, which are typically soluble in the parent base oil and therefore present a lower risk of deposit formation.

Continued on page 60

Is Machine Design at Fault for Varnish Formation?

Maybe, says Peter Dufresne of lubrication maintenance company EPT, but it's much more practical for industrial equipment operators to change lubricants than invest in new equipment.

"Most lubricant users have their hands tied and are not able to change the mechanical properties of their system," he explained. "If we could start all over, I would design the mechanical systems differently. In a perfect world, you would not combine lube oil and hydraulics into one common system. You would increase reservoir sizes, keep return lines below the oil surfaces and increase the surface area of filters. You would also eliminate stagnant oil lines and try to maintain more uniform temperatures throughout the mechanical system."

—Mary Moon

Continued from page 58

PAGs are also blended with API Group II and Group III base stocks to boost their polarity. Recently developed oil-soluble PAGs are less prone to hydrolysis than esters, which formulators typically use to enhance the polarity of industrial and automotive lubricants, said Greaves.

One application where varnish formation was a significant concern in the past was smaller turbo-machinery, such as rotary screw air compressors, lubricated with hydrocarbon based fluids. Ingress of air in contact with the lubricant at high temperatures represents a challenging environment where severe oxidation can occur.

In the late 1980s and early 1990s, some manufacturers of these compressors transitioned away from hydrocarbon based lubricants to PAGs and experienced much cleaner equipment operation and significantly longer fluid service life, Greaves reported.

Thousands of compressors today operate successfully on PAGs, he said. This field experience collected over many years was leveraged to solve varnish problems in the heavy-duty gas turbine industry, where PAGs have been used since 2007.

However, Dufresne warns that switching to PAGs may not be the best solution in every situation. Monitoring lubricant condition with membrane patch colorimetry and other tests, using appropriate conditioning methods such as filtration to remove contaminants, preventing the ingress of water and avoiding addition of incompatible product "top-up" to in-service lube are all essential steps to prevent varnish formation in any oil.

Dispersants

Greg Livingstone, chief innovation officer, and Josh Wagner, director of marketing with Fluitec International in Bayonne, New Jersey, boasted that the company's Infinity TO turbine oil comes with a 10-year guarantee that its membrane patch colorimetry value will stay in the normal range, and varnish will not cause performance issues on turbine bearings, servo valves or other components.

MPC is described in ASTM D7843, "Standard Test Method for Measurement of Lubricant Generated Insoluble Color Bodies in In-Service Turbine Oils using Membrane Patch Colorimetry." Oxidation byproducts are collected from a lube sample on filter paper, and their color is measured to evaluate the likelihood that they will form varnish, affecting machine performance.

The guarantee does have some conditions attached to it: The system must be cleaned prior to addition of the oil, and other formulations cannot be added to the system thereafter.

The average life of turbine oil is eight years in a large-frame gas turbine, and 12 years in a modern steam turbine. Fluitec's product provides comparable service lifetime to other premium turbine oils available in the market. The oil is designed to have the antioxidant system replenished while in service, allowing it to be used much longer—potentially for the life of the equipment, the company says.

Infinity TO is based on API Group II oil. "It's non-varnishing because it contains a superior additive system that provides high deposit control performance," Livingstone said. "It uses a unique [dispersant] chemistry that manages oil degradation byproducts in a significantly different way than other formulations. As a result, deposits don't form under normal oxidative conditions."

"A few years ago, we did not believe that formulating non-varnishing turbine oils was possible. Even PAG-based chemistries have been shown to form deposits under certain conditions," he recalled. "We realized that we were on to something novel when our formulation surpassed commercial premium turbine oils in Fluitec's accelerated oxidation test. What really surprised us was that the oil produced no deposits after extending the test for more than three times the typical duration."

Ten years ago, Fluitec developed an accelerated oxidation test called the Turbine Oil Performance Prediction test. A 350-milliliter sample of new turbine oil is placed in a glass test cell containing a steel and copper coiled wire catalyst conforming to ASTM D5846 ("Standard Test Method for Universal Oxidation Test for Hydraulic and Turbine Oils Using the Universal Oxidation Test Apparatus"). The test cell is placed into a 120 degree Celsius, solid-block temperature bath and dry air is bubbled through the oil to accelerate aging. Oil samples are collected weekly during the TOPP test, which typically lasts six weeks.

The samples are evaluated with metal spectroscopy, MPC, Rotating Pressure Vessel Oxidation (RPVOT), and Remaining Useful Life Evaluation Routine (RULER) tests, and for acid number, viscosity at 40 and 100 C, foam, color, air release and demulsibility.

Looking forward, Livingstone expects that, "Eventually, 'fill-for-life' lubricants will be the norm, not the exception. Any application that doesn't thermally degrade the base oil or have harmful contaminant ingression is a candidate."

However, he cautioned, "the complexities of in situ additive replenishment in formulations using surface-active components is significantly higher. Even reformulating antioxidants in turbine oils, which are relatively simple formulations, is complex and requires significant up-front testing." ∎

Mary Moon, Ph.D., is a professional chemist, technical writer and editor. She has hands-on R&D and management experience formulating, testing and manufacturing lubricating oils and greases. She is skilled in industrial applications of tribology, electrochemistry and spectroscopy. Contact her at mmmoon@ix.netcom.com or (267) 567-7234.