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High Quality Basestocks For Modern Applications

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ABSTRACT

Increasing petrol and diesel engine severity, requirements for fuel economy, and extended lubricant drain intervals put additional stress on lubricants and demand higher levels of engine oil performance. To achieve this higher level performance, lubricant formulators are using more high-quality basestocks, especially those defined as API Category Group II and Group III. The increasing demand for these high quality, hydroprocessed basestocks is driving more basestock refiners to seek the best process options for quality, reliability and high yield.

ExxonMobil offers a broad range of lube technologies that provide refiners with the flexibility and reliability that they need to manufacture high quality basestocks. A review of basestock quality drivers, process options and performance considerations will be presented in this paper.

KEYWORDS

Lubricants, Basestocks, Baseoils, Dewaxing, Fuel Economy, Lower Emissions, Drain Intervals, Hydrotreating

INTRODUCTION

The worldwide use of lubricants is estimated at around 38 million tons per annum (tpa)[(1)] and its growth is being driven by increasing demand in the Asia-Pacific region, particularly China and India. Currently, the Asia-Pacific region represents almost a third of global lubricant demand (Figure 1). As per a recent report from PFC Energy[(2)], India is the fifth largest lubricant market in the world, and demand is projected to grow at about 4% in the coming years. A little over 50% of the lubricants are used for transportation, with another 40% going to the industrial sector. In terms of production, India has about 1.1 million tpa basestock capacity, with about 30% representing the higher quality Group II and Group III basestocks, while the rest is primarily Group I production. Despite currently planned capacity increases, India is expected to remain a net importer of basestocks into the future.

TRANSPORTATION LUBRICANTS

India is a growing economy, and industry reports indicate that the total number of vehicles in the country increased by almost 10% in 2006. Unlike the situation in Europe and North America, however, over two-thirds of the vehicles are still two and three-wheelers, which typically have a lower overall lubricant requirement. With increasing levels of disposable income, however, the shift towards passenger cars is inevitable, which would result in a rise in lubricant usage over time.

The standard lubricants used in India today are primarily the 15W-40 and 20W-50 grades[(2)]. As the auto market in the country continues to grow, it is expected that lubricant quality will improve similar to what has been seen in the US and Europe. In those markets, tightening environmental requirements (higher fuel economy, lower tailpipe emissions) and more severe engine operations (smaller oil sumps, hotter operating temperatures, etc.) have driven increases in engine oil quality. This evolution is illustrated by the changes in API petrol engine oil service categories shown in Figure 2. While much of this change has been accommodated by improvements in additive technology, improvements in baseoil quality have also been required. Virtually all current quality petrol engine oils in the U.S. and Europe require the use of some Group II+ or Group III basestocks.

Basestock quality serves several functions in improving the environmental performance of an engine oil. First, there is a fundamental relationship between basestock viscosity, viscosity index (VI) and Noack volatility (which correlates with emissions). At a constant VI, volatility decreases as the viscosity increases; and at a constant viscosity, the volatility decreases as the VI increases. Therefore, for an engine oil to have lower volatility (and thereby lower emissions) requires that it be formulated from high VI basestocks. Secondly, severely hydroprocessed basestocks have very low sulfur and nitrogen content, which reduce the engine oil contributions to SOx and NOx emissions from the vehicle. Lastly, engine oils formulated to lower viscosity grades (e.g. 0W-XX or 5W-XX) have improved fuel economy performance due to lower internal resistance to flow. Therefore, for engine oils to play a role in meeting future emission standards in India, lighter viscosity and higher VI basestocks will be required. This basestock supply must be met through either domestic production of Group II and Group III basestocks or increased imports.

Of course, it is important to note that while evolution of lubricant quality has improved the fuel economy and emissions of modern engines, improved lubricant performance cannot compensate for poor fuel quality. Higher quality basestocks will not help lower emissions if sulfur levels in petrol and diesel are not also reduced simultaneously.

