Sampling methods outlined in the American Society for Testing and Materials (ASTM) standard D7718

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1. Abstract

Oil analysis has enjoyed a long history of effective use in many industries and applications. With some care and knowledge about oil flow and circulation, representative samples can generally be obtained routinely with the right tools and perhaps some minor machine modification. Grease however has presented a greater challenge to effective sampling. With the important function of a grease being its ability to stay in place in the machine, getting it back out of the machine for sampling purposes has historically proven difficult. More recently, innovative approaches and novel tools have been introduced to overcome these challenges and provide the opportunity for more routine and effective sampling of critical grease lubricated assets. This paper addresses the sampling methods outlined in the American Society for Testing and Materials (ASTM) standard D7718, "Standard Practice for Obtaining In-Service Samples of Lubricating Grease", and how they are used in applications including wind turbines, auto manufacturing robots, pharmaceutical manufacturing equipment, mining machinery, power plants, and electric motors. Further examples are given of analysis methods possible with the small sample sizes obtained in this way, and case studies of effective monitoring through grease analysis.

2. Lubricant Sampling

Machinery reliability programs rely heavily on diagnostic technologies, including oil analysis. Oil analysis, in turn, is only successful when significant effort has been taken to ensure representative samples are obtained. This is achieved by evaluating machine operation, lubricant flows and circulation, the presence of filters, sumps and other particle separation effects in the system. Often, machine design requires the installation of sampling fittings, valves or other configuration changes to allow such samples to be obtained.

One method used for oil sampling is known as "drop tube sampling". This involves using a source of suction, usually a hand pump, and a narrow section of flexible plastic tubing that is inserted into a reservoir, tank or housing. While samples can be obtained this way, this is generally viewed as an unreliable sampling method for most applications, since the location of the tubing cannot be controlled and results in variable samples when trended over time.[1] Likewise, in similar machines sampled this way, the undefined location of the end of the tubing when the sample is taken also creates variability and difficulty in comparing samples. The image below from lubrication training organization Noria shows the drop-tube method on the right, and the preferred installed sampling fitting method on the left.

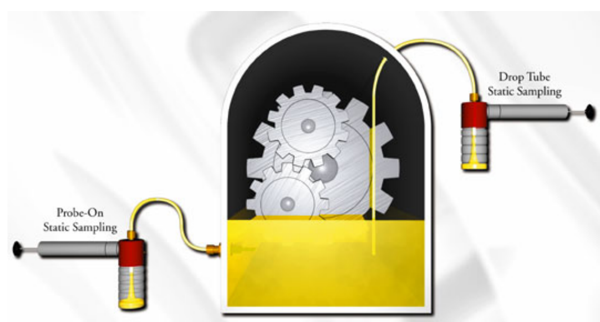

Figure 1: Drop tube sampling for oil analysis. (Fitch, www.noria.com)

2.1. Efforts to obtain grease samples

For greases, the challenge is different, in that the grease does not readily circulate as oil does, and the sample must be extracted from the machine. Still, some early efforts at grease analysis have identified the use of

[1] Fitch, J., "World Class Oil Sampling – It is Possible", *Practicing Oil Analysis,* Noria Corporation, July 2000

suction and an inserted tube, much like the drop tube method for oil, to obtain grease samples for analysis. This has been typically accomplished with a large volume syringe and a tight fitting plastic tubing, often the same type used for oil sampling. The result can be the same inability to control the point at which the sample is taken, and additionally, the risk of filling part of the grease sampling tubing with grease that is not representative of the area close to the target bearings or gears, known as the "live zone".

This method was identified by the Electric Power Research Institute (EPRI) for obtaining inservice grease samples from Motor Operated Valves (MOVs) in industry publications in the late 1990s and early 2000's.[2] However later studies showed difficulty in ensuring that the grease obtained in this method would be wholly representative of the region surrounding the target worm gears. A later EPRI study evaluated an active sampling method to "core" the sample at a set depth, immediately adjacent to the worm gear. Studies showed the ability to confirm up to 95% of the sample being from a small region surrounding the gear, and an evaluation of an introduced fault showed this method only being able to detect the trending changes in wear concentration resulting from misaligned gears.[3]

2.1. Wind Turbine Research

In 2012, members of the Danish Wind Energy industry formed a research team to evaluate methods for obtaining and analysing grease samples from wind turbine main bearings. Employees of DONG Energy, Vattenfall, and The Geological Survey of Denmark and Greenland (GEUS) combined to study a new tool for coring of grease samples and evaluate its effectiveness in the main bearing application. This research over a two-year period produced a modified T-handle tool to combine with the active core-sampling device to produce reliable and repeatable samples that were directly correlated to the as-found condition of the disassembled bearings.[4] Figure 2 from that report[4] shows the trends noted on multiple bearings taken over several months, which corresponded to the observed condition on these locations.

