Streamlined Grease Sampling and Analysis for Detection of Wear, Oxidation and Mixed Greases

Richard N. Wurzbach[1]
Maintenance Reliability Group, LLC
2101 Pennsylvania Ave
York, Pennsylvania, 17404

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 a viable test slate for evaluating grease condition, wear and contamination, and grease mixing issues.

Greasing Equipment

As a general rule, greases with different thickeners should never be mixed. When incompatible greases are mixed, the resulting lubricant is generally softer than either of its components. The softer mixture tends to slump in the bearing or grease housing, and in some cases the oil will bleed completely out of the grease. In some mixtures, such as those involving aluminum complex greases, the opposite effect can occur. In this case, the base oil is bound tightly in the grease's lattice-like fiber network and is unable to bleed properly, resulting in hardening. Both softening and hardening have negative effects on grease performance and can lead to premature bearing failure.

Greases that have the same thickener and similar base can sometimes be mixed without harming grease effectiveness. However, even greases belonging to the same family of thickeners can differ in formulation and internal chemistry. The mixing of greases with different thickeners, such as polyurea and lithium, has recently become more common in motor bearings, as most motor manufacturers use polyurea in initial bearing fills and during motor shop rebuilds. When individuals tasked with relubrication of motors are not aware of this potential problem, the wrong grease is added to these motor bearings.

The traditional grease lubrication of bearings has been time-based preventive maintenance. In other cases, greasing is done only in response to high bearing temperatures or noisiness. These methods can result in over or under greasing, depending on the periodicity of greasing, quantity added by the technician, operating conditions and run time of the machinery. More recently, some lubrication programs have added ultrasonic monitoring to the greasing process to aid in the identification of the proper quantity to achieve lubrication. In certain cases, ultrasonic noise generated from the electrical field of the motor, can interfere with the effectiveness of this method. There is also some question about how one can rely on ultrasound level changes to determine when to stop, if the bearing has proper lubrication when it is approached for greasing. In other words, how can you listen for the drop in ultrasonic levels, if the ultrasonic levels are already low because it is properly lubricated? Some individuals have recommended listening for an increase in ultrasound as the bearing begins to get excess lubricant, or to look for rising bearing temperatures. There is limited data to show if this approach achieves optimum lubrication in all cases, given these concerns.

[1] Contact info: Richard N. Wurzbach, rwurzbach@mrgcorp.com, 717-699-2908

Electric Motor Greasing—The "Two-Part PM"

Electric motors can be supplied with either "Lubed-for-Life" bearings, or with bearings that are intended to be relubricated. When motors are designed with zerk or other grease fittings, a delivery pathway to the bearing, and bearings with an open face to accept the grease, a program must be initiated to ensure that the right amount of grease, of the correct type, is delivered to the bearing on the proper interval. In most plants this is accomplished with the use of the Preventive Maintenance (PM) Program. PM activities are generally set on a calendar (or sometimes run-hour) basis, with directions on where to grease (location of the fittings), the type to use, and the quantity to deliver (ounces, grams, # of pumps, etc.) Some programs, as has been mentioned, specify the use of ultrasonic detectors in place of set quantities, but the rest of the process is the same. Most electric motors, particularly larger ones, are provided with an externally accessible drain plug, which is usually threaded into the motor housing. This is meant to provide a drain path for excess grease to exit the bearing, relieving the buildup of pressure in the housing. Advanced lubrication programs will generally direct lubrication technicians to remove the plug prior to greasing, clean any accumulated grease, dirt or hardened material out of the drain hole and then perform the greasing. Because the draining or purging of excess grease in not immediate, technicians are generally given direction to keep the plug out for an extended period of time (usually hours or more) to allow the new grease to mix into the bearing, heat up due to viscous churning, and slowly flow to the exit drain.

In practical terms, it is not realistic to expect a technician to be able to wait around to re-install the plug. That means that after a lubrication route is complete, the technician must return later to reinstall all the plugs that were removed during the lubrication activity. This is an inefficient process, and in some cases, it is likely that the plugs are not reinstalled at all, or perhaps are not taken out in the first place. To address the latter, some programs have installed grease relief plugs, which are spring-loaded at varying relief settings, to allow any purging grease to exit. While preferable to a solid plug, any grease that does exit lands on the floor and is not always preserved in a condition for meaningful inspection.

