



CLEAN GREASE is not an oxymoron

By Paul Bessette

Contrary to conventional wisdom, evidence demonstrates that ultrafiltration does not jeopardize grease's physical properties.

Tribological principles dictate that effective rolling element bearing greases have the necessary film-forming characteristics when speed, temperature and

load all conspire to induce asperity contact. Although mathematical expressions allow the calculation of the critical film thickness under elastohydrodynamic (EHD) conditions, no current formalism exists to account for the cleanliness of lubricating grease and the impact of particulate contamination on bearing performance and life.

This article explores the history of clean grease development, discusses one of the methods used to size and count particulate contamination and confronts some of the technical misgivings regarding the filtration of lubricating grease.

Grease is essentially a material composed of liquid and an appreciable amount of insoluble solids. It is not evident that such materials are filterable through 10-micron membranes with impunity.

Historical perspective

In the late 1950s engineers at MPB (now Timken Super Precision) determined that clean grease was required to improve the feel of bearings being used for electro-mechanical devices. Moreover, for high-speed spindle applications the engineers believed that clean grease would improve high frequency bearing run out. Apparently no commercial grease fit the new requirements at the time, and MPB contracted an outside source to develop a novel grease that would accommodate the technical challenges.

The effort resulted in a lithium soap-thickened synthetic ester grease containing no particle larger than 35 microns and no more than 1,000 particles in the 10 to 34 micron range per cm³ of grease. The MBP product is an ultra clean instrument bearing grease meeting the requirements of MIL-G-81937. To my knowledge, MIL-G-81937 remains the most stringent military specification for clean grease, and few commercially available greases meet or exceed this cleanliness standard.

My own work developing clean greases occurred in the mid-to-late 1970s. I had the

responsibility to ultra filter a few pounds of grease used in bearings for inertial guidance systems. The grease at the time was an amorphous silica-thickened grease based on KG-80, a paraffinic Pennsylvania bright stock used in numerous aerospace applications and a precursor to PAOs. The KG-80 grease was filtered to the same level as the MPB grease and packaged in precleaned plastic jars. All the work was conducted in a laminar flow clean bench using a 47-mm high-pressure filter assembly.

The random inspection of other grease revealed that the contamination problem was widespread and the possibility of commercializing grease filtration loomed large.

I recall inspecting one polyurea grease that contained so much metallic contamination that it was difficult to believe that the sample was taken directly from the original container. Moreover, a high-speed spindle-bearing grease popular at the time contained particulate contamination larger than some of the rolling elements used to fabricate miniature bearings.

Subsequent microscopic examination of

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Editor's Note:

This month's cover story is a must read for anyone, who uses grease and the machinery that relies upon it for lubrication. In this article, Paul Bessette, a well-known technical expert in the grease industry, shares his perspective on the importance and methods to ensure adequate cleanliness of grease in your machines. During his career, he has experienced every grease headache imaginable, from unwanted debris particles, which must be filtered to ensure cleanliness, to the use of intelligent filtering to improve grease consistency. I'm sure you'll learn more about clean grease solutions than you could ever imagine from this article.

– Dr. Christopher DellaCorte,
TLT editor

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a whole host of industrial greases revealed the presence of fibers, carbonaceous residues, metal flakes, pieces of plastic and poor dispersion of the thickener. Removing particulate contamination just made sense to some customers while others were pleased that filtration facilitated the dispensing of precise amounts of grease. A decade later, grease filtration was firmly entrenched at Nye Lubricants.

Technical misgivings and rebuttal

Initially clean grease was a notion supported by only a few exotic applications and not well substantiated by hardheaded empirical evidence of benefit. Although some quarters raised technical objections about the usefulness of grease filtration, bearing companies and end-users in growing numbers requested filtered grease for various reasons.

Two of the more frequently raised objections pertained to the impact of filtration on thickener and additive concentration. Let me ameliorate the thinking on this by providing some guidance on grease composition.

Lubricating greases are composed of three primary ingredients: a base oil that carries most of the tribological responsibility and consists of approximately 90% of the formulation for the typical NLGI Grade 2 grease, a solid thickener (e.g., lithium 12-hydroxystearate) that serves to immobilize the base fluid and is responsible for the grease's rheological characteristics, and additives that promote certain desirable characteristics. Antioxidants, corrosion inhibitors and boundary additives are examples of additives that enable a grease to be multitasking.

However, all of these diverse ingredients have one thing in common. They are all composed molecules with their greatest dimension measured in Angstroms or 10^{-10} meters. Nanophiles should be aware that greases are formulated from really small stuff!