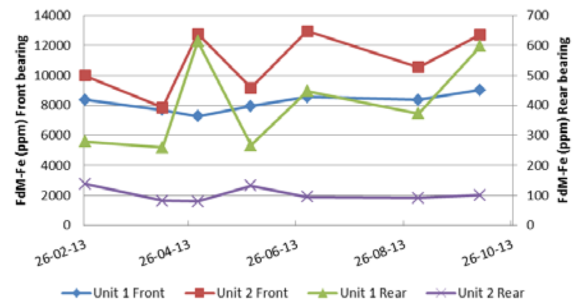

Figure 2: Trend analysis of ferrous wear metal, FdM-Fe in Vestas V80, 2 MW units (Møller, H., et. al.)

2.2. Gearbox Research

In the mentioned EPRI research, a similar design to the tool used in the wind turbine research was used to obtain the samples from the gearbox. This included a clear plastic body with a precisely fitted piston, and a handle so that the piston could be remotely actuated. Additionally, the piston had a front "stinger probe", allowing the proper position to be located for sample acquisition. In both designs, the obtained sample is about 1 gram, judged to be a realistic quantity to obtain in most applications.

Evaluating the accuracy of sampling using this method was accomplished by operating the valve actuator gearbox for 1 minute cycles and sampling every 20 cycles. After establishing a normal trend value for the gearbox wear rate, the motor drive gear was deliberately misaligned to increase the rate of wear, and the operation and sampling cycle was continued, producing the graph seen in Figure 3. These results demonstrated that the active sampling method developed for sampling these enclosed gearboxes was both repeatable, and trended to represent the changing conditions of wear that were introduced.

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[2] Bolt, R., Brown, C., Pugh, M., "Easy Testing for Grease Thickness", *Machinery Lubrication,* Noria Corporation, May, 2003

[3] Electric Power Research Institute, "Nuclear Maintenance Applications Center: Effective Grease Practices", Technical Report # 1020247, October, 2010

[4] Møller, H., et. al., "Analysis of Grease in Wind Turbine bearing – a tool for condition monitoring. Part 2", *LUBMAT 2014 Proceedings,* Manchester, UK, June 2014.

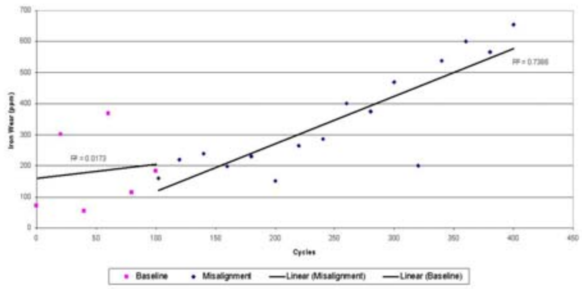

Figure 3: Trending of wear levels in gearbox before and after misalignment

3. Standard Development

Based on these studies and industry demand for guidance in obtaining grease samples, a working group was assembled in the American Society of Testing and Materials (ASTM) Grease subcommittee. Over a two-year period, a peer-reviewed document was produced and sent to ballot to the ASTM Main Committee. In 2011, ASTM D7718, "Standard Practice for Obtaining In-Service Samples of Lubricating Grease" was published to provide this industry guidance.

3.1. Addressing existing practice

The Grease subcommittee was intent on ensuring that certain existing industry practices were included. It was noted that certain industries were utilizing tools such as syringes and plastic tubing to extract samples. Also, a long-standing and common use of grease analysis was applied in failure analysis. The practice was written to address the special considerations when presented with failed components and there is a need to analyze any residual grease for indications of contributing failure causes.

The sampling containers are also addressed, and include many of the acceptable, if not optimal, commonly used devices such as oil sampling bottles, both plastic and glass, and metal containers as well. Methods include use of spatulas, plastic tubing, syringes and other tools to access appropriate locations in the target machine.