Grease Analysis—Information Opportunity

The advent of ultrasonic greasing not withstanding, greasing of electric motors and bearings remains an activity with little effective feedback to the technician on the effectiveness of the endeavor. When problems occur on critical grease lubricated equipment, investigations are often limited by the lack of grease condition information, and any post-mortem collected grease samples are only a snap-shot in time taken after the failure. Even so, these root cause investigations have in the past delivered valuable information with regards to grease condition, mixing, and even the presence of gross quantities of wear material in some cases, aiding in corrective action determinations.

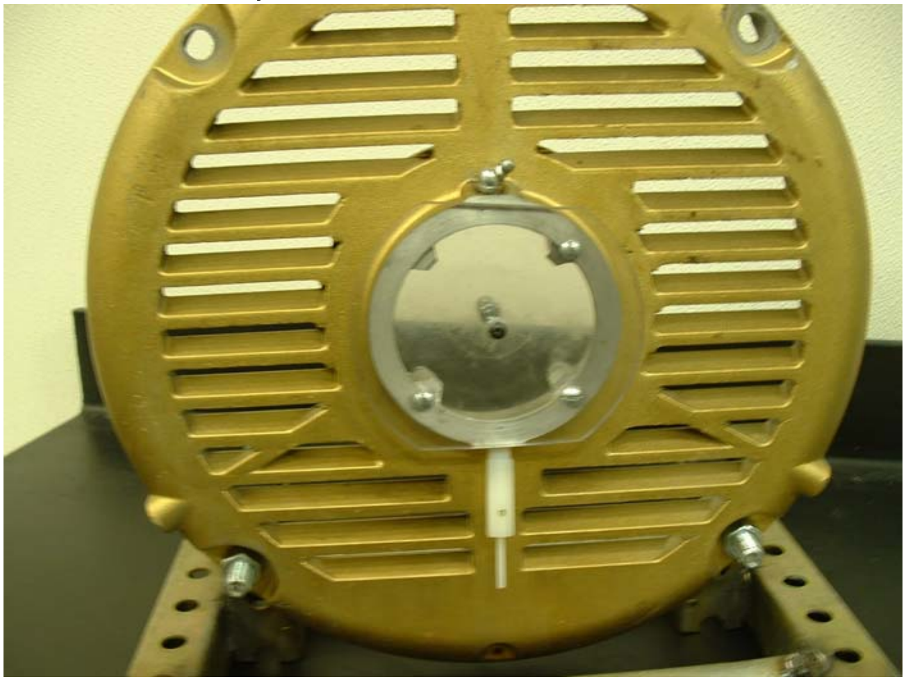
An even greater opportunity exists in evaluating in-service greases in being able to identify developing conditions of wear, mixed greases, oxidation or other degradation modes. When a representative in-service grease sample can be obtained, numerous analysis tests can be performed, including:

- Consistency (Cone Penetration)
- Dropping Point
- Wear Particles
- FTIR
- RULER
- DSC
- Rheometer testing

Obtaining the samples-the challenge in standardizing grease analysis

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 a representative “worked” sample from near the bearing while the component is still in service.

