Sustainability in the Processing of Lubricants

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There is a saying that expresses some of the problems in grease processing:
"We cannot solve our problems with the same thinking we used when we created them."

Introduction

As the concept of sustainability in lubes and greases grows in popularity and is more widely analysed, it becomes more comprehensive. It also becomes clear that sustainable lubricants involve more than just the raw materials and finished goods. It should also include a thorough life cycle assessment, from the extraction of base oil to transportation, processing, distribution, end use and finally disposal.

This paper highlights the incorporation of 3 approaches to manufacturing conventional or biobased greases. Its scope is on the sustainability of the manufacturing process and does not cover the raw materials or their sources.

There is a common appreciation of the fact that biodegradable lubricants are more environmentally preferrable. But to the educated end user, true acceptance would require lifecycle analyses in all aspects of the process of producing biobased products. From the growing of the crops, to extraction of oil, transportation, and to manufacturing process involved in producing the finished lubricants. The process described below came about due to the observed difficulties of making biobased grease in over 23 years of manufacturing. Improvements were made out of necessity to reduce manufacturing cost to better compete in the market with a mature and well-established mineral-oil based lubricant products.

First, in 2007, a manufacturing plant designed to manufacture ELM's biobased greases was destroyed in a heat transfer oil fire after 7 years of operation. The fire necessitated a genuine search for a different approach to heating for reaction and resulted in the invention of microwave-based grease processing. The concept has been reported in earlier issues of this magazine and was also presented at the National Lubricating Institute's annual meeting in 2013.

The next problem with manufacturing grease seemed to be the effectiveness of cooling or quenching once the reaction is completed at temperatures of 200°C-230°C. As grease is a poor conductor of heat, both the heating for reaction and the cooling of the reacted product requires a significant amount of time, expensive dual motion jacketed mixing vessels and cooling towers or chiller systems. Slow cooling results in a softer grease and for the practitioners this is a costly problem because it is easier to thin down a thick grease than thickening a thin grease. Fast quenching also leads to higher yields as a more condensed soap structure is formed with effective quenching, thus requiring more thinned down oil, and resulting in more final product (yield). The grease performance properties are also impacted by fast or slow cooling and abundant literature exists on this subject.

The third problem deals with mixing of the grease during cooling and during finishing processes. If the grease needs to remain in the mixing vessel for several hours to cool, then the grease yield is impacted. Finishing also requires the addition of small quantities of additives that may require extensive mixing to ensure the entire grease in a large vessel is uniformly additised. An example would be the addition of 400g of a liquid blue dye to change the colour of 5,000 Kg of grease in a vertical vessel. The amount of time in mixing and pump circulation required to effectively dye the entire volume of grease could add significant amount of time and cost. Importantly, some greases like the aluminium complex thickened grease are not shear stable. This means that often in the process of excess mixing for cooling or for additising, the grease shears down one to two grades, resulting in undue cost and waste.

In expanding a biobased grease manufacturing capacity, three approaches were introduced to not only address the observed shortcomings of the more conventional grease processing concepts; but also incorporate sustainability into the process. The first improvement is in the heating for reaction as follows.

1. An alternative method of heating

Patterson Industries, a grease vessel manufacturing company in Canada has begun producing grease reaction vessels that use microwaves. The equipment includes one or two microwave transmitters (also called generators), waveguides that deliver the microwaves to the vessel, and a temperature sensor that creates a closed loop and adjusts the microwave power to the desired temperature. Microwave transmitters for processing grease or chemicals operate at 915MHZ and have a wavelength of 32.75 cm (12.9 inches). Microwave generators are normally 75KW or 100KW each and rather economical when compared to equivalent hot oil systems. The microwave-operated Patterson kettle has two new patented technologies that allow the kettle to be used for manufacturing mineral-based grease as well as biobased grease (Figure 1). The laws of thermodynamics show that the amount of energy needed to react a certain volume of grease is the same regardless of the methods of heating. But, microwaves (radio waves at 915MHZ on the spectrum) are directly applied to the magnetic fields of materials being heated. Unlike heat transfer oil or steam heat, they do not require conversion of thermal energy to heated oil or steam, heat transfer lines, and heating of the walls of the vessels via vessel jackets, or similar equipment. The unfortunate grease manufacturing fire incidents at Environmental Lubricants Manufacturing in 2007 and Chemtool grease plant in 2021 (both in the Unites States) have shown the desirability of a safer approach to general industrial process heating and to the grease manufacturing processing in particular.

