RECENT STUDIES RELATED TO THE MEASUREMENT OF SEPARATION OF WATER FROM LUBRICANTS : WHY PERFORM A WATER SEPARABILITY TEST AND WHAT DO THE RESULTS MEAN ?

Water is known as one of the best choices for liquid cooling applications due to its high heat capacity and thermal conductivity. It is also compatible with copper, which is one of the best heat transfer materials to use within a fluid path and even possesses more favorable thermal characteristics than oil, but water's use in the realm of bearings is still restricted to some rare applications [1,2]. Moreover, the presence of water in lubrication circuits is seen as not at all desirable and can be a dangerous contaminant for oil. Primarily, corrosion from water can incur costly damage to equipment and shorten its working lifetime dramatically. Several testing methods and innovative practices for minimizing contamination have been introduced to control water contamination through proper removal and prevention. New technologies can extend the life of the lubricant and machine through the proper detection and removal of water.

The presence of water in lubricants can have many detrimental effects on both oil and equipment. The following are common adverse effects of water contamination; rust and corrosion, hydrogen embrittlement, reduced lubricating characteristics, and the diminishing effectiveness of protective additives [3]. When metals are exposed to water and oxygen for a prolonged period the metal oxidizes. When a metal rusts or corrodes, metal oxides can flake off the metal surface and contribute to abrasive wear in the system. Water also serves as a source of hydrogen during the process of hydrogen embrittlement, which is when hydrogen diffuses through metal and causes metal surface damage. The absorbed hydrogen causes high-pressure build-up within metals leading to blistering and cracking. Lubricating oil viscosity increases as pressure increases, which is an important property for components like rolling element bearings operating under high load conditions. However, water does not increase in viscosity as pressure increases, creating increased contact between metal surfaces that can cause fatigue wear. As water promotes oxidation in the presence of heat, oxygen, and metal, it can lead to the formation of oxidants and free radical components. These radical components can deplete the levels of oxidation inhibitors and diminish the effectiveness of protective additives because of the water's polar nature [3].

Water contamination in oils can be categorized into three forms of water: dissolved, emulsified, and free. Dissolved water is the lowest level of moisture contamination in lubricating oils and is characterized as individual water molecules dispersed throughout the oil. Not visible to the naked eye, lubricating oils can contain a significant concentration of dissolved water which is classified as any value greater than 50-300 ppm (or 0.005%-0.03%) [4]. The acceptable levels of dissolved water do not greatly affect the compressibility or viscosity of the oil, but it does enhance the oil's chemical reactivity since water is dispersed throughout the oil which can lead to degradation of metals and depletion of additives. The most destructive form of contamination in lubricants can form when dissolved water is left unchecked and continues to increase within the oil sample until it reaches a saturation point [5]. At this point, any added water will precipitate out as cloudy emulsified microdroplets. When the amount of water is beyond the saturation point and has likely entered the lubricating stream, the lubricant is contaminated with emulsified water [6]. The saturation point varies for different lubricants, with mineral oil having a saturation level of 100 ppm, while some hydraulic fluids have a saturation level as high as 5000 ppm. Free water is neither dissolved nor emulsified within an oil sample but remains in a distinct and separate aqueous liquid phase. It can cause significant rusting where an engine can suffer irreparable damage and the cost of replacing the engine and labor will be substantial. Lubricants are tested and filtered to clean them thoroughly, but moisture will eventually absorb into the engine system. Monitoring for moisture content is of great importance for in-service lube oils, which can be done through appropriate methods and test of moisture analysis.

Table 1 Lab-scale ion exchange treatment of 14 different in-service steam turbine oils [9].

In-Service Oil Sample	Initial Demulsibility	Post IX Demulsibility	Emulsion Decrease (%)	Separation Time Improvement (%)
1	40-25-15 (>30)	40-40-0 (10)	100	67
2	39-8-33 (>30)	40-36-4 (>30)	88	0
3	5-0-75 (>30)	40-36-4 (>30)	95	0
4	40-33-7 (>30)	40-40-0 (10)	100	67
5	5-24-51 (>30)	46-34-0 (>30)	100	0
6	15-25-40 (>30)	41-38-1 (15)	98	50
7	40-37-3 (30)	40-38-2 (10)	33	67
8	0-27-53 (>30)	41-37-2 (25)	96	17
9	0-11-69 (>30)	9-22-49 (>30)	29	0
10	40-38-2 (15)	41-39-0 (10)	100	33
11	4-3-73 (>30)	37-37-6 (>30)	92	0
12	40-38-2 (15)	40-38-2 (10)	0	33
13	40-38-2 (10)	40-38-2 (5)	0	50
14	30-18-32 (>30)	40-40-0 (10)	100	67
Average	24-23-33 (26)	38-37-5 (18)	85	31

