Membrane Dehydrators for Efficient Water Contamination Control in Lubricating and Hydraulic Fluid

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ABSTRACT

Ingression of water or ambient moisture over time into industrial lubrication and hydraulic fluid systems causes major operational and maintenance problems. Water can be present in such systems as free, dispersed and dissolved water. The contamination level of water in lubrication oil adversely affects the service life of the associated components. Industry studies show gear/bearing life can be increased fivefold by reducing the dissolved water concentration to a very low level. A new commercial membrane dehydrator system has been introduced in the market recently to dewater lubricating and hydraulic fluids in real time. The device can remove free, dispersed and dissolved water and extend the reliability and life of gearboxes, reduce maintenance costs, and increase uptime. First generation commercial systems have demonstrated stable performance over 12 months of continuous field operation. A larger dehydrator system with 7 fold increase in productivity has also been developed.

Keywords: membrane dehydrator, lubricating oil, water contamination control, environmentally acceptable lubricants

1 EFFECTS OF WATER IN LUBRICATING OIL

Water ingress affects both the performance of the lubricant itself and the machinery being lubricated. The presence of water in lubrication oil undermines the ability of the oil to perform its two basic functions: enabling performance and preventing damage to machinery. Even when lubricants can continue to perform their primary lubrication function in the presence of water, they must remain clear of water (free, emulsified and dissolved) in order prevent loss of lubricity, component damage and degradation that will shorten the service life of gears, bearings, and hydraulic systems.

Lubricant manufacturers and lubrication specialists recognize the damaging effects of water on components (e.g., through acid buildup, corrosion, spalling, hydrogen embrittlement, biomass buildup, especially with presence of salt). For this reason, lubrication management best practices and standards are written for the control of (free) water (Duncanson, Marianne, 2005).

Managing water is a concern in several areas where ingress is an ongoing challenge, given the nature of the environment. Such applications are far reaching and include: power plants, paper mills, coal conveyors, cooling towers, steam turbine, wind turbines, and marine systems. Wind turbines and cooling towers are particularly challenging due to difficulty in accessing and maintaining dehydrating hardware.

Managing dissolved water is an emerging concern in marine lubrication, where EALs are now the regulated standard per 2014 changes by the EPA. EALs are hygroscopic, attracting a high concentration of water, even in dissolved states. In fact, EALs are often designed to be water soluble and hold water in a dissolved state in order to meet EAL standards of biodegradability. This design feature creates a challenge as it solves a problem.

Even very small amounts of dissolved water in lubricating oil can have substantial impact on bearing fatigue life, accelerating metal surface fatigue. In a detailed Timken study, (Cantley, 1977) investigated the effect of dissolved water in lubricating oil on the fatigue life of roller bearings. The chart (Figure 1) below shows an adaptation of Cantley's findings. Bearing life could be extended over 500% (i.e., 25 years vs. 5 years), if the bearing lubricant contained only 25 ppm dissolved water compared to 400 ppm. In fact, the degree of life reduction resulting from an increase of the water level from 25 to 100 ppm was much greater than the fatigue life decrease experienced by raising the water content from 100 to 400 ppm (Cantley, 1977).

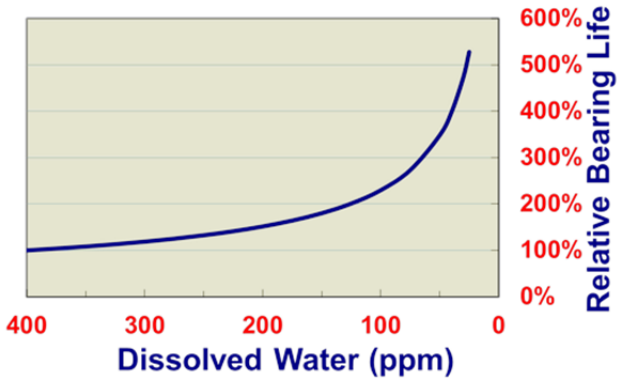

Figure 1. Bearing life vs. Dissolved water concentration

2 REMOVING DISSOLVED WATER IS CHALLENGING

Free water can be removed by decanting or centrifugation; but these solutions can't remove dissolved water. Smaller concentrations of emulsified water can be removed by coalescing filters or cellulose absorbent filters, but become costly and labor intensive to manage in applications with water ingress – and they still leave dissolved water behind.

Vacuum distillation is the most effective alternative at eliminating free, emulsified, and dissolved water, but does so at a high cost with a bulky, heavy and complex solution. They cannot easily be used inline in tight quarters (e.g., onboard ships, in wind turbines) to address the ongoing need for water removal in a system with high uptime and/or water ingress. Vacuum systems can also damage and/or remove oil additive packages, as a part of the heating and evaporation processes. Given their size, high capital cost, high voltage and energy needs (to heat the oil) and need for complexity oversight (to reduce risk of flooding and foaming, replacing and repairing multiple mechanical parts prone to wear and breakage), vacuum distillation is not a practical solution in many situations.

3 MEMBRANE DEHYDRATORS FOR CONTROLLING WATER

Compact Membrane Systems (CMS) has developed a compact novel membrane-based system to dewater lubricating oil in real time. The Mini system is designed for easy installation into an existing lubrication circuit using a kidney loop configuration, using the lube or hydraulic system's own fluid pump or pressure port. The Cart versions provide their own pumping and can be moved between unpressurized oil reservoirs. With oil circulated on one side of the membrane module and a vacuum with sweep air on the other side; the device can remove free, emulsified and dissolved water. The systems can be made explosion proof by using a small compressed air driven vacuum system. A photograph of the commercial membrane dehydrator systems is shown in Figure 2.

