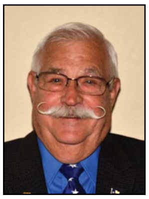
Controlling Equipment Failures Caused by Petroleum-Based Fluid Degradation



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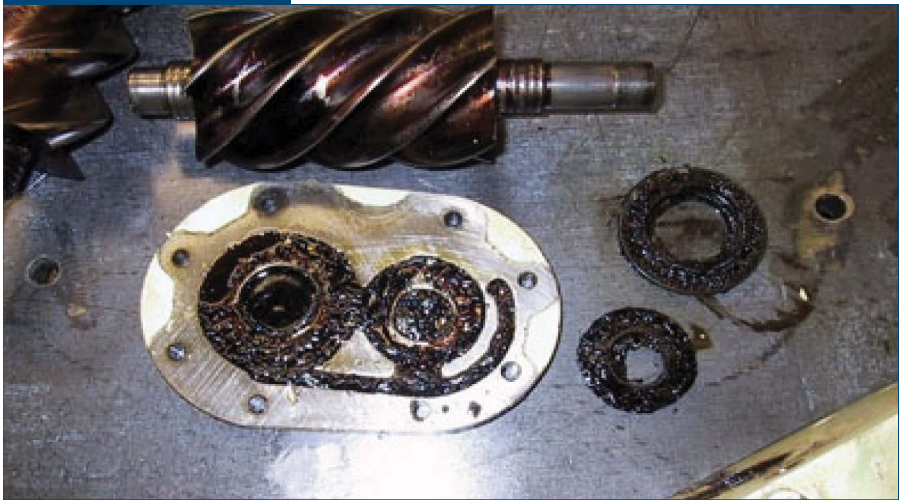
Air compressors, gearboxes and hydraulic systems that use mineral oils are susceptible to varnish and sludge. The life expectancy of petroleum-based fluid is generally determined by the rate of oxidation. When oxygen comes in contact with a petroleum-based fluid, oxidation occurs. The problem is usually dealt with by dumping the fluid and flushing the system or purchasing a varnish removal filter. New fluid technology is eliminating this problem in a way that is much less expensive and more efficient. Suppliers have developed oil-soluble polyalkylene glycols that, when added to the oil in small amounts, eliminate varnish, reintroduce oxidation additives and decrease total acid number.

Due to technology advances, the physical size of production equipment is becoming more compact. Revamped internal components allow faster operations with more precision and power in a smaller package. Auxiliary pieces like gearboxes, hydraulic components and air compressors, which have also been reduced in size, must contend with higher production demands. Equipment engineers and designers are constantly pressing to get more production out of their equipment.

One area that size reduction affects is lubricant holding capacity. Smaller capacity provides less volume into which heat can dissipate — less ability to pull out heat generated during operations. New fluid technologies have relieved some, but not all, of the problems associated with high temperatures.

Air compressors, gearboxes, oil-circulating systems and hydraulic systems that use mineral oils are susceptible to varnish and sludge (Fig. 1). This is an inherent problem associated with petroleum-based

Figure 1



Compressor parts damaged by varnish.

fluids. The life expectancy of petroleum-based fluid is generally determined by the rate of oxidation. When oxygen comes in contact with a petroleum-based fluid, oxidation occurs, causing sludge, varnish and an increase in total acid number (TAN). High temperatures exacerbate the development of varnish, which can cause major operational problems.

Some companies with large oil-circulating systems have purchased costly filtration devices to remove suspended varnish. This process, however, will do nothing to remove varnish that has plated out on equipment metal. Draining the system and then cleaning with solvent is another expensive solution to a varnish problem. Today, however, advancements in technology have made varnish filters and solvent cleaning unnecessary. This paper will discuss this new method.

Polyglycol Technology

Polyglycol products have been available since the 1940s in the form of water glycol, which was developed by Dow Chemical for use in the mining industry and in Navy ship-board hydraulic systems. Today, water glycol is used in many industries where fire-resistant fluids are needed.

