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Viscosity matters

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Motor oil is a vital part of the internal combustion engine. Without oil, the engine will not run. This fact was understood already at the very beginning of over the century-long history of the automobile. Benz Patent Motor Car, which was outed to the public in 1886 and is usually regarded as the first production vehicle powered by a four-stroke internal combustion engine, used a rather alien drip-feed lubrication and a grease cup. However, the first true mass-produced automobile, the famous Ford Model T launched in 1908, already used a splash oiling system which is conceptually similar to what we see in modern cars, except that both the engine and the transmission of Model T shared the same oil.

Since the internal combustion engine is so critically dependent on oil, the need for standardization of motor oil was quickly realized. In fact, it was already in 1911 that the first classification of motor oils was adopted by the newly founded Society of Automotive Engineers (SAE). That first SAE classification – the so-called Specification No 26 – ranked motor oils based on specific gravity, flash and fire points. More viscous oils were “heavier” and had higher flash and fire points. Ever since - even nowadays - motor oils are still sometimes referred by weight, although oil viscosity began to be used as the basis for all future SAE specifications since 1923. The latest SAE J300 specification was adopted in 2015.

In fact, SAE J300 specifies four different types of viscosity: kinematic viscosity at 100oC (KV100), maximum permissible viscosity for cold cranking (CCS) and cold temperature pumpability, and high-temperature high-shear (HTHS) viscosity. Hence, one can firmly state that viscosity does matter!

Oil viscosity is one important quantifier of its fitness for purpose. In a firing engine, all moving parts ride on an oil film. Any incidence of unlubricated metal-metal contact may have catastrophic consequences and has to be avoided at any cost. For oil to do its job, it has to be timely delivered to the critical lubrication points. Oil flow through the oil channels – or galleries – in the engine is largely determined by its kinematic viscosity, that’s why KV100 is the first thing to look at when choosing the right oil. However, you should also be able to start your car in winter. As temperature drops, motor oil is getting more and more viscous, eventually turning into a soap-like solid substance. If this happens, you won't be able to crank your engine. That's why SAE J300 also list CCS and low-temperature pumpability. Finally, under high engine load, the oil temperature in bearings may increase to 150-200oC, and at the same time, very high shear forces tend to shred oil molecules into smaller fragments. As a result, oil viscosity drops. To guarantee adequate lubrication of bearings under such harsh conditions, SAE J300 defines the minimum HTHS viscosity for each viscosity grade.

If viscosity is too high, it isn't good: oil may fail to arrive in time and drive away heat quickly enough. However, using thicker than recommended oil isn't fatal: after all, this happens each time you start a cool engine. If viscosity is too low, it's far more dangerous: oil will flow away too easily and won't build sufficient pressure. This will cause rapid wear of bearings, piston/ring scuffing, seizure, and other critical problems. You will also almost certainly see increased oil consumption.

Many vital subsystems in the engine are critically dependent on oil pressure, for instance, hydraulic timing chain tensioners and variable valve timing (VVT) systems. If the oil pressure is low, these systems may start to malfunction: the chain tensioners will fail to build up enough pressure to eliminate chain slack, and the cam phasers will fail to advance the cam normally. This will offset the engine timing, which in its turn will affect engine performance, fuel economy and emissions, and will eventually turn on the "Check Engine" light.

Conventional base oils used for manufacturing crankcase lubricants are obtained by distillation and purification of crude mineral oil. Light distillate fractions are used to produce different types of fuel, constituting the main source of profit for the refineries, while heavy bottom fractions – often referred to as the bottom of the barrel – are used to manufacture lubricants and some other products including asphalt and wax. Historically, lubricant manufacture has been regarded as the cheap end of the oil refining process, attempting to transform a by-product of fuel manufacture into a value-added product.

Historically, the most important base oils used to formulate crankcase lubricants have been those of 100 to 600 SUS viscosity (20 to 130 cSt at 100oF), as well as the most viscous class of mineral base oils with a typical viscosity range of 1000 to 5000 SUS – the so-called bright stocks. However, over the last few decades, there has been a steady decline in the production volume and use of conventional mineral base oils (constituting API Group I) as the old solvent refining process is losing ground to a more modern, economical and environmentally clean refining process known as hydrorefining. The latter is used to manufacture API Group II and III base oils. One major downside of hydrorefining is that it cannot produce high viscosity products – nothing higher than 200 SUS. Hence, modern lubricants depend heavily on polymeric thickeners, used to replace bright stocks. Such polymeric thickeners have also another useful function – they increase the viscosity index (VI) of the oil, hence their common name – viscosity index improvers (VII).

Today, nearly all automotive motor oils are “multigrade,”since they provide adequate performance both in cold and hot climates. Multigrade oils are described by two figures, like this: SAE 10W-40. The first figure – 10 followed by “W” – refers to the low-temperature performance. Basically, it says that, in winter time, this oil behaves like a legacy SAE 10W winter grade: it should let you to crank your engine at -25oC and it won’t lose its ability to flow at temperatures down to -30oC. The second figure, 40, says that in summer, the same oil behaves like a legacy SAE 40 monograde: it has KV100 in the range of 12.5 to 16.3 cSt and HTHS viscosity minimum 3.5 of cP.

