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Methods for Trending Wear Levels in Grease Lubricated Equipment

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ABSTRACT

Oil analysis is well established as a routine tool to optimize maintenance activities, improve reliability and equipment life and prevent component failures. As part of a comprehensive Predictive or Condition Based Maintenance program, lubricant analysis is an effective complement to other diagnostic technologies such as vibration analysis, infrared thermography, ultrasonic detection and motor circuit evaluation. However, when the equipment is grease lubricated rather than oil lubricated, the important lubricant analysis piece is usually left out of the mix. However, new tools have been developed for improved sampling techniques and grease analysis tests to allow the inclusion of lubricant analysis for grease lubricated equipment. This paper will discuss the challenges and options to obtain representative and consistent grease samples from motors, motor operated valves, and other critical equipment, and the use of a hall-effect sensor device for reliably and repeatably determining changes in wear levels for samples of grease as small as 1 gram.

KEYWORDS: Lubricants:Greases, Wear:Equipment Wear Tests, Wear:Wear/Failure Testing Devices

INTRODUCTION

Oil analysis is well established as a routine tool to optimize maintenance activities, improve reliability and equipment life and prevent component failures. As part of a comprehensive Predictive or Condition Based Maintenance program, lubricant analysis is an effective complement to other diagnostic technologies such as vibration analysis, infrared thermography, ultrasonic detection and motor circuit evaluation. However, when the equipment is grease lubricated rather than oil lubricated, the important lubricant analysis piece is usually left out of the mix. However, new tools have been developed for improved sampling techniques and grease analysis tests to allow the inclusion of lubricant analysis for grease lubricated equipment. This paper will discuss the challenges and options to obtain representative and consistent grease samples from motors, motor operated valves, and other critical equipment, and a viable test slate for evaluating grease condition, wear and contamination, and grease mixing issues.

Also presented in this paper are results of an experiment to compared wear analysis methods for grease. The purpose of this experiment was to evaluate grease sampling methods and wear debris analysis techniques. Traditional oil analysis wear debris monitoring tests of Direct Reading Ferrography (DR-III) and the Rotating Disk Electrode spectrometer (RDE) were utilized, along with a hall-effect sensor device, the Kittiwake FdM+ ferrous debris analyzer.

OBTAINING SAMPLES

In most circumstances, procedures for obtaining representative grease samples from bearing housing and gears are not consistent and most likely do not represent the true condition of the "worked" grease near the lubricated surface. It may also contain particulate and other contamination picked up during the sampling process. Historically, in-service grease samples from motors, valves, and various bearing housings, typically have required the equipment to be out of service. A key factor is that a large volume of sample is needed to perform current analytical testing methodologies and along with this issue is that it is extremely difficult to obtain that representative sample from near the bearing while the component is still in service.

Therefore the challenge in optimizing a grease analysis program is the development of test methodologies to measure in-service grease conditions utilizing a smaller amount of grease and a sampling process that enables representative grease samples be taken without disassembling of the component. For motors, new design components are available that allow a replaceable fitting to be installed at the motor drain port. This fitting serves two purposes. First, it takes the place of a drain plug, allowing displaced grease to drain from the cavity without building up pressure--compromising the bearing shield/seal. Secondly, it provides a protected pathway for representative grease draining from the cavity to be captured and submitted for analysis.

In current designs, the sampling fitting is also optimized for the subsequent laboratory analysis. By providing a sealing surface in the fitting cylinder, the entire volume of grease is available for analysis. Extraction of the grease is done under variable pressure and force conditions, and the response of the grease can be measured and related to the grease consistency and serviceability, important characteristics for in-service greases. As the grease is extracted for analysis, it can be delivered in a thin film for accurate analysis by FTIR, RULER, and Spectral Analysis, giving detailed information about grease oxidation, contamination, mixing and wear.

For motor operated valves, gearboxes, and bearings that do not by design deliver grease to a drain point, other sampling tools have been developed. Similar to the principle of a liquid sample "thief", the device must be able to travel from the access hole to the active lubrication location, near the bearing or gear mating area, and bypass the non-representative grease along the way. This requires the device to push grease out of the way in the space between the access hole and the lubricated surface, and then capture a small amount of grease close to the mesh point or bearing grease shear area. Such a device has been developed and tested to demonstrate the capability to deliver a representative sample.