To immobilize the base oil and form grease, the solid thickener is by design only partially soluble in the oil. The result is a loose confederation of oil and thickener consisting of individual thickener molecules and numerous agglomerations. The techni-

cal dilemma relates to whether agglomerations are removed during filtration, thereby altering the structural and rheological properties of the grease. Since one ugly fact can destroy a beautiful theory, approximately 20 years ago I investigated the impact of three-micron filtration on the properties of different greases. Polyurea, sodium complex, lithium-thickened, organo-clay and amorphous silica-thickened greases were all ultrafiltered to determine if the process changed physical properties.

The results unequivocally demonstrated that ultrafiltration did not jeopardize the physical properties of grease. Dropping points and oil separation remained unchanged while some of the greases exhibited a slight decrease in penetration, (i.e., the grease became firmer), indicative of an improved dispersion of the thickener after filtration. The conclusion of the study was that filtration did not remove thickener and actually improved thickener dispersion for some greases.⁽¹⁾

Additives that dissolve in the base oil pose no problem. Many additives that are insoluble in the fluid component, polytetrafluoroethylene for example, are filterable since discrete particles of PTFE are smaller than the openings in the filter. Agglomerates are readily dispersed by the shear encountered during high-pressure filtration. Grease containing sodium nitrite, molybdenum disulfide and graphite do present problems—however, they are not insurmountable! Molybdenum disulfide or graphite-fortified grease can be filtered, but residual contamination levels cannot be determined due to the opacity of such greases. On the other hand, to successfully filter sodium nitrite fortified greases may be a grind but worth the effort as explained below!

Trouble with an excellent corrosion inhibitor

One version of MIL-G-81322 is formulated from a synthetic hydrocarbon fluid thickened with an organo-modified clay. I bristle when people refer to this grease gallant as dirt since manufacturers of this type of thickener go to great lengths to render the mineral suitable for manufacturing precision bearing greases. At any rate, organo-modified clay is

a lamella solid that needs to be energetically dispersed in the base oil to affect gellation and optimize grease yield, (i.e., minimize percent thickener to achieve a given grease consistency). Individual clay platelets are approximately 10 Angstroms thick and 100 Angstroms along the other axes.

About 10 years ago, one bearing company was having difficulty with bearing distress using the clay-thickened MIL-G-81322 grease. Apparently, the mirror finish on the races was being compromised during run-in. Additional high pressure homogenization improved performance of the grease in the bearing while grease filtration cured the problem.

Subsequent work on filtered MIL-G81322 conducted by the military revealed that the grease lost its corrosion resistance. Clay-based greases are difficult to fortify against corrosion with traditional rust inhibitors due to the susceptibility of the clay-activator matrix to structural instability in the presence of polar additives. Therefore, sodium nitrite is commonly used as the rust inhibitor of choice for these high-dropping point greases. Two physical properties of sodium nitrite make it a difficult candidate for filtration. It's hard and also hygroscopic. Discrete particles of sodium nitrite larger than the pore size of the filter will be removed from the grease during filtration.⁽²⁾

However, the problem with sodium nitrite should not be an indictment against filtration, but rather an opportunity to determine if improved milling techniques and storage can produce a material with a particle size under 10 microns and perhaps below 1 micron. It's doubtful that sodium nitrite air milled to below 10 microns would be removed during ultrafiltration using a 10-micron filter.

Benefits of filtration

The benefits of grease filtration include:

- Improved tribological behavior.
- Improved microrheology.
- Reduced noise and vibration.
- Improved grease dispensing.

To mitigate the ravages of metal contact, the critical film thickness in a concentrated



(Photo courtesy of Lubrizol Corp.)

contact should be three times greater than the height of the highest asperity. Since this rule serves us well in most applications, let me propose the following corollary: A lubricant should contain no particulate contamination larger than one third the thickness of the lubricating film. Exogenous asperities also must be considered contributors to friction and wear.

From a rheological standpoint, greases are ideal lubricants. While at rest or under very low shear, they exhibit solid-like properties and remain where applied. However, under high rates of shear, a rapid decrease in viscosity occurs resulting in less viscous drag. The rheological duality of grease gives it a distinctive advantage over oil when a closed system or elaborate sealing are not options.

However, how does grease behave from a microrheological standpoint? If agglomerates of thickener are reduced or eliminated from a particular grease, would such a grease exhibit improved flow into the contact? The tendency of greases to lubricant starvation might result from agglomerates of thickener plugging the inlet zone. This could be the explanation for the improved wear performance of some ultrafiltered greases.

Contamination in grease is expected to

The widest use of grease is in lubricating bearings. Pictured is a close-up of a grease-coated bearing.

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generate vibration and noise when moving elements contact particulate matter especially at high speeds. Contaminates in a lubricant larger than the rolling elements in a bearing are expected to play havoc with the acoustical signature of the bearing. Bearing noise-testing equipment is available that could delineate the roll of filtration on bearing vibration and noise.

