Advanced Biolubricants and Used Oil Re-refining

Introduction

The lubricants industry has been active in developing processes and technologies that meet regulatory and societal demands for sustainability and reduced environmental impact. There have been several approaches taken, which include use of higher quality lubricants that can operate under extended oil change intervals, implementation of collection and recycle services which includes re-refining, use of biodegradable and non-toxic lubricants, and finally, production of lubricants from renewable sources. These approaches can be taken individually or they can work together for an overall benefit.

Within this environment, it is important to note that advances in lubricant technologies and practices have the potential to impact the operations of other parts of the industry. For example,

- extended oil change intervals would reduce the total amount of oil used, and therefore reduce the amount of used oil available for re-refining.
- increased use of higher quality synthetic hydrocarbon fluids such as API Group III oils and polyalphaolefins can translate to less oil degradation and more efficient re-refining.
- use of Group V oils, such as synthetic esters, polyalkylene glycols, alkylated naphthalenes, and vegetable oil derived base oils have been identified as potentially decreasing the yield of higher valued hydrocarbons from the re-refining process.

Since a large part of the used oil collection and recycling industry includes re-refining, the re-refining industry continues to raise concerns regarding the impact of new unconventional lubricants on their industry. This review provides an assessment of the potential impact of the increased use of renewable (natural and synthetic) ester base oils on used oil recycling/re-refining practices in Ontario.

Overview of Re-refining

Lubricant recycling is an important practice that can meet social, economic, and environmental needs for managing this high volume waste product. In most areas of the world, the majority of collected used oil is recycled as a low grade heating fuel. Re-refining to produce industry standard base oils is common in North America and Europe, but globally, re-refined base oils make up less than 4% of the total base oil market and just over 5% in North America.[1] Other uses of used oil are as additives to asphalt and for explosives, but re-refining is considered the preferred option because it diverts used oil from low efficiency oil burners, landfilling, and other means of improper

[1] Lubes 'N' Greases Guide to Global Base Oil Refining 2014

disposal to a process that creates valuable products. Re-refined base oil can meet API Group I and Group II specifications and can be used to manufacture fully formulated lubricants for nearly all common lubricant applications, including for cars, trucks, and all manner of mobile and stationary equipment with rotating parts.

Used oil refining is similar to virgin crude oil refining in that higher quality and pure crude oil feedstocks produce higher yields of valuable refined products. Impurities must be removed and then the hydrocarbon fractions can be catalytically homogenized and fractionated. Impurities in used oil include foreign products (fuel, water, coolant), residual chemical additives used in the originating lubricant formulations, and any non-hydrocarbon lubricants or base oils that were used in the originating lubricant formulations. Used oil refineries produce both lighter and heavier hydrocarbon fractions from their catalytic refining process, estimated as follows:[2]

lubricant base oil	69%
liquid fuels	20%
asphalt	11%

Re-refining in Ontario

Ontario's annual lubricant consumption is nearly 500 million litres (450,000 metric tonnes).[3] Ontario does not report collection and recycling rates, but other provinces (BC, Alberta, Quebec) report collection of close to 70% of collectable used oil. Collectable oil is the used oil volume that is not consumed or lost during use and is generally 70% of the total volume sold. Close to 30% of lubricant volume is lost during use via spills, leaks, and burning/volatilization.[4] This level of used oil recovery is also close that reported by other studies.[5] Therefore, each year in Ontario, approximately 350 million litres (315,000 tonnes) of used oil is available and at a 70% collection rate, 245 million litres (220,000 tonnes) are estimated to be collected and available for re-refining and other uses.

Safety-Kleen operates 3 used oil refineries in North America, including its Breslau, Ontario facility with a production capacity of 1,900 barrels per day of re-refined base oil (700 barrels of Group I and 1,200 barrels of Group II base oil). This corresponds to processing 190 million litres per year of used oil, based on typical re-refining yields.

[2] Newalta North Vancouver Facility Fact Sheet.
[3] Statscan: The Supply and Disposition of Refined Products in Canada, April 2013, Table 1-7
[4] www.usedoilrecyling.com
[5] Kline and Company, 2011, estimated lubricant loss/consumption at 36% (64% collectable)

Used Oil Composition

The composition of used oil has a direct impact on the efficient conversion to desirable products. The two key factors are the composition of the original lubricant formulations and the level of contamination with other materials. Contamination with water, coolant, fuel, etc., is a result of less than desirable used oil management which is difficult to control and is outside of the scope of this discussion. The focus here is on the impact of typical lubricant components used to produce the original products.