The glycol family is large, ranging from basic glycol antifreeze to sophisticated pharmaceutical glycols. A large portion of the family, polyalkylene glycols (PAGs), are used as synthetic lubricating fluids, providing many advantages over other fluids and oils used to lubricate equipment. PAGs are not a petroleum-based product. They are made from natural gas and therefore do not have the inherent problems of oxidation and varnish that petroleum-based mineral oils and polyalphaolefins (PAOs) have. PAGs also can handle large water incursions. Compared to mineral oil, which can handle 300 to 500 parts per million of water before degrading, PAGs can handle more than 10,000 parts per million (1%) water before steps would have to be taken to curb the infiltration. When water does occur in quantity, fluid degradation does not occur. Any free water can be removed with a vacuum dehydrator with no damage to the PAG. Many papers have been written about polyalkylene glycols. While some have been very accurate as to the advantages and disadvantages, some have not. This paper focuses on the ability of a polyalkylene glycol molecule to not varnish, how the molecule attracts free radicals (oxygen atoms) in mineral oil, and how adding PAG technology to petroleum-based fluids will control varnish and give longer life to the fluid.

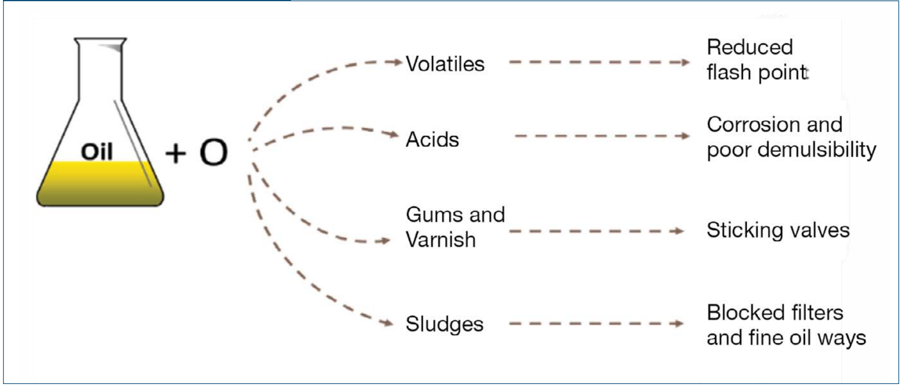
There are three basic types of polyalkylene glycol: insoluble in water, water soluble and oil soluble. Each was developed to provide specific lubricating characteristics and each has a place in industry with distinct advantages.

Oxidation and Varnish

An oil-soluble polyalkylene glycol (OSPAG) has recently been developed that, when added to petroleum-based oils, reverses oxidation and rehabilitates the fluid back to a usable and stable condition. Varnish is a product of petroleum-based oil oxidation. Oxidation is caused when a free radical (oxygen atom) infiltrates an oil molecule (Fig. 2). Oxygen is a very reactive atom and can cause an increase in the molecule's total acid number. The acid that is developed will eventually cause total degradation of the oil. Heat, water and contaminants can accelerate this action. To help alleviate this action, oil suppliers blend oxidation inhibitors (usually amines and phenols) into finished mineral oil. The inhibitors are polar and attract free radials (oxygen atoms) away from the lubricating oil molecule, thereby reducing the chances of oxidation.

