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Efficiently removing water and air from oil-based lubricants via a membrane system

A new technique utilizes a membrane system to get rid of water.

Water contamination remains a major problem for those maintaining lubricating oil systems. A previous TLT article looked at the effect of various contaminants on the ability of machinery to operate at an optimal level.[1]

Free water, dissolved water and emulsified water all play a role in hindering lubricant performance. The presence of water changes the lubricity, film thickness and viscosity of the fluid. Free water promotes corrosion.

Other problems that occur include the growth of microbes that release acidic byproducts, decomposition of specific components in the lubricant such as esters that are susceptible to hydrolysis and oxidation.

KEY CONCEPTS

- A fluoropolymer-based membrane proved very effective in removing water from lubricating oils.
- This membrane dehydrator uses a vacuum to force water to permeate from the oil through the membrane.
- Field testing is underway in such applications as gear oils used in paper mills, coal conveyors and wind turbines.

Air also can cause problems in lubrication systems when it is present in three states (free, dissolved and entrained). Oxidation is the largest threat that air imposes on lubricants, meaning the fluid must include antioxidants to reduce the possibility of decomposition. In cases of a large degree of air entrainment, foam also may be an issue, so measures need to be taken in the lubricant system to facilitate the release of air.

There are techniques available to deal with the removal of water such as vacuum dehydration filtration, superabsorbent filtration and centrifugal separation. Each has its strengths and weaknesses.

A need exists though for a simple, lightweight and more efficient way to remove water and air from lubricating oils. Such a technology is now available.

MOLECULAR SIEVING MECHANISM IN A MEMBRANE

A dehydrator unit based on a fluoropolymer membrane that has been in use for the past 10 years is now available to the lubricant industry. Dr. Sudip Majumdar, director of application development at Compact Membrane Systems, Inc., in Wilmington, Del., says, "We have developed a system that is very effective in removing water from lubricant oils. The dehydrator is based on a membrane module and is approximately the size of a tennis ball can."

The membrane module itself is configured similarly to a shell-and-tube heat exchanger. Water-laden liquid lubricant follows across one side of the hollow fiber membrane while a vacuum is applied on the other side. Majumdar explains, "The membrane dehydrator uses a vacuum to force water to permeate from the oil through the membrane. Our product technology functions by separating components in lubricating oil based on their size. As a small molecule, water moves through the membrane at a much faster rate than the other species in the lubricant. The water vapor is then discharged into the atmosphere."

A water molecule is approximately 2.6 angstroms in diameter, according to Majumdar. In contrast, the hydrocarbon propane has a diameter of about 5.1 angstroms. Majumdar adds, "Due to its smaller size, water permeates 50 to 100 times faster than propane. As you evaluate higher alkanes such as those formulated into lubricating oil, their large size and low vapor pressure makes it very difficult for them to go through the membrane."

The performance of the membrane dehydrator was assessed in bench-top studies with an ISO 320, polyalphaolefin-based, synthetic gear oil. At a temperature of 38 C and a flow rate of 0.45 liters per minute, the gear oil passed by the membrane at initial water concentrations ranging from 1,150 ppm to 2,500 ppm.

Water content in all cases dropped below 100 ppm in a matter of two hours or less and continued to drop to the level of 25 ppm over time. The impact of how flow rate affects water removal also was evaluated for this ISO 320 gear oil. Water removal was evaluated at 0.45, 1.0 and 1.5 liters per minute. More effective water removal is seen as the flow rate increases until the water is almost completely removed.

Majumdar says, “Increasing the flow rate of the oil enables the water molecules to diffuse more quickly from the oil to the surface of the membrane. The Reynolds Number increases because of the higher shear rate, which decreases the resistance encountered by water molecules in the oil.”

In contrast, water is more difficult to separate as the viscosity of the oil increases. Majumdar says, “This factor is also related to the Reynolds Number. Viscosity is in the denominator of the Reynolds Number equation, which means that a higher viscosity value will reduce the efficiency of water removal. But the degree of water removal is still quite effective with our membrane dehydrator, especially at higher flow rates.”

Higher temperature improves the diffusion rate of water in the oils because it will reduce oil viscosity and also increase the permeation rate of water through the membrane. Majumdar says, “The membrane dehydrator is designed to operate up to an oil temperature of 100 C.”