Another trend in both passenger and commercial vehicle lubricants are increasing drain intervals, again led by Europe and the US. Figure 3 shows the increase in drain interval for European and US auto manufacturers from 1998 to 2002. ExxonMobil has produced lubricants with drain intervals of 5000, 7500 and 15000 miles for sale in the US. In comparison, typical drain intervals in India are around 9,000 km (5500 miles) for passenger cars[2], a number that might be driven as much by financial considerations as it is by quality.

As previously mentioned, the two and three-wheeler segment of the vehicle market is quite significant in terms of sheer numbers. To meet emission standards, two-wheeler manufacturers are moving to four stroke as opposed to two stroke engines. As the market evolves, it will be interesting to see whether the same quality improvements expected with lubricants for cars and trucks are also seen with the two-wheeler lubricants.

In the next section, we look at a few options to make higher quality Group II/III basestocks - one involving an upgrade to an existing Group I facility using the RHC™ process, while the other is the highly successful standalone catalytic lubes dewaxing technology MSDW™ that is now in use at over a dozen locations worldwide. Both of these technologies can be applied to meet the challenge of providing higher quality basestocks in India to support the increasing range and number of applications.

PROCESS TECHNOLOGY OPTIONS

The performance of a basestock is not related solely to the quality specifications but also to the manner in which the basestock is manufactured i.e., the processing scheme.

The basestock refining industry has been going through significant changes trying to meet OEM's requirements for high quality lubricants. In general, basestocks have been lighter in boiling range and viscosity to improve fuel economy, as well as less volatile to reduce oil consumption and exhaust emissions. In many cases, new technologies such as advanced hydroisomerization and hydrogenation had to be developed and implemented. This growth has been steady at about 0.7 million tpa[1]. At this time, about 20% of the total paraffinic lubes market is based on hydroisomerization technology.

The growth has been most notable in the lighter grades, with Group I+ blended into 10W-40, Group II+ blended into 5W-30 and Group III+ into 0W-30. This is because Noack volatility has been more constrained, which in turn drives the basestock to be higher in VI. Iso paraffins provide the highest VI and lowest Noack volatility at a given viscosity.

Hydroisomerization growth in the heavier grades is still significant, thus plants are being built for both heavy and light grades. Application of MSDW and MAXSAT™, ExxonMobil's catalytic technologies for hydroisomerization and hydrogenation, has grown steadily over the last decade and now represents a significant share of the market in terms of number of operating units (Table 1) and barrels processed.

Many of these units produce 500N and 600N grades, with 150BS also having been produced in limited volumes. As these stocks are severely hydrotreated, oxidative stability is generally quite good. Most other lubricant properties also improve. Even though solvency can be a challenge in a highly saturated basestock, additive suppliers have been able to provide formulation solutions to overcome this problem.

Another driver to building catalytic plants has been the cost to produce basestocks. The newer Group II/III plants are typically of larger capacity, so economies of scale as well as increased crude flexibility and high quality by-products (ie, high cetane low sulfur diesel, low sulfur petrol) can result in low production cost when the entire refinery economics are taken into consideration.

A catalytic plant to make Group II and Group III basestocks consists of three major processes (or catalytic functions) as shown in Figure 4. The first part is a simple hydrotreating (HDT) or hydrocracking (HDC) of vacuum distillates, raffinates, slack waxes, or deasphalted oil. These catalysts remove sulfur, nitrogen, CCR, asphaltenes as well as saturate aromatics. Conversion and aromatic saturation tend to raise VI. In general, the VI improvement is directly related to conversion with the specific catalyst (HDT and HDC) being of secondary importance.

The second part of the process consists of catalytic dewaxing (or more specifically, hydroisomerization) of the wax molecules in the feed to lower the pour point of the feed. As the wax molecules are no longer removed but are converted to lubes, the VI of the hydroisomerized oil is higher for a given pour point than if it were solvent dewaxed.