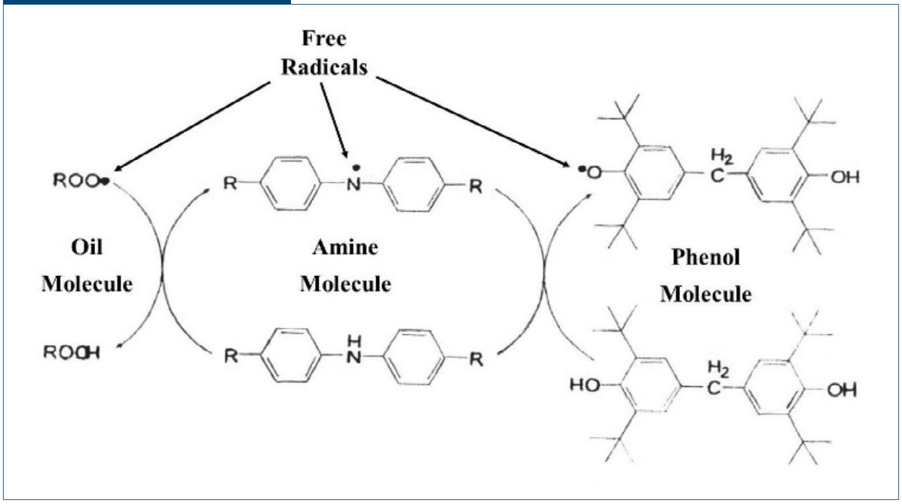
Generally, the amine molecule is the active element in the antioxidant additive package. It receives the free radical and then passes it off to the phenol molecule (Fig. 3). This action continues until both the amine and phenol molecules become totally saturated with free radicals (Fig. 4). At this point they drop out of solution and become a varnish particle. The particle not only traps amines and phenols, but it will also pull in free water molecules and even very small contaminant particles. Because they are extremely polar and loaded with free radicals, the varnish molecules

Figure 2



Heat, water, air and contamination will accelerate the oxidation.

Figure 3



Simplified version of antioxidants in action.

will be attracted to each other, producing larger particles, or will be attracted to, and plate out on, metal surfaces such as bearings, valves and rotating devices.

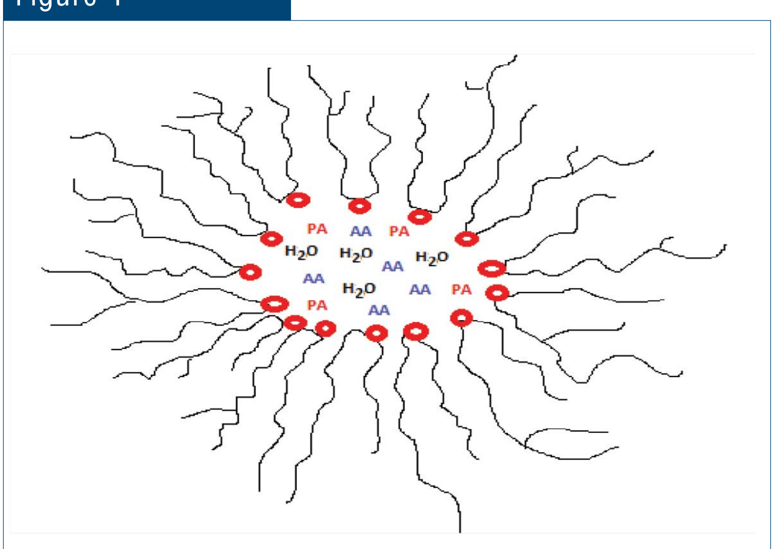
Places where temperature gradients are found, such as between rolling elements in a bearing or in small oracles in hydraulic valves, are natural places where the varnish molecule will plate out. Plating in turn increases heat generation, causes hydraulic valves to stick and reduces overall system efficiencies.

The increasing acid numbers will cause the oil to degrade rapidly to the point where it is no longer usable. Until now, dumping the system and recharging has been the only solution. With new fluid technologies, however, this expensive solution can be avoided. Adding a small portion of oil-soluble polyalkylene glycol into systems using mineral oil will solve these varnish problems.