The greater the difference between the second and the first figures, the broader is the multigrade. The broadest multigrades of today, such as 0W-40, 5W-50 and 10W-60, feature a VI around 180, though it is possible to boost the VI even further, up to 200-220. A high VI is a welcome feature since a high VI oil shows less variation in viscosity with temperature. However, the actual spectrum of benefits depends on how this high VI was attained, as there are many pitfalls.

Let's consider an example of how polymeric VI boosters are used in practice. Assume, you have got 150N API Group II base oil with KV40 = 28 cSt and KV100 = 5.2 cSt (VI = 109). If you add 15% olefin copolymer (OCP) type of VI improver, such as Paratone 8006, you will end up with a polymer-thickened product with KV40 = 83 cSt and KV100 = 12 cSt (VI = 140). So, the VI has increased from 109 to 140. How can you decipher that this a polymer-oil blend and not a polymer-free 600N oil? The first thing to check is the flash point: polymer-thickened oils will have nearly the same flash point as the original base oil (150N, FP 220oC), which is much lower than the flash point of an equiviscous polymer-free base oil (600N, FP 270oC). The second useful check is the evaporative loss: polymer-thickened oils will exhibit nearly the same evaporative loss as the original base oil (150N, 15 wt.% Noack) which is much higher than the evaporative loss of an equiviscous polymer-free base oil (600N, 2 wt.% Noack).

The conclusion from this example is that polymer thickening and VI boosting should be used with care: though it helps you easily tune product viscometrics, some other vital properties may be overlooked. Excessive use of polymers may compromise shear stability – that's why SAE J300 defines the HTHS range for each viscosity grade, and why commercial VII additives are characterized by shear stability index (SSI). Other common problems are oxidative thickening and gelation in used oils.

There are substantial differences between different classes of VI improvers in terms of efficiency, shear stability, solubility, and of course, price. For instance, olefin-copolymer (OCP) VI improvers have nowadays become a "plain-vanilla" type of VI improvement technology, with a primary focus on value-engineered products, while styrenic and polyalkyl methacrylate (PAMA) VI improvers are increasingly used in top-tier products. This fact proves that the viscosity data referred to in the SAE J300 still do not paint the whole picture: you can match all four viscosity readings and still see differences in product performance. This is because conventional viscometry says nothing about, for instance, chemical stability of VII molecules, their possible interactions with other ingredients of lubricant formulations, or non-Newtonian rheological behavior of polymer-containing lubricant films. Even though the theoretical understanding of the VII action of various polymer classes and their effect on the lubricant tribology has advanced enormously, experience remains the best teacher in this largely empirical field.

Nowadays, thinner oils are actively promoted to improve fuel economy. Keep in mind, however, that in a running engine, crankcase lubricant is always to some extent “diluted” by fuel. The degree of fuel dilution depends on the engine type and driving conditions. Stop-and-go city traffic is one adverse scenario most people are not even aware of. In the worst cases, oil may contain as much as 10-15% of fuel. Another adverse scenario is high-speed driving, such as stock car racing, where rich air-fuel mixtures are deliberately used to cool engines. As a result of fuel dilution, motor oil easily goes one grade down: you start with 5W-30 oil and soon find it diluted to a 5W-20 level. Oil also becomes thinner when the engine is heavily loaded and runs hot, for instance, while towing a trailer. Some manufacturers tend to incorporate a greater safely margin in their formulations, setting the v100 target just in the middle of the respective viscosity grade and HTHS well above the permissible minimum value. Others try to push their products to the edge to max up fuel economy benefits. For instance, a 5W-40 with KV100 = 14.5 cSt will withstand 4-5% fuel dilution without falling off grade. A similar 5W-40 “enhanced fuel-economy” product with KV100 = 13.0 cSt will fall off grade already at 2% fuel dilution. Hence, in general, you are always safe to go one grade up of what you engine manufacturer recommends, but never use thinner oils than recommended.

With the exception of few flagship products, mainstream lubricants are always engineered for value. But we at BIZOL are obsessed with quality – we want to bring our customers the best we can. To understand the difference, look at the diagram below, or – even better – try BIZOL.

Value-engineered oil	Performance-engineered oil
Cheapest locally available base oil + Cheapest OCP type VI improver with mediocre shear stability + Value DI package bringing minimum performance requirements + Tweaks with undeclared “component extenders” to further cut costs ***This is “just oil”.***	Purpose-engineered blends of extra high vis index full synthetic API Group III, IV and V base oil alternative carbon number poly alpha olef (ACN PAO), alkylated naphthalenes for impr solubility, stability, and seal compatibility, as w esters and OSP for improved lubricity an high-temperature performance. + State-of-the-art non-OCP type contact V improvers and surface-gel-forming COMB LubriBoost additives + Customized purpose-fit high performanc DI package to max up product performan and guarantee compliance with the broadest p range of individual OEM specifications ***This is BIZOL G+.***