Since all used oil is treated similarly under current collection systems, used oil is an aggregate or blend of all types of lubricant formulations sold into the market. Most lubricants are produced using pure hydrocarbon base oils - approximately 5 – 8 percent of a lubricant is chemical performance additives (detergents, dispersants, antioxidants, friction reducers, antiwear additives). In addition, across the full spectrum of lubricant applications, some non-conventional (Group V) synthetic base oils are used that do not contribute to valuable hydrocarbons during re-refining. This group includes organic esters, phosphate esters, silicone fluids, and polyglycols that are used to formulate niche and high performance lubricants. These synthetic fluids often contain shorter hydrocarbon chains linked with oxygen, phosphorus, or silicon and during the thermochemical reactions of re-refining, they degrade into shorter chained hydrocarbons that are not useful as lubricant base oil.

The use of high performing API Group V base oils is generally increasing as part of ongoing trends towards reduced maintenance, extended oil change intervals, and more severe operating conditions. Organic esters are the highest volume of these synthetic fluids. The use of esters is often required in high performance engine oil formulations where ultra-pure hydrocarbon base oils (PAOs and Group III+ oils) are used. The addition of 5 – 25% of an ester can provide the needed solubility characteristics for the performance additives. This tends to be the case for modern automotive engine oils which require both high purity synthetic hydrocarbon base oil and high levels of performance additives. Based on estimates of the total use of esters in all lubricants, the ester content in used oil is the range of 0.1%.[6]

Biobased Lubricants

The non-conventional lubricating base oil category also includes biobased and biodegradable lubricants -- nearly all of which are based on vegetable oils. Vegetable oil based lubricants have been under development for more than 30 years, originally in Europe as part of a program to utilize agricultural land for rapeseed oil production. These fluids are natural esters known as triacyl

[6] MTN Consulting Associates

glycerides (TAGs). The primary advantages for TAGs are a low carbon footprint, biodegradability, and non-toxicity. In North America, soy and canola oil lubricants are readily available, and while market penetration is growing, it has remained as a very small (less than 1%) and niche market mainly due to limitations in high temperature durability.

A range of synthetic esters derived from high oleic vegetable oils have recently been developed that provide greatly improved temperature and stability as compared to natural esters. These bio-derived synthetic esters are classified as Group V base oils and been proven in industry standard (API) engine tests to be of the high quality required for use in modern engine oils. Other novel lubricating oils include bio-derived hydrocarbons meeting API Group III and Group IV specifications and with these new technologies, lubricant manufacturers have more and more options for formulating premium quality lubricants with increased levels of biobased content.

Conclusions

Under the current industry and market environment, there is increasing demand for biobased lubricants in all automotive and industrial applications. Vegetable oils continue to be a valuable raw material but in most cases, some chemical manipulation is required in order to meet industry standard performance requirements. However, this processing comes at a cost and new products entering the market such as modified vegetable oils (including estolide fluids), are likely to be priced higher than conventional hydrocarbon Group I, II, and III base oils, although not as high as premium synthetic hydrocarbons and esters produced by the petrochemical industry. It is anticipated that new modified vegetable oils will provide a blending option for formulators looking to increase the biobased content in lubricants, potentially at a lower cost than synthetic oils and at a higher performance than conventional petroleum or vegetable oils.

Some entities within the used oil recycling industry claim that an increase in use of any vegetable oil derived esters would have a negative impact on the re-refining industry due to reduced yields. The logic behind this claim is that if used oils were to contain increasing levels of esters that may degrade into shorter chained hydrocarbons during re-refining, the yield of higher valued lubricants at a re-refinery could decrease.

The specific level of impact of re-refining high quality biobased esters would require a technical/economic study in order to document the specific degradation products. However, during the foreseeable future, the availability of modified vegetable oils such as estolides is not expected to negatively impact the re-refining industry. Key points supporting this position are as follows:

1. A manufacturing plant producing 20,000 tonnes per year of estolides would represent just 0.2% of a 9 million tonne North American market.
2. The lubricants market is not regional, as lubricant products for North America are produced at

a limited number of points of manufacture and then distributed widely. Therefore, products using estolides would be distributed across the entire market and would not impact a specific re-refining facility more than another.

3. In terms of overall lubricant compositions, increased availability of high performance modified vegetable oils, such as estolides, are likely to displace a significant amount of synthetic esters already in use, due to similar characteristics, performance, and reduced cost. In this instance, net increase in ester use would be moderated and any potential impact on used oil composition would be further minimized.
4. Under typical re-refining processes, estolides are likely to contribute to the yield of fuel grade products such as marine diesel oil or heating oil that could accurately be classified as valuable renewable or biobased fuel.