Water is effectively removed no matter its state in the lubricating oil. This covers dissolved water, emulsified water and free water.

Besides water, the membrane dehydrator is very effective at removing dissolved gases from the lubricating oil. Majumdar says, “This secondary benefit of our technology reduces the rate of oxidation and minimizes foam generation. We have found gas removal to be especially valuable in wind turbine applications.”

As lubricating oils degrade, the level of oxidation products and acidity increases. The membrane dehydrator was evaluated at elevated levels of water to determine how it performed to prevent a vegetable oil-based hydraulic fluid from breaking down over time.

Majumdar says, “We added approximately 1,000 ppm of water to the biodegradable hydraulic fluid and kept two samples in an 80 C oven for 25 days. One sample was periodically treated with the membrane dehydrator and the water replenished. The second sample was maintained as a control. During the test period, the acid value of the control increased to nine by the end of the test. No such rapid increase was seen with the sample treated with the membrane dehydrator.”

A second test procedure using the membrane dehydrator involved starting with a sample at an acid value of approximately five. Majumdar says, “Over an 18-hour period, the acid value decreased steadily until it reached a value of three.”

Majumdar indicates that after extensive bench level development, his company is in the process of field testing the membrane dehydrator with lubricating oils in gearboxes for paper mills, coal conveyors, cooling towers and wind turbines.

Demonstrations with hydraulic fluids in coal power plants, wind turbines and nuclear power plants also are underway. Majumdar adds, “Some of these hydraulic systems use fire-resistant phosphate ester oils that have challenging corrosive properties, which we expect will not be a problem for our fluoropolymer membrane.”

Figure 1 shows an image of the prototype membrane dehydrator system. This set-up easily can be incorporated into a current lubricating oil system using a kidney loop configuration. The current commercial prototype system weighs 55 pounds. By contrast, vacuum dehydration filtration systems weigh a minimum of 165 pounds and have many more moving parts. This weight reduction should be valuable in many applications, especially remote locations like wind turbines.

Majumdar adds that the membrane dehydrator unit has been successfully used to treat transformer oils during the past 10 years. Further information on the membrane dehydrator can be found at **www.compactmembrane.com** or by contacting Majumdar at **smajumdar@compactmembrane.com.**

Majumdar wishes to acknowledge the U.S. Department of Energy for its assistance in funding the development of this technology.

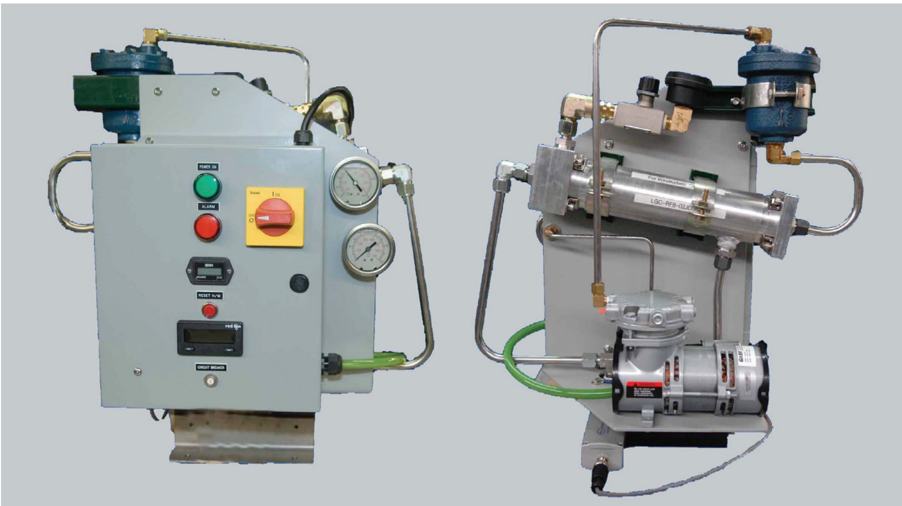

Figure 1 | **Proven effective in removing water from lubricating oils, this prototype membrane dehydrator system is being field tested in a number of applications including wind turbines.** *(Courtesy of Compact Membrane Systems, Inc.)*

REFERENCE

1. Johnson, M. (2009), “Industrial Fluid Contaminants and Their Effect,” TLT, **65** (9), pp. 26–31.