We all need to like customers, even when they do something stupid. One year ago a client selling totes of polyurea grease to a tier one automotive supplier requested that I assist in helping diagnose a dispensing problem. The commercial grade polyurea grease was being pumped directly from the tote through a very small in-line filter onto a latch mechanism. The customer complained that the grease would not pump after only a fraction of the tote was emptied. Field analysis revealed that the in-line filter had two major shortcomings: it was a static filter and it was far too small for the task at hand.

For low-pressure shop floor filtration of lubricating grease, dynamic filters are required to prevent the filter surface from being over-challenged by particulate matter found in commercial grade grease. To minimize frequent maintenance, motorized filters are needed that constantly clean the filter surface. To do otherwise is to invite unnecessary downtime. Moreover, users must be educated that it's not possible to filter a ton of commercial grade grease through a filter no larger than one on a water faucet.

Filtration of the polyurea grease to 125 microns eliminated the maintenance problem with the undersized in-line filter and restored line productivity. This was not an isolated incident associated with the polyurea grease. My client was asked to filter another manufacturer's grease, and the amount of contamination removed from approximately 10 pounds of that grease is shown in Figure 1.

Let me make this axiomatic! Lubricants are to tribology what plasma is to the circulatory system. Particulate contamination is as detrimental to sound lubrication practices as microbes are to good health.

A skirmish with definitions

In this article, reference is made to commer-

cial grade grease. What is commercial grade grease? Commercial grade grease is grease pumped directly from the grease-making vessel. Such grease-making equipment is usually large and may or may not be equipped with a motorized filter. Filters that are attached to grease-making vessels are by necessity sufficiently coarse to permit timely discharge of the vessel contents. Following are ratings for grease cleanliness:

Commercial Grade. This represents grease as delivered from the manufacturer. It may or may not be filtered. The level of particulate contamination has not been determined and is highly variable.

Clean Grease. This grease has been passed through a nominal 125-micron filter, and residual particulate contamination is sufficiently low to permit satisfactory grease dispensing. The determination of residual levels of particulate contamination may not be warranted.

Super Clean Grease. Grease is filtered at high pressure to render the grease free from all particulate contamination larger than 35 microns and no more than 1,000 particles per cm^3 in the 10-to-34-micron range. Super clean greases require special packaging to maintain cleanliness.

UltraClean Grease. An ultraclean grease reduces the level of contamination in the 10-to-34-micron range to no more than 500 particles per cm^3 . Lower limits may be set based on customer demands.

Residual contamination

Contamination like sin cannot be completely eliminated, and it is therefore necessary to determine the amount of residual particulate contamination in a grease after super or ultrafiltration. Since particulate contamination comes in numerous shapes and sizes, filtration through even a 10-micron absolute filter is no guarantee that all contamination 10 microns or larger has been removed. Long slender particles can raptate through the filter and emerge in the filtered grease. If the largest axis of such a particle was greater than 35 microns, the filtered grease would fail the criteria for classification as a superclean grease.

In my judgment, the best method used to size and count residual particulate contamination is microscopy based on Federal Test Standard Number 791 Method 3005.4. In this procedure, residual grease contamination is determined by sizing and counting the contamination is one cubic centimeter of grease placed in a rectangular template supported between glass slides. Grease samples need to be air-free and the glass slides must be scrupulously clean to avoid contaminating the grease. Although the technique suggests 60-times magnification, 100-times magnification in conjunction with an eyepiece grid-type reticle can greatly facilitate the task of counting the residual contamination in the grease.

Making progress

Progress is being made on the clean grease front. Manufacturers have come to realize that reducing particulate contamination in a grease is a benefit to a growing number of customers. In addition, filtration equipment manufacturers are now offering equipment to grease producers and end-users that offer promise in reducing the level of tribologically troublesome particulate matter in lubricating greases. In fact, two manufacturers of specialty grease filtration equipment spoke at the NLGI Annual Meeting in San Antonio last October while some engineering firms are assisting clients with the design and construction of specialized grease filtration systems.

Grease filtration is not a free ride, and manufacturers must resist the temptation of offering such products at commercial grade prices. The production of clean grease requires good execution, and to not benefit economically is to invite mediocrity.

Conclusions

The need for clean lubricants was recognized more than fifty years ago to improve bearing performance in various critical applications. Clean lubricants are being used by bearing manufacturers, aerospace, medical, and the computer industry. Super-clean and ultraclean grease will continue to be used for demanding applications where tribological reliability is critical for long-term effective lubrication.

Greases by their very chemical and phys-

Figure 1.



ical nature are amenable to filtration to 10 microns and below. Such filtration is time consuming and expensive, but specially cleaned greases are being demanded by more customers to solve dispensing problems, reduce noise and provide improved bearing performance. <<

Particulate contamination removed from approximately 10 lbs. of commercial grade clay grease.

References

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