The Synthetics Are Coming

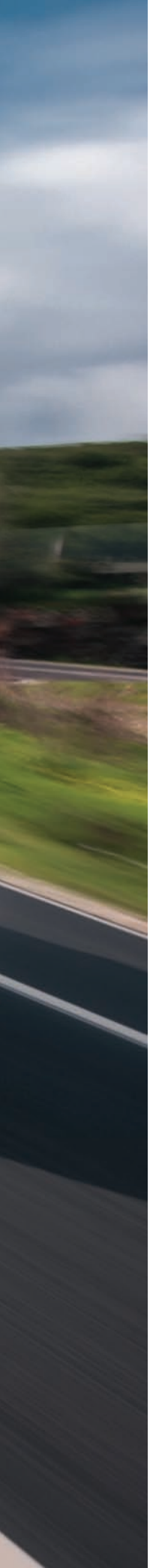


Photo: Luis Viegas-AdobeStock

By Caitlin Jacobs

Every formulator is familiar with some universal trends in industry: demands to improve fuel efficiency, mandates to reduce emissions, higher performing engines and harsher operating conditions. "These fundamentals have driven healthy synthetic lubricant demand growth for several decades now, and they are going to persist," stated Michael Toohey, market development lead with ExxonMobil Chemical Co., during the ICIS Pan American Base Oils & Lubricants Conference in December.

Synthetics accounted for 22 percent of global finished lubricant demand, which reached 40.5 million tons in 2018, according to consultancy Kline & Co. That should climb to 26 percent by 2023, and even higher in mature markets such as North America and Europe.

As the leading product type, automotive engine oil is a key driver of synthetic uptake as specifications become increasingly stringent. And for engine oils, API Group III also falls into the synthetic category.

"No spec says you have to use this [API] group or that group, but because of the way the specs are written, the spec forces the base oil group," said Chris Castanien, technical services manager–Americas for Neste, at the Jersey City, New Jersey, gathering.

Engine oil specifications are driven by fuel economy targets, he said, and four parameters within those specifications dictate base stock selection. Kinematic viscosity and high-temperature, high-shear viscosity are specific to the design of the engine for which a lubricant is formulated, and these properties affect pumpability and fuel efficiency, respectively. The other two parameters stem from the base stock itself: Noack volatility and cold-cranking simulator performance.

Volatility is important for the long oil drain intervals automakers now recommend, which have been extended to two years in some European models. It's important that the engine oil doesn't boil away over that time frame, observed Castanien.

Noack volatility requirements for the latest ILSAC, API and OEM specifications are about 12 to 15 percent. European specifications reach as low as 11 percent with talk of going down to 9 percent. This is in contrast to 25 percent when 5,000-kilometer drain intervals were the norm, he continued.

The cold-cranking simulator test is based on a 1964 starting system and mimics the ability of the system to crank a sump of cold engine oil. "Today's systems really don't have a problem with that, but this is a big driver" of engine oil formulations, Castanien noted. The test temperature changes with the oil's winter grade; for example, SAE 0W-XX oils must crank at minus 35 degrees Celsius, while SAE 10W-XX grades must work at minus 25 C.

"Balancing CCS and volatility is the key to base oil selection," he emphasized. Thinner base oils, which crank more readily, are more volatile. On the other hand, he explained, "Group II is more volatile than Group III, which is more volatile than PAO."

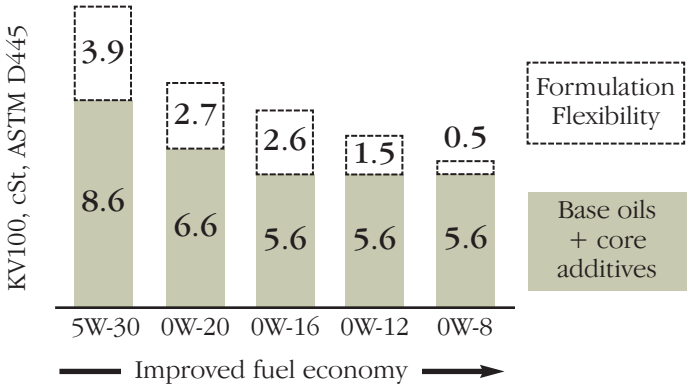
"Balancing out the cold crank and volatility is the job that our additive company friends do for us every time we get an approval," he noted.

Even with additives, meeting low volatility and extremely low temperature CCS targets pushes formulators to API Group III and IV base oils. "As we move to these low-volatility 0W oils, the technical demand is going to continue to rise," Castanien said.

Oils meeting API and ILSAC passenger car engine oil specifications account for about 80 percent of the North American market. API SP, which will make its debut on the shelves in May, will require a maximum 15 percent Noack volatility. However, the accuracy of the Noack test is within about 0.5 percent. Castanien pointed out that, with the limit set at 15.0 percent, formulators must aim even lower to ensure they will pass.

A "good portion" of the market also complies with General Motors' Dexos1 specification, which requires 13 percent volatility or lower. It's possible to formulate an SAE 0W-20 API SP oil with standard

The Formulation Squeeze



Source: ExxonMobil

API Group III base oil, but to make a Dexos-approved product, the formulation must include "Group III+ in significant amounts, or even some Group IV," he said.