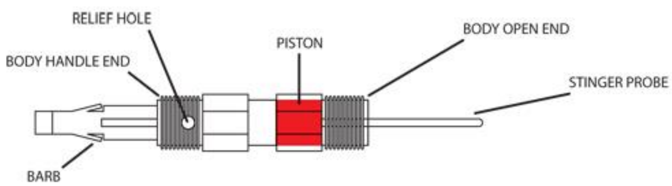

Figure 1: Grease sampler for gearbox testing

The grease sampler is inserted into a t-handle extension to permit remote actuation and capture of the sample at the site of active grease use and wear generation, adjacent to the mating gears or bearing surface.

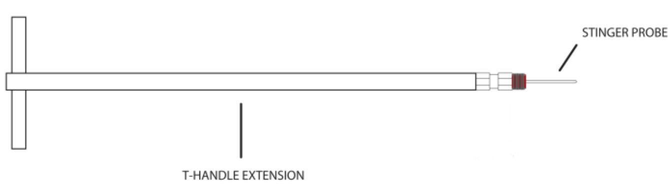

Figure 2: Grease sampler in t-handle extension

EXPERIMENT

To begin the required analysis for this experiment samples were collected from a Limitorque Actuator in a test stand. Two such valves are utilized in the test stand, MOV-104 and MOV-121. MOV-104 is an SMB-0, and MOV-121 is an SMB-00. The grease samples were obtained by application of a Grease Thief™ Type II grease sampler with stinger probe and a retractable T-handle tool. The Grease Thief™ was positioned so that the stinger probe was completely exposed. The Grease Thief™ and T-handle was placed into an open hole, made available by removing a threaded plug. This port was located on the top of the MOV, directly above the worm or mating pinon gears. After the sample was collected the Grease Thief™ was cleaned off and capped. After each sample, the MOV was run to the full closed position and then to the full open position, each cycle consisting of an approximately 45 second run of the motor at normal synchronous speed. This allowed for additional grease to return to the section of the MOV that was sampled. For some testing, twenty open and close cycles were performed between samples, but this proved to have little impact on the wear concentration, possibly owing to the lack of gross faults in the tested components.

To begin the grease analysis the iron concentration was determined by using the FdM+. Each sample was run three times, and the data from them was averaged to obtain a representative measurement. The repeatability of the FdM+ method was extremely good, with little variation on the three runs for a given sample (as seen in Table 3). Five samples with consistent results were chosen for comparative analysis by traditional oil analysis debris monitoring techniques.

To prepare the five samples for further analysis they were analyzed by the Grease Thief™ Analyzer. This instrument extrudes the samples onto a low density polyethylene substrate while determining their consistency. A 0.25 gram sample was weighed out into a 20 mL scintillation vial. A 5 mL portion of a 50:50 mixture of heptane and toluene, grease solvent, was dispensed into the vial. Approximately 5 to 10 glass beads were added to the vial to help break up and dissolve the grease. The vial was then agitated with an orbital shaker for 5 minutes to obtain satisfactory dissolution of the grease. A 10:1 dilution was prepared with filtered blank oil for the DR-III test. To make this dilution, 1 mL of the original sample was mixed with 9 mL of filtered blank oil in a scintillation vial and agitated for 5 minutes on the orbital shaker. Once the sample preparation was complete, this procedure was repeated for the next portion from this sample. Where sample quantity permitted, three such preparations were made for comparison.

RESULTS

This first graph shows a comparison of ferrous debris measurement techniques from consecutive samples taken from a Limitorque Actuator, a gearbox used in Motor Operated Valves.