A paper presented at the NLGI Annual Meeting 2013, documented the time and energy savings of processing grease in the ranges of 40-50% total savings. Widespread use of this concept over time, will result in a more sustainable grease processing than the current technologies.

Figure 1: *Patterson Kettle Microwave-Operated. courtesy of Patterson Industries Canada – division of All-Weld Company Limited*

The second improvement is in cooling of the reacted grease.

2. An alternative method of cooling grease

Grease is a semi-solid mixture of soap and oil. It requires reaction heating up to 200°C – 230°C. Grease cooling or quenching refers to the cooling of grease after the reaction process is completed. Quenching impacts the quality and the yield of grease. A grease that is cooled quickly creates harder soap structures and subsequently a higher yield as more oil is needed to thin it to the desired consistency (grade). Slow cooling results in a softer grease and subsequently lower yield. For quenching to be effective about 80 to 100°C of temperature drop would be needed within a short period of time after the reaction.

Current grease manufacturers rely on cooling towers and chillers to cool the grease in jacketed vessels. Cooling water is pumped into the jacket of a vessel to cool its inside walls. Scrape surface mixing blades wipe the wall surface of the vessel. Grease is a poor conductor of heat and scraping the walls of the vessel replaces only thin layers of grease that are in touch with wall surfaces. Also, vessels that have scrape surface mixers, require heavy mix arms, gear reducers and high-powered motors to operate.

The use of water for cooling in industrial processes is an old concept that has been in use for centuries. Considered abundant and inexpensive, water as a cooling medium has become ubiquitous across many industries. Sophisticated compressors, heat exchangers, antifreeze, anti-rust and corrosion chemicals have been developed in support of water-based cooling systems.

Research has shown that relative to many solids, water is not an effective absorber of heat. For example, a 3″ diameter steel ball would weigh 1.6Kg and would take up about 20% as much space as 1.6Kg of water (Figure 2).

Figure 2: *Volume comparisons for a 3″ diameter steel ball and equal mass of grease*

The steel ball can absorb heat from a heat source much faster than the same mass of water. In contrast, water would retain the latent heat for a longer period than the steel ball would and would further take longer to cool. This concept eliminates the need for cooling water and jacketed vessels with scrape surface mixing mechanisms. It relies on solid re-useable metal objects for cooling grease from the reaction temperature to its desired quenched temperatures which is around 60°C-80°C. Simply explained, a predetermined number of steel balls whose aggregate mass equals 25% to 50% of the mass of the hot grease are introduced into the grease at carefully timed intervals. The exposure time of each ball to the grease is timed to allow full saturation of heat. During the exposure time a volume of the grease that is in contact with the ball is cooled to the desired temperature while the ball is heated to its maximum heat absorption capacity. A special wiper design wipes the grease off each ball at the end of its exposure time and the ball is transferred into a holding vessel to allow for heat exchange and heat removal. Accompanying components include an auger, indexing valves for proper timing of the release of each ball into the hot grease and its removal from the grease (Figure 3). In the northern United States, where the grease manufacturing plant is located, for about 4 months of the year, ambient temperatures are near or below freezing. Steel balls that occupy small volumes can be cooled outside before application to the grease. This in effect is the use of solar energy for heating in reverse as cooling, because no compressor energy is needed to generate the cool air used for cooling the balls before exposure to the grease.

Figure 3: *(Left) Illustration of speed-controlled auger, steel ball feeding device, grease holding tank, and steel balls and (Right) photo of a 15 ft auger used in production*

The use of solid media for cooling to replace water cooling has shown success in reducing the grease temperature by as much as 100°C in under 30 minutes with minimal mixing. This has also resulted in more stable grease, less shearing and in the case of aluminum complex grease a significant increase in yield.

The third improvement is in the selection of mixing vessels that are more suitable for use as finishing vessels.

3. Vertical vs. horizontal mixing/blending

The need for more effective blending became evident when a private-label client of a grease manufacturer requested a special light blue colour grease. The grease is aluminum complex and prone to shear thinning if mixed or milled excessively. Figure 5 shows variations of vertical mix tank mechanisms. These designs have been in use for decades and are effective in mixing some products. But, for the semi-solid grease some vertical mixing designs are not effective. It is akin to trying to mix two different colour solid granules in a vertical tank. For mixing solids, the product needs to be physically lifted and turned in order to mix effectively.

