All Hydroprocessing Route to High Quality Lubricant Base Oil Manufacture Using Chevron ISODEWAXING Technology

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Extended Abstract

Introduction

Chevron has made significant, long-term commitments to the production of high quality petroleum products. This is especially true for lubricant base oils, where Chevron is a world leader in the production of premium base oils made exclusively by an all-hydroprocessing process technology route.

Early Base Oil Processing

Base oil technology has undergone many phases of evolution. In the 1920s, clay treating, acid treating and SO2 treating were used to remove some of the worst components in the petroleum base oil. These compounds were usually aromatics and highly polar compounds containing sulfur and nitrogen. By 1930s, solvent processing emerged as a viable technology for improving base oil performance using a fairly safe, recyclable solvent. Most base oil producers still use this process. Solvent refined base oils are commonly called Group I base oils which have higher aromatics and sulfur. Table I shows the API Base Oil Categories.

Table 1. API Base Oil Categories

Group	Sulfur, Wt %		Saturates	V.I.
I	>0.03	and/or	<90	80-119
II	□0.03	and	□90	80-119
III	□0.03	and	□90	≥120
IV	All Polyalphaolefins (PAOs)			
V	All Stocks Not Included in Groups I-IV (Pale Oils and Non-PAO Synthetics)			

Solvent processing has evolved over time but the basic processing steps remain the same. Aromatics are removed by solvent extraction in the first step, and wax is removed from the oil by chilling and precipitation in the presence of a different solvent in the second step. Finished oil quality improved mainly due to the addition of additives. For several decades, the lubricants industry continued to rely heavily on additive technology to improve the performance of finished oils. This also imposed limitations on the crude source of the starting material.

Lubes Hydroprocessing

Hydrotreating was developed in the 1950s and first used in base oil manufacturing in the 1960s as an additional "cleanup" step added to the end of a conventional solvent refining process. This process removed some of the nitrogen and sulfur containing molecules but was not severe enough to remove a significant amount of aromatic molecules. This made a small improvement in base oil quality until all-hydroprocessing technology was available.

Recent lube hydroprocessing include hydrocracking and catalytic dewaxing processes. Hydrocracking is a more severe form of hydroprocessing. Hydrocracking reshaped feed molecules by converting low Viscosity Index (VI) components to high VI base oil material and also by cracking low VI components to lower boiling range materials. A great majority of sulfur, nitrogen, and aromatics are also removed. In 1969, the first hydrocracker for base oil manufacturing was commercialized in Idemitsu Kosan Company's Chiba Refinery (a Chevron Licensee). This could replace the solvent extraction step for VI upgrade, or use in conjunction with solvent extraction to result in higher waxy base oil yield.

Catalytic dewaxing was developed in the 1970s to remove wax from oil. Catalytic dewaxing was a desirable alternative to solvent dewaxing because it removed n-paraffins and waxy side chains from other molecules by catalytically cracking them into light hydrocarbons. Catalytic dewaxing was used in place of solvent dewaxing, but still coupled it with solvent extraction to manufacture conventional base oils.

Chevron's lube hydroprocessing experience extends back to 1984. Chevron was the first to combine catalytic dewaxing with hydrocracking and hyrofinishing in their Richmond Lube Oil Plant (RLOP) in California (Figure 1). The hydrofinishing step was added to the lube hydroprocess to completely saturate aromatics to obtain excellent oxidation and thermal stability. This results in superior color and better response to additive in the finished lubes. In 1984, RLOP was started up to produce premium base oils from crude oils that are deficient in high VI components. These poor-lube-quality crudes, such as Alaskan North Slope and heavy California San Joaquin Valley, were readily available but primarily used at that time for fuels production. This was the first commercial demonstration of an all-hydroprocessing route for lube base oil manufacturing.

Figure 1. Chevron Richmond Lube Oil Plant (RLOP)

RLOP produced light, medium, and heavy neutral base oils in two parallel hydroprocessing trains. The Light Train, which made light and medium neutral oils, consisted of a hydrocracker followed by a catalytic dewaxer. The Heavy Train, which made heavy neutral, consisted of a hydrocracker and a solvent dewaxer.

During the next several years, Chevron developed a selective, wax isomerization catalyst. The culmination of the development effort was its commercialization in RLOP in 1993. The new process became known as ISODEWAXING and represented a breakthrough improvement in hydroprocessing technology. Instead of removing wax molecules (as in solvent dewaxing) or cracking them to light hydrocarbons (as in catalytic dewaxing), the ISODEWAXING® catalyst isomerizes the wax molecules into low pour point lubricating base oil. The ISODEWAXING® catalyst significantly increases lubricant base oil yield over competitive technologies (solvent dewaxing, catalytic dewaxing). It also can significantly improve the product VI due to the isomerization of wax (highest VI component) into the lube fraction.

When the ISODEWAXING process was commercialized in 1993, Chevron shut down the solvent dewaxer and made all of the lubricant base oils in the ISODEWAXING unit (converting from catalytic dewaxing). In 2000, as part of an expansion project, a separate ISODEWAXING unit was added to the Heavy Train. RLOP now consists of two parallel all-hydroprocessing trains.

By using an all-hydroprocessing route (combining Chevron's ISOCRACKING, ISODEWAXING, and ISOFINISHING technologies), feedstocks with poor lubricating qualities are transformed and reshaped into higher quality base oils. VI, Pour point, and oxidation stability are controlled independently. All three steps convert undesirable molecules into desirable ones. Among the many benefits of this combination of processes is greater crude oil flexibility which allows lube plant to be less reliance on a narrow range of crude oils. In addition, the base oil performance is exceptionally favorable and substantially independent of crude source, unlike solvent-refined base oil.

Base Oil Market Change

The need for higher fuel economy and higher performance engines created a market for higher quality base oils. Lube base oils made by hydroprocessing technologies showed favorably differentiated performance which prompted the API to categorize base oils by composition (API Publication 1509) in 1993, as shown in Table 1. Group II base oils made from the all-hydroprocessing route are differentiated from Group I base oils because they contain significant lower levels of impurities. From a lubricant performance standpoint, improved purity means that the base oil and the additives in the finished product can last much longer. The base oil market has gradually shifted from Group I to Group II base oils due to the new automotive engine oil specifications that favor Group II quality. Today more than half of the paraffinic base oil market in North America has now converted to Group II quality. Many Group I plants have been converted or closed.

The all-hydroprocessing route can also produce higher VI Group III base oils. This is typically done by increasing the severity of the hydrocracking process. In modern base oil manufacturing, VI, pour point, volatility, and oxidation stability can be independently controlled. These modern Group III oils have greatly improved oxidation stability and low temperature performance than conventional Group I and Group II base oils. They substantially match existing levels of performance in finished lube applications already established by traditional synthetic oils such as PAOs. As well-designed Group III base oils become abundant in the market place, the performance gap between Group III and PAOs (Group IV) is closing.

Looking at the base oil market, we see high quality Group II and Group III base oils emerging in almost all regions. Group II /III base oils are appearing mainly because of simple economics. Refiners are not building new solvent plants (Group I) because new Group II/III plants are more economic in the long run. They also give refiners more flexibility with both crudes and products. The world wide market share of Group II/III base oils has grown from about 11% in 1995 to about 26% today. Availability of and advances in Chevron's all-hydroprocessing route using ISODEWAXING technology have created world wide premium base oil markets. This is truly a remarkable transformation for any refining segment in recent history.