ExxonMobil has been a leader in zeolite catalysis for over fifty years, and has commercially operated catalytic dewaxing plants for over twenty years. ExxonMobil's first hydroisomerization plants produced fuels (MIDW™), but later applied hydroisomerization technology to producing lube basestocks. The MSDW process converts wax to oil by hydroisomerization as opposed to cracking.

As the feed stock undergoes hydroisomerization, significant aromatic saturation also takes place. Aromatics can be reduced kinetically by increasing reaction temperature; however, there are distinct thermodynamic limits to aromatic saturation that arise based on reaction severity and other process conditions.

These processes can be integrated into a solvent plant, and thus reduce capital investment, because of a lower hydrogen consumption and, in some cases, a lower operating pressure since the extraction step in the solvent plant removes aromatics while improving VI. Highlighted below is an overview of the relationships between various processing options.

INTEGRATED SOLVENT HYDROPROCESSING

The first method involves integration of hydroprocessing technology into an existing solvent plant through the Raffinate Hydroconversion (RHC) process. This scheme maintains the extraction section and then uses moderate conditions to hydroprocess raffinates to achieve the target properties. If wax production is important, the hydroprocessed stream is dewaxed through a solvent dewaxer - if not, it can be hydroisomerized. using ExxonMobil's MSDW to further increase the basestock VI and yield.

This integrated approach has the advantage of lower capital cost than distillate hydrocracking, since pre-extraction permits the subsequent hydroprocessing step to function at relatively mild temperatures and pressures, with resulting lower hydrogen consumption.

Furthermore, this process can be leveraged by using raffinates with much lower VI's than would normally be used to make a Group I basestock. Under-extraction can be used to offset the yield loss associated with hydroprocessing conversion and topping to correct for viscosity loss. Under-extraction also debottlenecks the extraction unit, which can allow extraction limited plants to process more distillate further offsetting yield loss.

For the integrated hydroprocessing option, where there is limited distillate availability in the Group I plant because of vacuum tower or other limits, further capacity increase can be obtained by hydroisomerization. In this scenario, hydroisomerization increases plant yields by converting wax to basestocks. It also allows the raffinate hydrotreater to operate at lower severity, further enhancing yields.

Typical process flow and yields are shown in Figure 5. The data are indicative of typical performance and variations shown in yield and VI reflect crude differences. ExxonMobil has licensed variations of these schemes in the industry, including within India.

ExxonMobil has operated a plant using the RHC processing scheme since 1999 in Baytown, Texas. The plant produces EHC-45 and EHC 60 Group II+ basestocks. In this case, the high VI material is hydroprocessed but solvent dewaxed instead of catalytically dewaxed, thus maintaining wax production.

WAX HYDROISOMERIZATION

A second approach to making high quality basestocks is via wax hydroisomerization to directly produce very high VI basestock (Figure 6). Plant size is often limited by the volume of wax available at any one location, and economic viability is also dependent on the value of the wax feed stream. Depending on the wax quality, product properties and yields can vary, but on typical waxes with oil contents between 5 and 25%, a very high percentage of the wax component can be converted into very high VI isomerate. ExxonMobil has been operating this latest catalyst technology for the past four years to produce their Visom™ Group III+ wax isomerate baseoils

Typical properties of these wax isomerate baseoils are shown in Table 3. These have been designed for use in high performance product lines with very high viscosity index and no measurable sulfur, and can be used to formulate the most demanding engine oil products. The baseoil slate has been designed to cover a wide range of viscosity for engine oils (4.0-6.6-cSt at 100°C), with broad applications, ranging from automatic transmission fluid to passenger and commercial vehicle lubricants. These baseoils are well suited for emerging applications. They will be able to meet increasingly stringent formulated-oil volatility constraints, while at the same time preserving excellent viscometric properties at very low temperature. They exhibit outstanding oxidation stability, with a combination of negligible amounts of aromatics or sulfur, and low levels of naphthenes. ExxonMobil's catalysts for both wax isomerization and catalytic dewaxing give us the ability to manufacture basestocks with near-PAO qualities.

