Moisture Contamination and its Effect on the Remaining Useful Life of Bearings

Determination and Analysis of Water Content in Lubricating Oils by RH Sensor

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Lubrication is Essential for Predictive and Preventative Maintenance

Lubrication reduces friction, minimizes wear and tear on moving parts, decreases the likelihood that particle contamination will occur and helps maintain lower operating temperatures, all of which helps keep your machinery in optimum operation condition and extend its useful life.

Lubrication is particularly important in regard to bearings. Bearings are the joints of a machine. They bear heavy loads and help execute and control the movement of the connected parts. When these joints fail, movement becomes less fluid and efficient and can eventually cause serious damage. Lubrication is a machine's method of protecting its joints and ensuring that the machine as a whole is in good working order. It creates a barrier between the softer material of the bearings and the other parts of the machine. This helps defend the bearings against the excessive wear and tear that can dramatically reduce their useful life.

When something threatens the potential effectiveness of lubrication, it not only affects the lubricant itself, but also the bearings and other moving parts that it was meant to protect. While each lubricant is designed with a specific purpose and application in mind, they all share a common nemesis: moisture contamination. This paper will discuss the dangers of moisture contamination, its effect on bearing life and the various techniques available for moisture analysis.

Different Bearings Require Different Types of Lubrication

The most common methods of lubrication associated with bearings are hydrodynamic and elastohydrodynamic.[2] An understanding of how these types of lubrication work will help demonstrate the important role that lubrication plays in ensuring that your machinery continues to run smoothly.

Both hydrodynamic and elastohydrodynamic lubrication use the motion of moving machinery parts to force the lubricant around or between those moving parts.[4] In hydrodynamic lubrication specifically, the lubricant is pushed up and around the bearing, surrounding it in a thin layer of oil. The continued motion of the machinery allows for a constant flow of lubricating oil, creating a protective layer that is always intact.

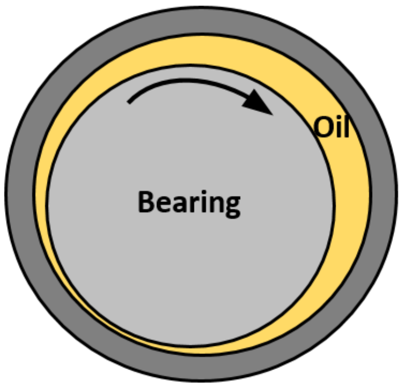

Fig. 1 Hydrodynamic Lubrication

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This coating prevents the surfaces of the bearings and other machinery parts from rubbing against one another. Without lubrication, small particulates would break off, cause particle contamination and increase abrasion. As more particulates break off, the rate of destruction increases exponentially, damaging both the bearing and the machinery as a whole.

In elastohydrodynamic lubrication, the lubricant flows between two contact surfaces. As flow pressure increases, the lube creates a film that completely separates the two surfaces.[3] This is especially important because the softer material of the bearing itself is more vulnerable to abrasion. The lubricating oil provides an extra layer of cushioning that protects bearings and other moving parts from excessive wear and tear.

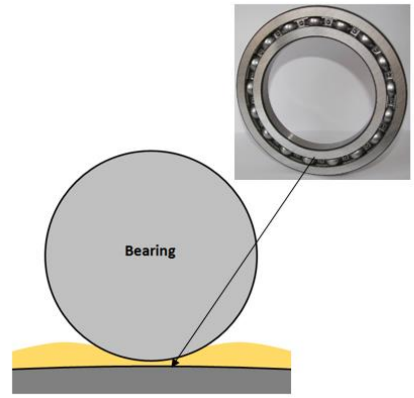

Fig. 2 Elastohydrodynamic Lubrication

Moisture Decreases Lubricant Efficiency and Causes Early Wear and Tear on Machinery Parts

Hydrodynamic and elastohydrodynamic lubrication methods are both at risk of failing when exposed to moisture contamination.[2] Not only does moisture decrease lubricant efficiency and causes early wear of machinery parts, it also increases maintenance costs and down-time while machinery is being repaired and can have devastating effects on the lubricating oils themselves.

Whether from condensation due to temperature fluctuations during storage or from exposure to ambient humidity, the threat of water contamination is always there. From base oil to full synthetic, oil's high susceptibility for water absorption increases the likelihood that moisture contamination will occur. Water also renders some additives ineffective while it reacts with others to create excess sediment, hydrogen sulfide and other compounds.[5] All of this leads to pitting and particle contamination, which in turn increase friction and decrease performance, reducing bearing life even further.[5]

Water can also cause premature breakdown of a lubricant itself through oxidation and additive precipitation.[9] Moisture contamination can also change the viscosity of an oil. Excess water lowers an oil's viscosity, negatively impacting the lubricant's ability to maintain the proper film thickness to protect the bearings and ultimately decreasing the load that those bearings can support.[9] When this happens, corrosion and pitting are more likely to occur. This again leads to particle contamination and further machinery damage.