3.2. Cautions to method limitations

While effort was made to include historically utilized methods, attention was given to necessary precautions and limitations of some of these methods. In this way, good and representative samples are the primary goal, and those using the standard operate from a position of awareness, knowing that some methods may be more effective than others, or some can give less than optimal results unless the noted precautions are taken. Included in this is the use of plastic tubing and a syringe to extract a sample from within a machine enclosure. While this method can be quite effective at producing a sample, one note in the practice points out the non-Newtonian properties of greases, and the potential challenges of inducing uniform flow of the grease using suction. Some concern is raised that the use of tubing does not preclude the capture of grease that unrepresentative, from locations in the machine some distance from the target component: "Note that the proximity of the lubricating grease in the interior of the tubing to the bearing or gear cannot be guaranteed when using this method."[5]

3.3. Inclusion of new technologies/approaches

Among the methods outlined in the standard are the "active" and "passive" techniques enabled by the use of the Grease Thief tool. While the standard does not endorse specific products, or preclude the use of others, there is recognition of the Grease Thief as being a demonstrated and effective tool to enable the techniques outlined in several of the methods in the standard. [5] It is noted that other effective products can be included in future revisions of the standard if brought to the attention of the ASTM committee and found pertinent.

4. Grease Sampling Standard

D7718 is broken into sections including sample handling, active sampling procedure for enclosed housings, an active sampling procedure for pillow (or pillar) block bearings and exposed bearings and gears, passive sampling procedure, and a procedure for sampling from failed components.

4.1. Scope and Terminology

The scope of the document is laid out to direct users in the taking of inservice grease samples from various components. It outlines the need to sometimes obtain multiple samples in order to fully assess equipment condition, and the occasional need to homogenize certain samples prior to analysis. The document references other ASTM standards, including the practice for manual

[5] American Society of Testing and Materials, "D7718- Standard Practice for Obtaining In-Service Samples of Lubricating Grease", West Conshohocken, PA, USA, 2011.

sampling of petroleum products, which could be considered a parent document to this more specific practice. The terminology explains the “passive” and “active” terms in their context in grease sampling, and terms such as “actuate”, where it is used to describe the active coring of grease samples from a machine. The apparatus is described, including various sample containers that can be used, and the sampling devices. Hazards and cautions are also described to ensure safe use of tools and methods.

4.2. General Procedures

Important considerations that apply to all methods are discussed, including cleanliness of sampling tools, homogeneity of samples, and the importance of uniformity and design of the sampling devices used. The importance of operator training and knowledge of equipment being sampled is discussed as it has an impact on sample quality.

Sample handling is described as best-practice, with importance given to shipping considerations and sample labelling. The use of containers and protective sleeves are important to prevent leakage and co-mixing of samples, and preservation of the integrity of the primary containers. Details required for proper analysis by the receiving laboratory are described as necessary in the labelling process, to ensure that this information is gathered and transmitted from individuals performing sampling to those responsible for analysis and interpretation.

4.3. Active Sampling

Active sampling is described as the process of introducing one of the described sampling devices to the surface of or inside of a given machine. Figure 4 shows the “Active Grease-Sampling Device” that features a “stinger probe”, allowing the device to be inserted into a gearbox, electric motor or other similar contained housing. The stinger probe allows the target surface to be located, and the coring of the sample to be precisely adjacent to the bearing or gear of interest. The procedure for using such a device is described, including the attachment of a handle that will allow the remote actuation and coring of the sample from within the machine.

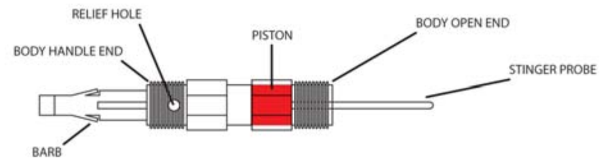

Figure 4: Active Grease-Sampling Device (shown as Fig. 1 in ASTM D7718)

Another active sampling method described is the plastic tubing method. While there are some limitations to the method described in the standard, it is in widespread use, and the standard addresses some critical considerations and technique to be considered for getting the best possible sample by this method. The procedure described is consistent with instructions found from some manufacturer or laboratory websites, such as sampling from Rothe Erde slewing bearings.[6] Figure 5 shows an image demonstrating this tubing sampling method.