Figure 2. Commercial membrane dehydrators

Membrane dehydrator maintains extremely low moisture levels (dissolved, emulsified, and free) in lubricating and hydraulic oils, working inline in wind turbines or while vessels are at sea to extend equipment and oil life and overall system reliability. Removes water without removing performance additives; works effectively in dehydrating oils in the presence of both fresh and salt water.

It is a simple, reliable, compact, portable, and lightweight system with low energy usage, requiring only a common 120 volt (or 220 volt) connection. The unit is compact enough to fit through ship hatches or to be lifted into a turbine nacelle. It avoids flooding, foaming and the constant attention required with standard vacuum oil purification systems. Once set up, the system runs without oversight and management, with fewer moving parts than vacuum oil purification systems. The flexible system can be used on one unit long term or to do batch processing across multiple operating units.

The device has been demonstrated in controlled as well as in industrial environments and has been shown to remove 100% of free and emulsified water, reduce dissolved water to well below 100 ppm and under certain conditions can remove dissolved oxygen. CMS membrane modules have been tested on over 20 lubricants, including different types of EALs (vegetable oil, polyalkylene glycol, esters) as well traditional lubricants (mineral oils, polyalphaolefins, phosphate esters). Performance with Mobilgear 320 wind turbine gear oil is shown in the next chart (Figure 3).

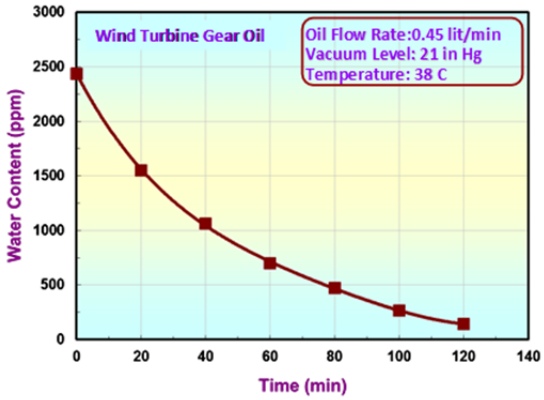

Figure 3. Drying wind turbine gear oil

Environmentally Acceptable Lubricants (EALs) are the new EPA standard in marine applications. While friendlier to aquatic life and the environment, these compounds pose a challenge to the lubrication engineer. EALs are hygroscopic, attracting and retaining large quantities of water in a dissolved or miscible state. Performance with a selection of EALs is shown in Figures 4 and 5.

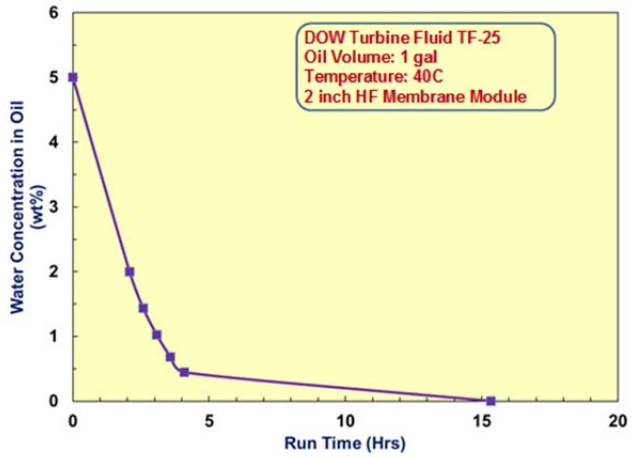

Figure 4. EAL drying with membrane dehydrator

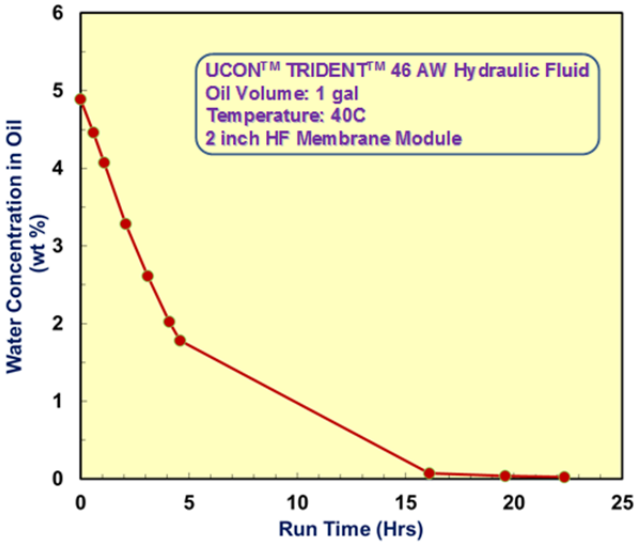

Figure 5. Test run with EAL hydraulic fluid

Esters, in particular, are subject to acid build-up as a result of hydrolysis, which poses an additional risk to machinery. CMS lab work indicates that membrane systems can prevent and mitigate hydrolysis and acid buildup when lubricant is in use. Such systems can actually reverse hydrolysis, by creating the conditions that encourage the conversion of the acid and alcohol back to an ester.

4 CONCLUDING REMARKS

- Membrane dehydrator effectively removes free, emulsified and dissolved water from all types of lubricants and hydraulic fluids.
- The dehydrator system is small, low power consumption (110 V or 220V), light-weight, high performance and reliable with minimal moving components.
- Commercial membrane dehydrator systems are available for small to medium size oil reservoirs.

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