As little as 100 ppm water can cause a 32-48% decrease in bearing life.[1] For this reason, it is essential to perform routine moisture testing on lubricating oils. Not only does this ensure that they are in optimum operating range, but it also helps to discover, correct and prevent moisture contamination problems before they cause costly or irreparable damage.

Historical Methods of Moisture Analysis

Traditional methods for determining the presence of water in oils include the crackle (scintillation) test, Fourier transform infrared (FTIR) spectroscopy and Karl Fischer (KF) titration.[5] Of these options, only FTIR and Karl Fischer can give quantitative data regarding the actual moisture content of an oil.

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The Crackle Test is Subjective and Nonquantitative

The crackle test is generally considered to be a reliable method of detecting the presence of free or emulsified water in oils. It is most commonly used to give a “yes of no” answer as to whether or not water contamination has occurred. In other words, the crackle test is non-quantitative. Even when commonly practiced, the interpreted data is only accurate as low as 500 ppm and is still considered subjective at best.[8] Other limitations include the test’s inability to measure chemically dissolved water and the imperceptibility of results when test temperatures have reached higher than 160°C.[8] Potential dangers of the crackle test include eye injuries, burns and inhalation or contact with toxic fumes and vapors.

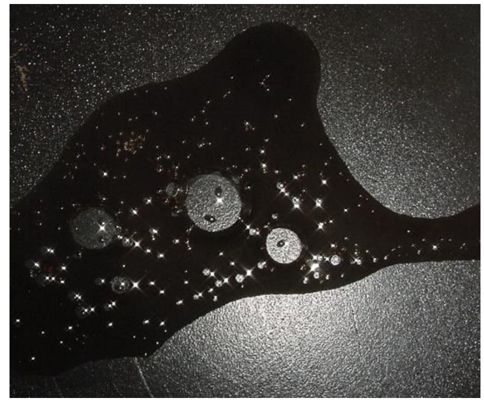

Fig. 3 Crackle Test

Fourier Transform Infrared Spectroscopy (FTIR) is Susceptible to a Number of Interferences

Fourier transform infrared spectroscopy (FTIR) is a method of analysis that involves observing the interaction between various wavelengths of infrared light and a sample, in this case a sample of oil. Additives and contaminants absorb and reflect different wavelengths of infrared light, and those measurements are then used to calculate the levels of those things that are present. The problem with this method of moisture analysis is that there are several interferences. Glycol, dust and soot, severe oxidation and certain additives can falsely inflate or deflate moisture contamination readings.[6]

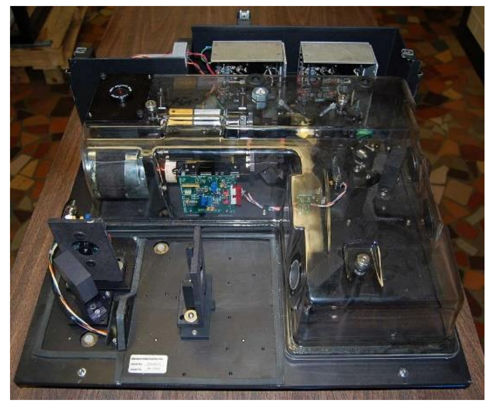

Fig. 4 FTIR

Karl Fischer Titration Requires Special Training and the use of Hazardous Chemical Reagents

Perhaps the most widely used method of moisture analysis is Karl Fischer titration.[5] Although it is capable of producing moisture specific results that are both accurate and precise, KF titration is difficult to use unless operated by someone with the proper training. A specially trained analyst also needs to be on hand to repair or perform troubleshooting on the KF.

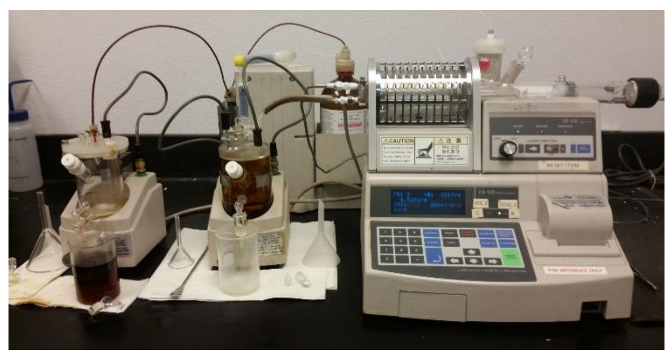

Fig. 5 Karl Fischer Titration

Common interferences of Karl Fischer that can bias test results include mercaptans, ketones, high pH materials, various functional additives and oxidation products.[5] Routine cleaning and replacement of chemical reagents and expensive glassware are major contributors to the high cost of ownership of a KF titrator.