COMMERCIAL OPERATIONS

Interestingly, the hydroisomerization step with MSDW catalyst has been one of the most stable of the three steps (i.e. hydrotreating, hydroisomerization, aromatic saturation) in terms of aging and catalyst life. Our

Jurong plant has operated for over seven years, even with increasing heteroatom concentration in the feedstock, without significant loss in dewaxing activity.

In fact, ExxonMobil continues to lead the industry using hydroisomerization catalysts in tough operating environments. In a six month pilot study, we demonstrated long term dewaxing activity for making bright stocks from four hydrocracked deasphalted oils (HDC DAO). The four test feedstocks were derived from two commercially prepared feeds that were each hydrocracked in the laboratory at two severity levels. MSDW catalyst reactor temperature stabilized well within normal operating range with no apparent aging, even with the most highly contaminated feed after six months of stream time.

Contaminant levels of hydrocracked DAO's used in this study were very aggressive for isomerization dewaxing catalysts. The enhanced robustness of MSDW catalysts at these high contamination levels reduces requirements on the "clean up" function of the hydrocracking step, allowing lower severity hydrocracking with accompanying higher yields of waxy bottoms and preservation of viscosity.

CONCLUSIONS

Growing demand for lubricants in the Asia-Pacific region will be met through a combination of new investments to make high quality Group II/III basestocks, as well as revamps to existing facilities to maximize the production of Group I basestocks. The drive towards better fuel economy and lower emissions will lead to lighter grades with higher VI.

ExxonMobil has significant experience converting solvent plants to manufacture Group II and Group III basestocks. We can achieve this goal with RHC (Raffinate Hydroconversion), to preserve the wax, or hydroisomerization using MSDW and MAXSAT technologies available for license. These ExxonMobil technologies utilize robust and proprietary catalyst systems for the manufacture of high quality basestocks.
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REFERENCES

(1) ExxonMobil Assessment of publicly available information

(2) "India Country Profile", PFC Energy Global Lubricants Service, 2007.

Figure 1. Worldwide lubricant demand by region[1]