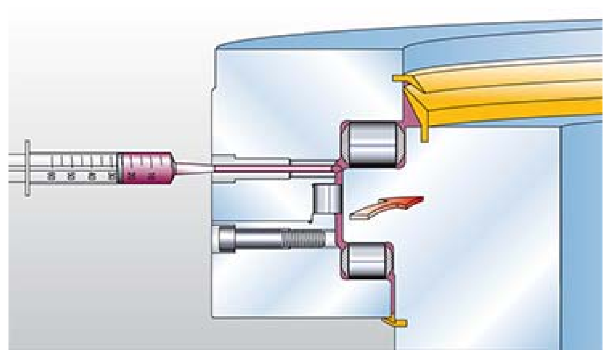

Figure 5: “Taking a sample” from Rothe Erde “Grease Sampling Set” instructions

Another section describes the active sampling process from pillow block bearings and other similar exposed bearings or open gears. This method generally relies on the use of a soft spatula to harvest the grease from the exposed surfaces, and the use of a syringe to gather and transfer that grease to the primary sample container. This method describes the importance of removing the outermost layer of grease prior to sampling, as this exposed grease often serves to capture extraneous environmental contaminants that are not representative of the component of interest. Two spatulas or a double-ended tool are described as suitable for this task. The

[6] ThyssenKrupp Rothe Erde GmbH, “Grease Sampling Set“, http://www.thyssenkrupp-rotheerde.com/gb/TG/Fettprobenentnahme.shtm

syringe to be used is described as having a minimum of no less than 1.8mm. This figure is based on rheological studies that determined that smaller syringe openings may change the consistency of the grease as it is sheared, and thus change some of the potentially measured properties of the grease.

4.4. Passive Sampling

Passive sampling is described by the method as the collection of grease that will naturally purge from the bearing upon relubrication and operation, by use of a device that is attached to the machine drain for this purpose. The device described here is shown in Figure 6, which is similar to Figure 4 but without the stinger probe. This device uses a thread to engage the drain of the housing. Another important design feature is the presence of purge holes, which allow excess grease to exit the container after it has been filled. In this way, the device captures the most recently purged grease within the body and protects it from contamination by environmental contaminants.

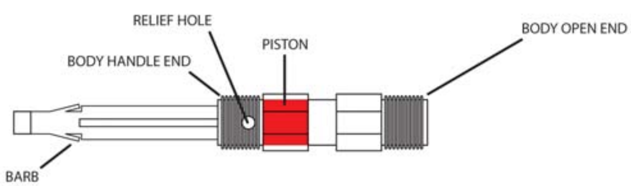

Figure 6: Passive Grease-Sampling Device (shown as Fig. 3 in ASTM D7718)

A key consideration for this method is the patience that may be required in waiting for a sample. Unlike the active methods that allow for immediate gathering of the required sample, this passive method relies on the purged quantity of the grease to be accumulated in a sufficient amount for the required sample size. While relubrication tasks contribute new grease that can provide displacement of the used portion, it is strongly cautioned that overgreasing must be avoided. It is never prudent to add grease for the sole purpose of purging out the required sample quantity. Therefore, attachment of the passive sampling device, normal relubrication frequency and quantities are employed, and sufficient time and operation of the machine is allowed to produce the needed sample. There is the added benefit that this approach ensures that a purge path is maintained in the machine.

4.5. Failure Analysis

The final method described is the harvesting of grease from failed components for the purpose of performing or complementing the analysis of the root-causes that have contributed to a component failure. Using appropriate tools, the component is safely and carefully removed from the machine, and where necessary, access is provided to the lubricant by removal of shields or seals. Dirt and debris is removed prior to taking the sample so that the external contaminants do not become mixed with the internal and formerly active grease. A straw or spatula is used to gather an appropriate and representative sample or samples. Samples obtained in this way can be a strong complement to the typical observational and metallurgical analysis typically performed on failed bearings and other grease lubricated components, and can contribute to a more comprehensive picture of the factors involved in a machine failure.

5. Summary

Oil analysis has been complemented by the development of proven techniques and hardware to ensure representative samples are used. While grease analysis is not nearly as widespread, there is a growing demand for analysis of grease lubricated components, and some applications have proven that significant cost-benefit can be obtained by effective grease analysis. Grease sampling, while at first primitive and limited, has received new attention, and methods and tools have been developed to improve the consistency and quality of samples being submitted for analysis. Important research by the Danish wind industry and the Electric Power Research Institute have demonstrated the importance and value of the proper methods and equipment in obtaining grease samples. The American Society of Testing and Materials and the Grease subcommittee have worked diligently to consider important factors in ensuring quality samples and the new techniques and tools that have become available to create industry guidance through this standard. Greater acceptance and use of this document will help to ensure that the lubricant analysis industry continues to grow and improve the value of inservice grease testing.