Computrac Offers a Chemical Free, Moisture Specific Alternative to Karl Fischer

With all of the interferences and limitations that come with traditional methods of moisture analysis, more and more reliability professionals are turning to relative humidity (RH) sensing technology to make moisture analysis easier, more accurate and less of a financial burden. Relative humidity sensor moisture analyzers have a comparable lower detection limit to that of the KF (10 ppm) but are as easy to use as the crackle test.[5] No guessing, no hazardous chemicals, no fragile and expensive glassware and no specialized training needed.

Fig. 6 Computrac® Vapor Pro® XL

The RH method allows for a much more simplified user experience. This decreases the chance of user error and increases the reliability of test results. Maintenance is also much less complicated. A yearly calibration is virtually all that is needed to keep your analyzer in working order. Because relative humidity sensors are moisture specific, there are also far fewer interferences. The mercaptans that cause so much trouble in a Karl Fischer have no effect on the results of a relative humidity sensor moisture analyzer, although methanol and acetonitrile can cause a slight interference when present in high concentrations.

Comparing Moisture Analysis Test Methods

Testing lubricating oils for moisture contamination is essential, but which method is ideal? The crackle test is simple to perform, but any data gathered is subjective and non-quantitative. FTIR is more sensitive than the crackle test but is prone to erroneous readings due to its many interferences. That leaves Karl Fischer titration and relative humidity sensing technology.

For years Karl Fisch er has been the gold standard for moisture analysis. Technicians with the proper training and education are able to obtain accurate and repeatable results. If, however, the relative humidity sensor could be proven to be equivalent to KF, it could revolutionize how we test for moisture contamination in lubricating oils. An RH sensor moisture analyzer requires much less upkeep and is durable enough that it can be used not just in the lab, but on the production floor.

In order to prove the RH sensor moisture analyzer's equivalence to KF titration, six lubricating oils with varying levels of moisture contamination were tested. All were tested using volumetric KF titration as well as the moisture analyzer with a built-in relative humidity sensor.

The moisture analyzer used for this experiment consists of an RH sensor with two plates that have a constant dielectric difference between them. When moisture travels between the plates, it changes the capacitance. That change is then used to calculate the amount of moisture present in the sample.

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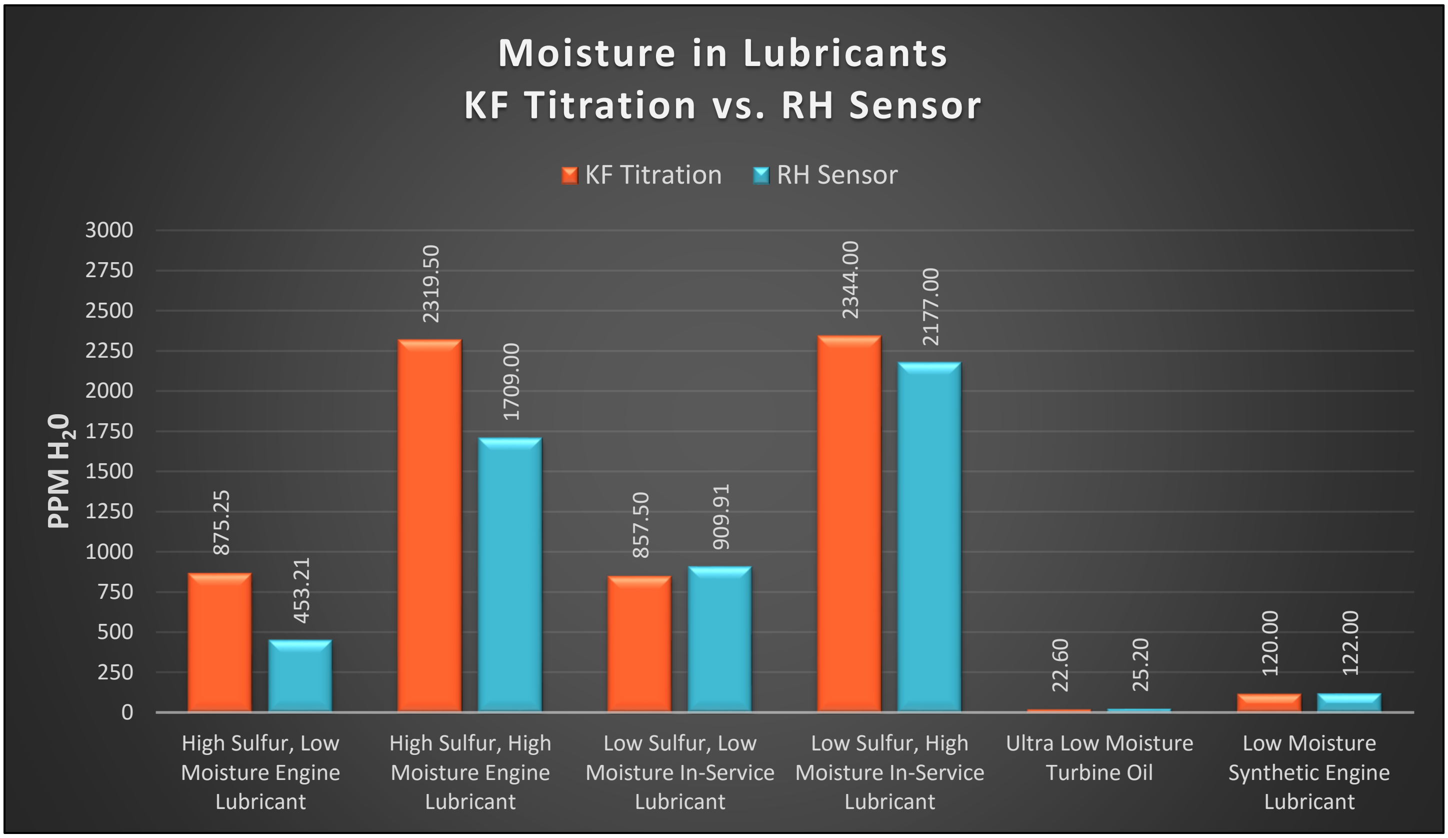
As you can see below, the RH Sensor method produces results that correlate well with Karl Fischer.