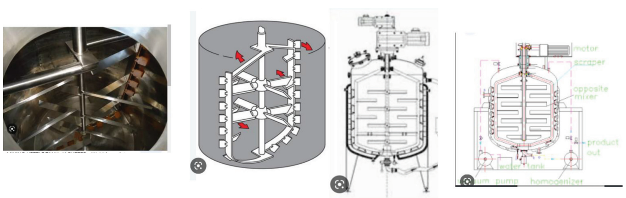

Figure 4: *Variations of vertical mixing arms in vertical mix tanks*

To mix solids like construction aggregate, different colour plastic pellets and the like, horizontal mixers are employed. Also called blenders, they include different designs such as ribbon blenders or paddle blenders. Experiments with thick greases have shown that paddle mixers present a more effective option for mixing. Paddle blenders use opposing paddles with different angles that act like a row on a rowboat. The outer paddles push the grease to one direction while the inside paddles push the grease the opposite direction creating an efficient mixing action. Additionally, since the mix tanks is usually not 100% full, the paddles lift the grease during half of the rotation, but the grease drops off the paddle surface due to gravity when the paddle are near vertical position. Horizontal blenders do occupy more floor space than vertical tanks do. But, for finishing grease especially when small amounts of additives or dye are to be mixed, they reduce mixing time, reduce shear in shear unstable greases and result in energy and time savings.

Figure 5: *Paddle Blenders for Blending granular materials, Aluminum Complex Grease on Paddles, and Horizontal Mixers designed specifically for blending grease*

Conclusions

Due to a number of factors ranging from a fire incident to the need to cut biobased grease manufacturing cost to better compete in the marketplace, several improvements have been introduced. These have now been fully incorporated in a new capacity expansion project as presented. The first improvement has been in the heating process using microwaves. The process has been well covered in earlier publications in this journal. Simply put, microwaves at 915 MHZ are applied directly to the product being heated resulting in molecular magnetic excitation due the interaction of the magnetic fields of microwaves and the product molecules. Since the amount of microwave power can be modulated infinitely, a temperature sensor is used to form a closed loop. In this way, the product can be heated to the desired temperature and maintained at that temperature accurately by modulating the microwave power. This accuracy removes the problems of overshooting the heating or delays due to slower heating.

The second improvement was made in the cooling process for grease. Relative to solids, water is slow in absorbing heat or in releasing heat. The use of water as a cooling medium has been known for centuries and the technology has matured in many industrial processes. Grease is a poor conductor of heat and the use of jacketed vessels for heating (using heat transfer oil or steam) and for cooling using towers or chilled water requires jacketed vessels and expensive scrape surface mixing mechanisms. The heat or the cold from the inside walls of the vessel has to be transferred to the entire body of the grease. To do this, layers of grease that are exposed to the inside walls of the jacketed vessel are wiped off by scraping blades of a mixer to be replaced by other layers. This process is inefficient and expensive.

An alternative cooling concept was introduced that uses re-useable solid metallic objects (in this case steel balls) to remove the heat from the grease quickly and eliminate the need for chilled water. Preliminary work with this waterless cooling method has shown promise and currently two fully operational reactors are using the waterless cooling system post reaction. Further documentation of the results of this technology is on-going.

Finally, it was observed that grease as a semi-solid product would likely be better mixed in paddle blenders instead of the commonly used vertical mix tanks. Since usually minute amounts of additives are added to the grease, effective mixing becomes critical especially if the grease is shear-sensitive. When adding colourants and additives, typically mixing is combined with pump circulation. The pumping and extensive mixing requires time and energy and, in some cases, causes shear thinning of the grease.

Paddle blenders are gentler on the grease and due to their design can impart more effective mixing especially when small amounts of additives are to be mixed in a large volume of grease. A fully operational grease manufacturing plant that incorporates the improvements explained in this paper is to start production in June 2023.

While each of the above concepts have been used and tested in experimental production settings, full implementation is expected to yield the same results. The overall impact of these modifications will be the start of a truly sustainable manufacturing process where new ideas are tested for a change in the conventional practices.

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