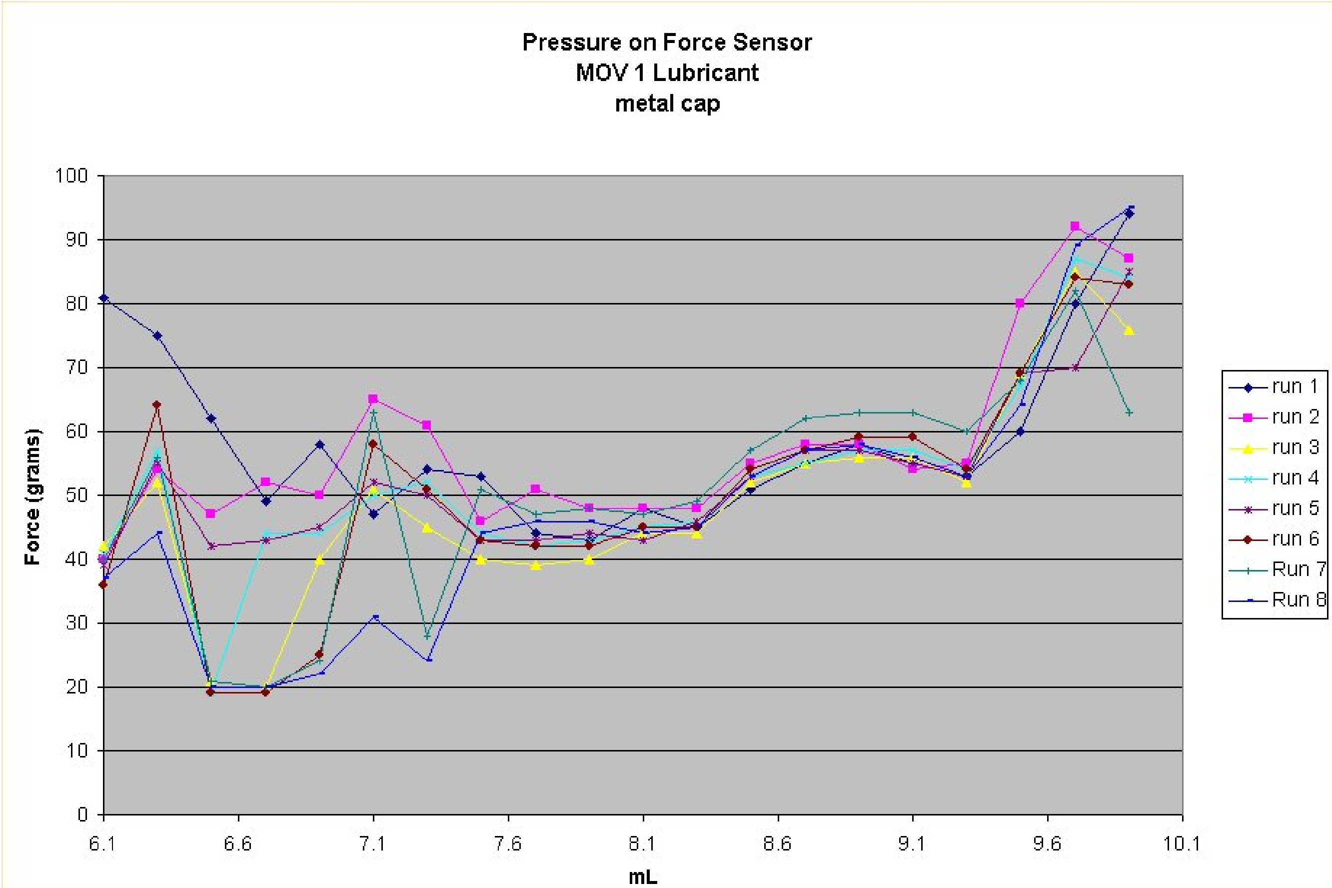
Therefore the challenge in optimizing a grease analysis program is the development of test methodologies to measure in-service grease conditions utilizing a smaller amount of grease and a sampling process that enables representative grease samples be taken without disassembling of the component. For 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.