The nature of the RH sensing technology as well as the lack of chemical reagents means that the RH sensor method has far fewer interferences than KF titration. A known interference for KF that causes positive bias when measuring moisture content is sulfur.[5] Of the samples above, 4 contained sulfur. As you can see from the two samples with high levels of sulfur, the KF reading was much higher than that of the RH sensor.

While there are methods and calculations that experts can employ to obtain unbiased results after a KF test is performed, these are complicated and time consuming. Overall, the RH sensor technology has proven to be more accurate and precise while being significantly easier and more intuitive to operate.

Conclusion

Whether your lube oil is designed for an engine, turbine or even an assembly line, accurate control of moisture in lubricating oils is critical to keeping your machines running at their fullest potential. Failure to control moisture in lube oils can result in excessive pitting, oxidation and particle contamination, which in turn increases friction and decreases not just the performance of machinery, but the length of its useful life.[9] For this reason, it is essential to routinely test your lubricating oils so that you can discover, correct and prevent moisture contamination before it develops into a more serious problem.

Of the methods available to test for moisture contamination, our evaluation has proven that an RH sensor moisture analyzer is equivalent to Karl Fischer titration. While it is possible for a trained technician to obtain accurate and precise results by using Karl Fischer, the instrumentation is much more complicated, fragile and expensive than a moisture analyzer with a built in relative humidity sensor, making the RH sensor moisture analyzer ideal for testing lubricating oils for moisture contamination.

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References:

1. Cantley, Richard E. (1976). The Effect of Water in Lubricating Oil on Bearing Fatigue Life. *ASLE Trans.*, 20(3), 244-248.
2. Fitch, J.C. & Jaggermauth, Simeon. Moisture – The Second Most Destructive Lubricant Contaminate, and its Effects on Bearing Life. http://www.maintenanceresources.com/referencelibrary/oilanalysis/oa-m.htm
3. Larsson, Roland. Luleå University of Technology. Elastohydrodynamic Lubrication – Part 1. https://www.youtube.com/watch?v=JCM2YHcd8kU
4. Larsson, Roland. Luleå University of Technology. Modelling thin film flow & Lubrication theory – Part 1. https://www.youtube.com/watch?v=2X6KPbpSg-o
5. Moore, James. Moisture in Oils: The Three-Headed Beast. http://www.azic.com/moisture-in-oils-the-three-headedbeast/
6. Noria Corporation. *Certification Series.* Level II Couse Workbook Oil Analysis. 2014.
7. Noria Corporation. Lubrication Basics. http://www.machinerylubrication.com/Read/24100/lubrication-basics
8. Noria Corporation. Monitor Water-In-Oil with the Visual Crackle Test. http://www.machinerylubrication.com/Read/301/visual-crackle-oil-test
9. Whitefield, C. David. Clean Up Your Oil – Revisited. http://www.cashmanequipment.com/bently/publications/articles/4Q01whitefield.php

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