Dexos1 Gen 3, which is expected to make its debut soon, will clamp down volatility even further to 12.5 percent, according to Khaled Zreik, GM's powertrain & vehicle fluids technical specialist, who also spoke at the conference.

"The shift from Dexos1 Gen 2 to Gen 3 will increase the concentration of either Group III+ or PAO—it has to," Castanien said. "The only way to get that Noack down is to put in something less volatile, and I expect we'll see a shift to Group III+."

However, he emphasized that SAE 5W-XX oils will remain the dominant viscosity grade at about 65 percent of the market for the next decade, and these oils do not need Group III+.

ExxonMobil Chemical is working with an eye toward the future. Data from Infineum that Toohey cited show that SAE 5W-30 will be replaced by SAE 0W-XX as the workhorse viscosity grade for passenger car motor oil in North America by 2029.

The company is also eyeing up the long-term low-viscosity trend in commercial vehicle engine oils. "We view this as the next big thing as a PAO producer," he said.

Meeting viscosity and volatility targets will only become more challenging as viscosities slide lower. Toohey described what he called the "formulation squeeze."

Base oils and core additives make up a certain portion of a formulation's viscosity. For example, an SAE 5W-30 engine oil can go up to 12.5 centistokes kinematic viscosity at 100 C. A typical base oil used in engine oils has viscosity between 4 and 6 cSt. Going below 4 cSt may result in volatility issues, Toohey noted. Basic additives would add about 2.6 to 4.6 cSt, leaving nearly 4 cSt for formulators to customize the product with additives that may increase the viscosity further.

For an SAE 0W-16, maximum kinematic viscosity is 7.1 cSt. Base oil and core additives would typically be 5.6 cSt, which only leaves 1.5 cSt of flexibility. "As formulators want to move from 0W-20 to 0W-16 to 0W-8, you can see that the formulation flexibility diminishes significantly," he explained.

"In order for formulators to develop the next generation of engine oils with good fuel economy, low volatility and good cleanliness performance, new base stocks need to be delivered," Toohey declared.

Using historical data and some new modeling techniques as a guide, ExxonMobil created and tested more than 200 materials and advanced "many" of them for development.

The goal was to increase the cohesive energy of the molecule to improve volatility, minimize side chains to balance low-temperature properties with lower viscosity, and reduce unstable carbon bonds in order to maintain good oxidation stability.

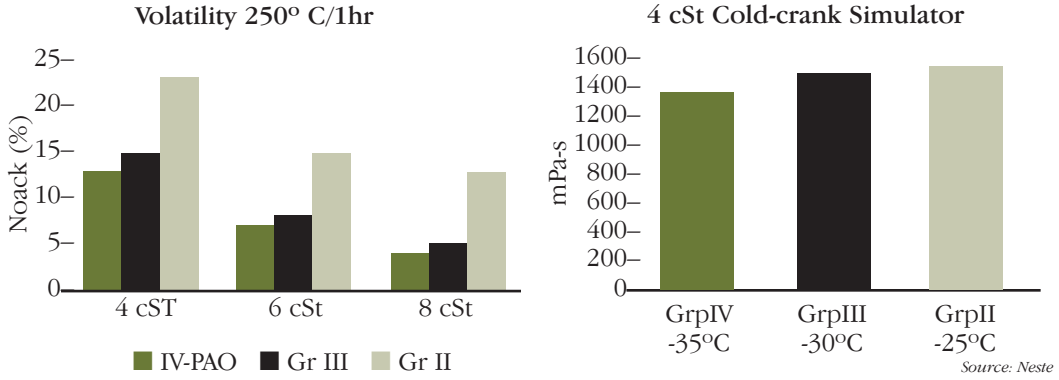
One of the resulting materials was a type of low-viscosity, low-volatility polyalphaolefin. One sample of these PAOs had KV 100 of 3.39 cSt, volatility of 12.5 percent and CCS at minus 35 C of 623 centipoise, which can be compared to a conventional 4 cSt PAO with KV 100 of 4.10 cSt, volatility of 12.4 percent and CCS of 1430 cP. Toohey also pointed out that the new PAO performed far better in oxidation stability, scoring 88 minutes in a rotating pressure vessel oxidation test, versus 41 minutes for the conventional PAO.

"Esters are a class that show significant promise," he continued. The low-viscosity, low-volatility esters developed as a part of the project moved even further down the volatility and viscosity scale to KV 100 of 3.14 and volatility of 11.7 percent in one example. However, pour point was only minus 15 C.

"There are gives and takes with molecules. Esters will improve solubility but create some other issues," Toohey observed, while emphasizing the need to understand an application to get the right fit.

As electric vehicles make gains in the market, Toohey sees significant opportunity for synthetics in applications such as reduction gearbox oil and thermal management fluids in electric motors, or axle fluids. There's a good possibility that they will be based on API Group IV and V molecules, he projected. ▮

Balancing CCS and Volatility in Base Stock Selection



Source: Neste