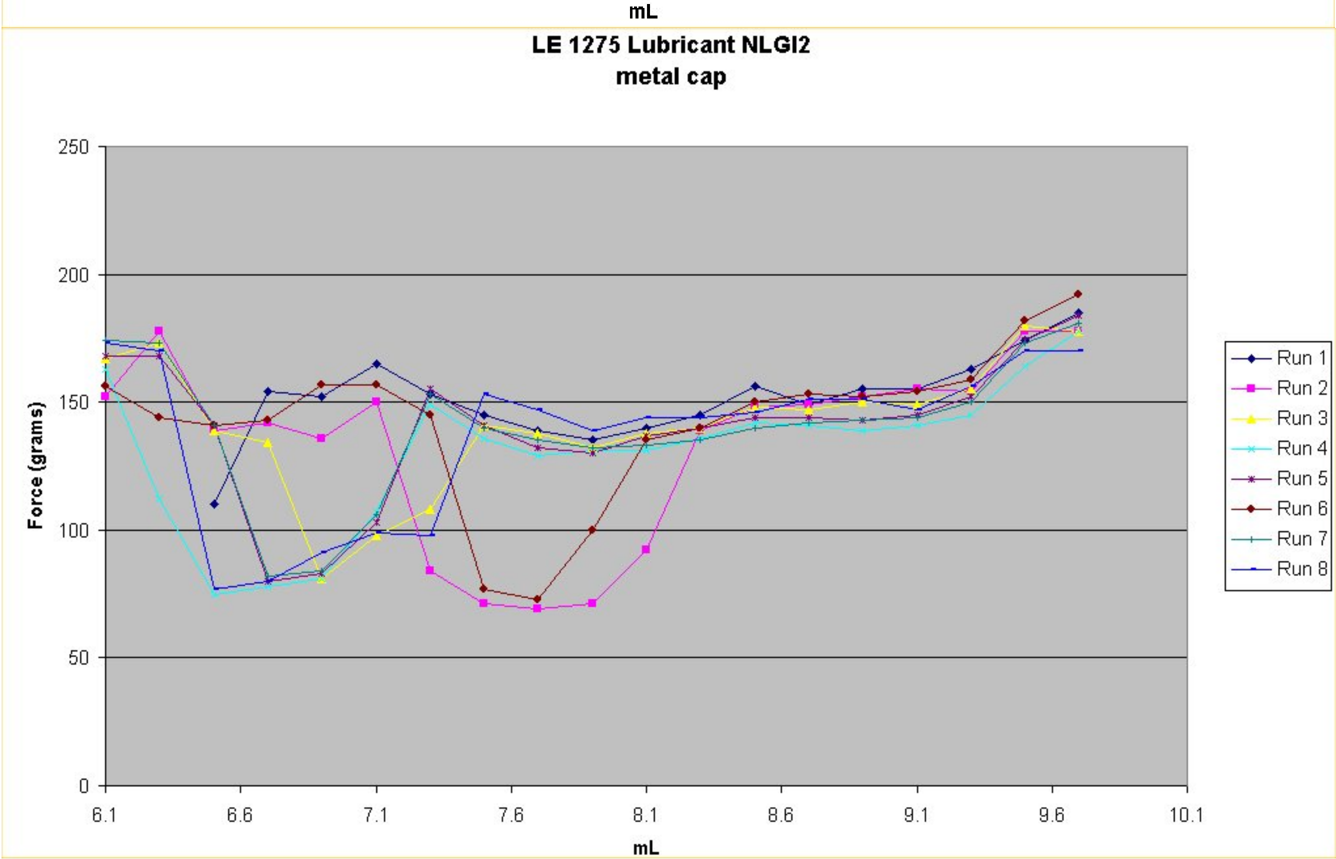


In current designs, the sampling fitting is also optimized for the subsequent laboratory analysis. By providing a sealing surface in the fitting cylinder, the entire volume of grease is available for analysis. Extraction of the grease is done under variable pressure and force conditions, and the response 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.

The follow graphs shows the response of the grease fitting when grease is extruded through a flat orifice. The resulting load on the unit, as measured by a load cell, demonstrated the repeatability of load values, and the differentiation that can be made between greases of varying consistency. The first graph shows an NLGI #2 Grade grease, and the second shows a NLGI #1 Grade grease. The measurable difference in consistency with this method is apparent.


Pressure on Force Sensor
MOV 1 Lubricant
metal cap
Force (grams)
mL
run 1
run 2
run 3
run 4
run 5
run 6
Run 7
Run 8


LE 1275 Lubricant NLGI2
metal cap
Force (grams)
mL
Run 1
Run 2
Run 3
Run 4
Run 5
Run 6
Run 7
Run 8

In other cases, bearing design is for uncontained release of grease to the surroundings (such as certain pillow block designs) which may require cruder sampling methods, such as the gathering of grease from the bearing face with a plastic spatula and using it to pack the grease sampling fitting.

Streamlined Grease Analysis

The following four tests comprise the streamlined grease analysis process. The use of the sampling fitting allows the first test to be performed as part of the preparation of the sample for the subsequent tests.