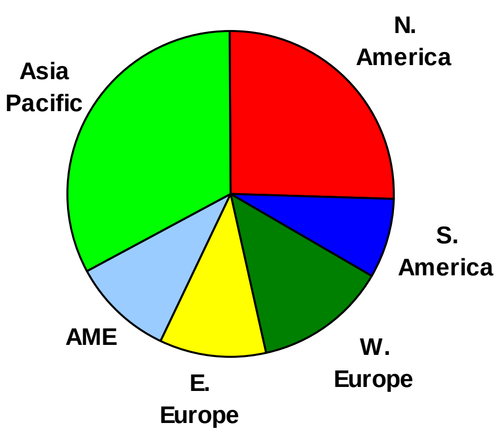


Figure 2. Evolution of API petrol engine oil service categories

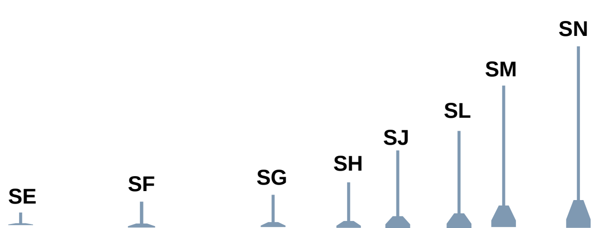


Figure 3. Lubricant drain intervals in Europe/US

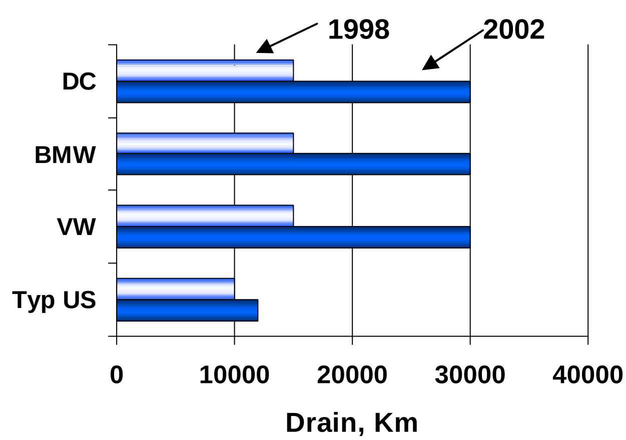
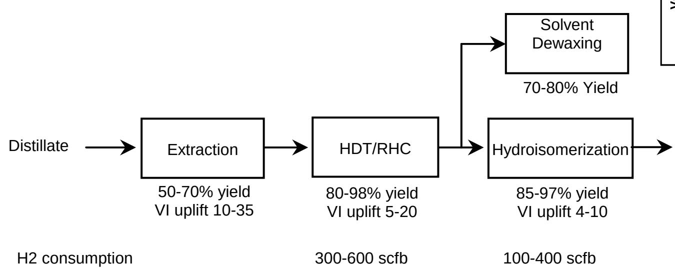


Figure 4. Schematic of All-Catalytic plant for Group II/III

Figure 5. Schematic of RHC process



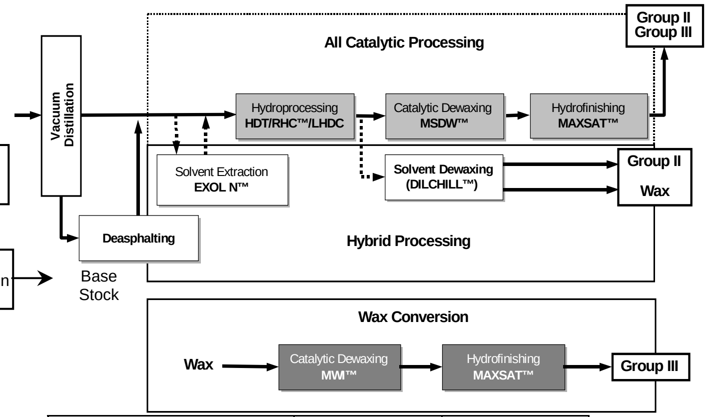


Figure 6. Schematic of process to make Group III basestocks from wax

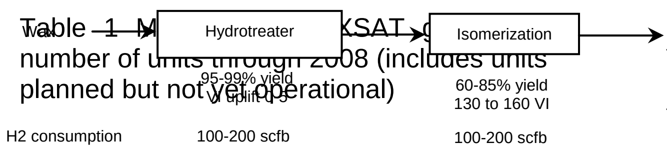


Table 1. M… XSAT … number of units through 2008 (includes units planned but not yet operational)

DATE	MSDW	MAXSAT
1997	1	
2000	2	
2001	3	1
2002	4	2
2003	6	4
2004	8	6
2005	9	6
2006	12	8
2007/2008	14	9

Table 2. Properties of Group II+ stocks made using RHC process (source: ExxonMobil)

Basestock	EHC 45	EHC 60
Viscosity at 100°C [cSt]	4.5	5.9
Viscosity Index	116	114
Noack Volatility [wt. %]	14	8
Pour Point [°C]	-18	-18
Saturates [wt. %]	96	95

Table 3. Properties of Visom stocks (source: ExxonMobil

Typical Properties	**Visom 4**	**Visom 6**
Kinematic Viscosity at 100°C [cSt]	3.9 to 4.1	6.4 to 6.8
Viscosity Index	135-140	140-145
Noack Volatility [wt. %]	15	8
CCS at -35°C [mPa • Sec]	1600	8500