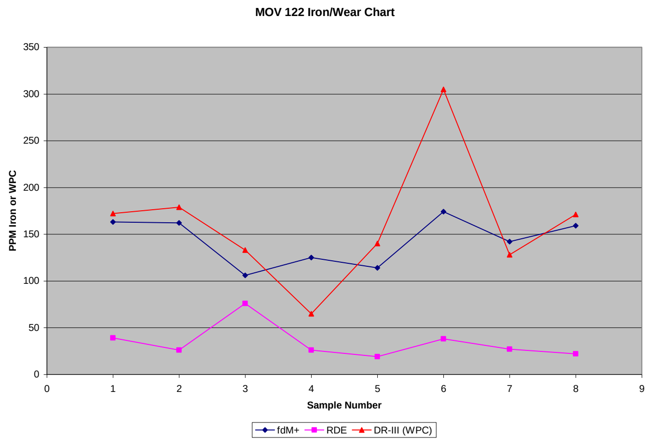

Figure 3

The graph (Figure 3) shows the variability seen in the RDE (spectroscopy) and WPC (ferrography) values, which are derived from a weighed portion of the obtained sample. Meanwhile, the FdM+ results are obtained by presenting the entire sample in the Grease ThiefTM in the FdM+ unit. The ability to present the entire sample for analysis without compromising the ability to perform further tests for contamination, oxidation and consistency, provides a more consistent trend of the wear condition.

Statistical analysis of these results are shown in the following table:

Sample #	FdM+	RDE	DR-III (WPC)
420	163	39	172
421	162	26	179
422	106	76	133
423	125	26	65
424	114	19	140
425	174	38	305
427	142	27	128
428	159	22	171
Average	143.13	34.13	161.63
StdDev	25.39	18.33	68.46
RelStdDev	**17.74**	**53.70**	**42.36**

Table 1

The relative standard deviation value for the FdM+ shows much greater consistency in the samples. To further evaluate the reasons for this, and to test for variability in ferrous debris concentration through a given sample, a selected number of samples in a separate experiment, again from a Limitorque gearbox, were extruded to prepare several analyses for each 1 gram sample from a grease thief. The relative standard deviation was then calculated for the RDE and WPC values to demonstrate the variability seen in a single sample when analyzed in three separate sections.

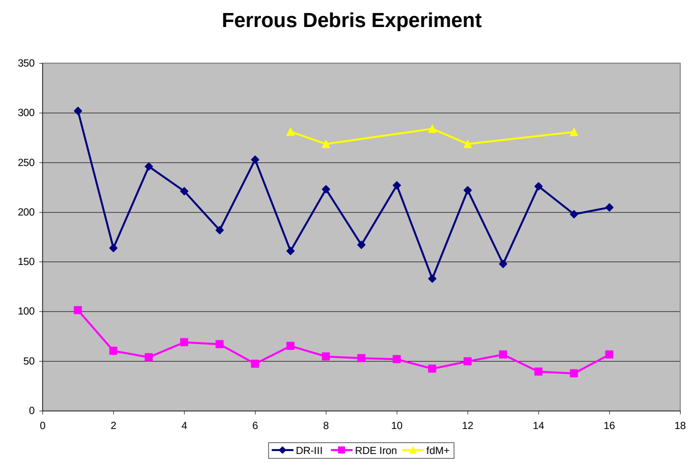

Figure 4

Method	Average	Standard Deviation	Relative Standard Deviation
fdM+	277 ppm	7	2.53
DR-III	205	46	22.44
RDE	57 ppm	16	28.07

Table 2

CONCLUSION

The results indicate a difficulty in obtaining trendable values for ferrous grease wear when employing methods that require dissolution of a portion of the grease sample and analysis of the liquefied sample in typical oil analysis instrumentation. This is due to the non-uniformity of distribution of wear in a grease sample, and the difficulty in achieving a uniform dispersion of that wear. Particle size limitations of those methods are similarly a concern. However, when utilizing a method that counts the entire ferrous content of the sample, this variation is minimized, and a more valid trend can be developed for samples from a given location. In any case, the challenges of obtaining samples that represent the condition of the monitored component remain, and must be addressed satisfactorily to obtain actionable data on the wear condition of those components.

REFERENCES

1. R. N. Wurzbach, "Streamlined Grease Sampling and Analysis for Detection of Wear,Oxidation and Mixed Greases" NLGI Annual Meeting, Williamsburg, VA, 2008