Grease Consistency – By measuring the load under varying conditions during the extraction of the grease through the orifice slot, the consistency of the grease can be compared to the new grease consistency. Changes in this value, whether indicating a thinning or thickening of the grease, can be used to flag this property. Followup detailed analysis with a rheometer can further classify the condition of the grease, and relate to such parameters as dropping point and cone penetrometer, based on earlier studies by Nolan and Sivik[2] and Johnson[3]

Comparative FTIR - FTIR spectrums are created from new grease samples for all greases in a facility's program. Using an HATR (horizontal attenuated transverse reflectance) rig, we apply a thin film of grease across the crystal and use the auto-gain function to maximize signal and get a representative spectrum. We then test the sampled in-service greases, and compare them to the spectra of new grease. In particular, for different families of greases, the FTIR spectra are quite different, and can be compared to see if significant mixing has occurred. In other cases, similar greases (two different polyurea greases) might not have a significant difference in their spectra, but there is less likelihood of compatibility issues in that case. Still, many greases within the same family from different manufacturers can be differentiated with FTIR analysis. The use of IR cards is also a valid method for analysis, and may speed the preparation and cleanup and further reduce costs associated with analysis.

RDE Spectroscopy – The grease is weighed out and added to a glass vial where it is diluted and dissolved with a filtered mixture of grease solvent. This liquid mixture is then analyzed by RDE spectroscopy, and the results are PPM normalized to 1 gram of grease based on the measured weight of grease that was dissolved. The concentration of metals in the grease can be compared to the new grease for the purpose of identifying significant differences in additive metals that could point towards grease mixing. Also, the presence of wear metals can also be deduced. Rotrode Filter Spectroscopy can be performed to evaluate the size influence of the wear, as this detects metal particles larger than 6 micron.

RULER - The RULER™ instrument works on the principle of linear sweep voltammetry. By applying this test method, in which a variable voltage is applied to the sample while measuring the current flow, the presence and concentration of various antioxidant additives (including, but not limited to ZDDP) can be determined based on their unique electrochemical oxidation potential and the magnitude of the induced current. This procedure has recently been developed as a full ASTM test procedure under ASTM D6971.

Together, these four tests can be used to evaluate the condition of the grease, determine the extent of mixing with a foreign grease, detect oxidation, measure the depletion of anti-oxidant additives, and categorize the extent of wear present in the sample. These tests can be done cost effectively because the consistency measuring instrument prepares the grease as a thin-film substrate for weight normalization and easy dissolution of the grease thickener, so the liquid sample can be analyzed with typical oil analysis equipment. Through this trending and screening process, if any concerns are identified with the sample, followup analysis can be performed:

---

[2] Nolan, SJ, Sivik, MR, "The Use of Controlled Stress Rheology to Study the High Temperature Structural Properties of Lubricating Greases", NLGI 71st Annual Meeting, Dana Point, CA, 2004.
[3] Johnson, B, "The Use of a Stress Rheometer in Lieu of Cone Penetration", NLGI 74th Annual Meeting, Scottsdale, AZ, 2007.

Dropping Point – a modified test can be performed that is usually employed to find the melting point of various substances with a capillary tube. While not directly linkable to the published dropping point values, comparing the temperature at which in-service grease might liquefy under increasing temperature can provide insight into the effect of mixing of greases or in-service degradation on its properties at operating temperatures and ability to continue to provide reliable lubrication.

Analytical Ferrography- this test can also be performed on the dissolved grease (prepared as for RDE Spectroscopy) to visually identify the amount, shape, composition and wear severity of the particulate in the sample.

Grease Rheology – Use of a cone and plate rheometer, and utilization of such features as normal force measurement and apparent viscosity can be significant in the characterization of the grease properties. Research is ongoing to optimize this analysis, and relate measured parameters to changing physical properties related to incompatible grease mixing, excessive grease working, and severe oxidation.

Summary

Grease analysis presents a significant opportunity to expand machinery diagnostic capabilities. The historical challenges of obtaining representative and trendable samples are being addressed through technological developments and new approaches. The further development of repeatable analysis methods that utilize smaller quantities of grease will produce greater value, and encourage the sampling of greases from locations where reliability is critical. By designing grease sampling equipment appropriately, the matter of proper grease purging may also be addressed through the establishment of sampling programs. Wherever there is a critical machine, regardless of configuration, the demand for reliability drives us to develop improved sampling methods to enable extracting the valuable information present in grease analysis.