The OSPAG is not an additive that adds antioxidation amines and phenols to the oil solution, it is a base oil modifier. It actually attacks varnish, leaving the original antioxidants to resume their protection (Fig. 5). When added to the base fluid, OSPAG shifts the polarity and gives the modified base oil the ability to resolubilize varnish throughout the system. This is accomplished when 10–15% OSPAG fluid is added to the mineral oil system. Because PAG oil is soluble, it mixes completely without compatibility issues. The polyalkylene glycol molecules are extremely polar and will remove the free radicals that have attached themselves to the amines and phenols that have fallen out of solution. By removing the free radicals, the antioxidants are now free to go back into solution. One-third of all atoms in a PAG molecule are oxygen atoms, so they readily accept the free radicals without causing other problems. The radical cleansing not only removes the varnish radicals from suspended particles, but will also pull oxygen atoms from varnish that has become attached to metal surfaces allowing those antioxidants to become soluble again.

Not only will the OSPAG remove the free radicals from the varnish molecules, but it will also pull oxygen atoms that are in fluid solution, thereby stopping the radicals from getting to the mineral oil molecule. As the radicals are released from the varnish molecule, small trapped water molecules are also released. These are generally not an issue because the small amounts are soon dissipated through vaporization.

Figure 4

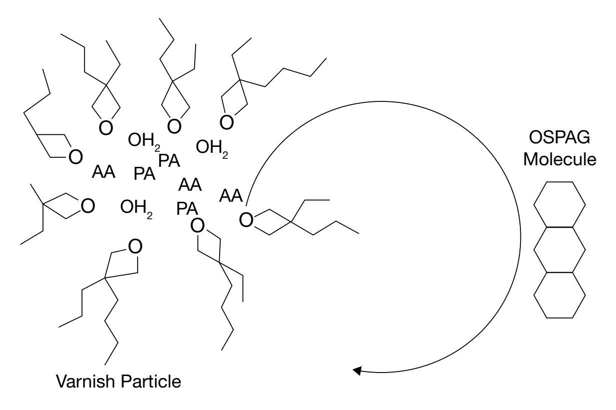


Anatomy of a saturated varnish molecule.

Concerns

Not every application is suitable for the use of OSPAGs. For instance, do not use PAGs in reservoirs that have been painted, unless it's epoxy paint. Glycol-based products are a great paint remover and

Figure 5



Oil-soluble polyalkylene glycol molecule breaking up a varnish particle.

Figure 6

Varnish has been removed from filters in a hydraulic system.

undissolved paint can clog filters or contaminate system components.

Another place OSPAGs should not be used is with petroleum-based oils that have zinc additives. Zinc is not compatible with any polyalkylene glycol and will cause gumming.

And finally, older systems that use organic seals, O-rings or gaskets should not use any synthetic fluid. Synthetic fluids can cause these products to shrink or swell, depending on the fluid, and leak.

It is suggested that before using OSPAG in any application, consult with the supplier on its use in the application.

Results

The usual time period for the OSPAG to work effectively is dependent on the condition of the system when it is converted. The typical period is about 45–60 days; however, the long-term working effect, in most cases, can be several years. The oil should be sampled on a routine basis to determine its condition. The TAN will be the determining factor as to the life of the fluid. As the varnish molecule is broken, releasing the antioxidants back into solution, the TAN will lower.

As seen in Fig. 6, OSPAGs have removed the varnish from filters used in a hydraulic system. These results were accomplished in 45 days using a 10% addition of OSPAG.

Conclusion

Because companies are demanding greater production from their equipment, lubrication fluid maintenance has become critical. Technologies have been developed to handle greater fluid stress and longevity, however the basic problem that petroleum fluids have — varnish — is still a problem.

Oil-soluble polyalkylene glycol is a base oil modifier that, when added to mineral oil or polyalphaolefin, reverses oxidation and acid accumulation, both detrimental to equipment.

Depending on the condition of the base oil, the amount of OSPAG needed to reverse the degradation can be from 8% to 15%, and the time for it to completely transform varnish can range from as little as two weeks up to three months. ✦

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