The ability of lubricating oil to separate water and resist emulsion is an important performance characteristic for applications involving water contamination and turbulence. The ASTM D1401 test method for Water Separability of Petroleum Oils and Synthetic Fluids measures the ability of petroleum oils or synthetic fluids to separate from water [7]. This test method provides a guide for determining the water separation characteristics of oils subject to water contamination and turbulence which can be used for specification of new oils and monitoring in-service oils. The standard water testing method can be carried out in different equipment, one being the Koehler Water Separability Tester [8]. Water separability is determined by stirring equal volumes of water and sample together at a controlled temperature to form an emulsion and observing the time required for separation of the emulsion to occur. The Water Separability Tester allows for full visibility of all functions and accurate testing of up to seven samples at a time.

An example of a run-through water separability experiment consists of mixing 40 mL of oil and 40 mL of water at 1,5000 rpm for 5 minutes. The oil-water separation is monitored at 5-minute intervals thereafter and the test is stopped when separation is complete or stopped after 30 minutes if separation is still incomplete. The results are recorded as: mL oil-mL water-mL emulsion (minutes required) [9]. The time reported is based on the product passing the product separability requirements against which it is being tested for or when the test limit for water separability is exceeded. Usually, the test limit for water separability is 3 mL emulsion or less for 30 minutes at 54°C, which is considered a passing result, and 60 minutes at 82°C [10,11]. Poor demulsibility can be addressed through two main strategies, restoration by addition or restoration by removal. Restoration by removal through ion exchange has shown to be low risk and has the most consistent results out of all the other strategies. Ion exchange decreases propensity towards emulsion formulation, decreases oil-water septation time, and removes harmful contaminants like acids, metals, and varnishes. The results showed a 94% decrease in emulsion forming tendency and water separated more than 20 minutes faster. Table 1 shows all 14 in-service oil samples used in the experiment and compared the initial demulsibility with demulsibility after restoration by removal of ion exchange. Treated oils were 85% less prone to the formulation of emulsion and treated oils separated from water 31% faster [9].

Water contamination in lubricants oils is one of the most detrimental factors in industrial applications. If the water content exceeds a certain level that the lubricating oil cannot accept, it may shorten the service of the lubricating oil and damage machine components gradually. Using precise and reliable testing technology to determine the ability of lubricating oils and other products to separate from water constitutes a valuable tool not only for determining specifications for new oils but also to monitor in-service oils. Standard testing methods allow for the optimization of prevention for reducing downtime and repair costs avoiding unnecessary unscheduled maintenance. While standard oil analysis may be sufficient for monitoring the lubricant condition of rotating equipment with a relatively small sump size, additional testing, like water separability, is essential in establishing the complete picture to save millions of dollars of unplanned downtime in machine operations.

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Figure 1 Koehler Water Separability Tester [8].

About the Authors

Dr. Raj Shah is a Director at Koehler Instrument Company in New York, where he has worked for the last 25 years. He is an elected Fellow by his peers at IChemE, CMI, STLE, AIC, NLGI, INSTMC, The Energy Institute and The Royal Society of Chemistry An ASTM Eagle award recipient, Dr. Shah recently coedited the bestseller, "Fuels and Lubricants handbook", details of which are available at

https://www.astm.org/DIGITAL_LIBRARY/MNL/SOURCE_PAGES/MNL37-2ND_foreword.pdf

A Ph.D in Chemical Engineering from The Penn State University and a Fellow from The Chartered Management Institute, London, Dr. Shah is also a Chartered Scientist with the Science Council, a Chartered Petroleum Engineer with the Energy Institute and a Chartered Engineer with the Engineering council, UK. An adjunct Professor at the Dept. of Material Science and Chemical Engineering at State University of New York, Stony Brook, Raj has over 400 publications and has been active in the Oil analysis field for 3 decades. More information on Raj can be found at

https://www.petro-online.com/news/fuel-for-thought/13/koehlerinstrument-company/dr-raj-shah-director-at-koehler-instrumentcompany-conferred-with-multifarious-accolades/53404

Ms. Alexandra Przyborowski is a student of Chemical engineering at SUNY, Stony Brook University, and currently works as an intern at Koehler Instrument Company, in Long Island, NY.

Alexandra Przyborowski

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Author Contact Details

Dr. Raj Shah, Koehler Instrument Company • Holtsville, NY 11742 USA • Email: rshah@koehlerinstrument.com • **Web: www.koehlerinstrument.com**