Base Stocks Help Carry the Load

Base oils often are not given enough credit for the inherent contribution they can make to a lubricant's load-carrying performance even in the absence of antiwear or extreme pressure additives. In the early days of motoring, most crankcase lubes were little more than straight base stocks.

Admittedly, engines were much less stressed than they are today. Nonetheless, these exceedingly simple lubricants managed to lubricate an engine, even if the oil drain interval was very short. Even today, some breaking in oils for piston aero engines are just selected straight run base stocks.

Some early sulfur/phosphorus additives were actually developed as antioxidants rather than as strictly antiwear or extreme pressure additives to extend the life of the base stock. Whereas their modern evolutions, which sometimes are still similar chemically, are primarily antiwear additives and only secondarily antioxidants.

Base stocks are more than just coolants or carriers for the additive package.

In both passenger car and heavy duty API sequences, the relative importance of base stock viscosity is manifest by the appearance of base oil blend viscosity in interchange guidelines. For example, the Sequence IVA and Mack T-12 engine tests evaluate wear, but both require lower limiting levels of base oil viscosity to allow certain interchanges. This can only mean that base oils have load-carrying capability that is related to viscosity grade and cannot be confidently equaled by contributions from viscosity modifiers or other thickening components such as dispersants.

Of course, thicker does not help when it comes to fuel economy and energy efficiency. In simple hydrodynamic lubrication, the load floats on a large, effectively flat plane between two conformal surfaces, with the surfaces held apart by the lubricant's base oil.

Here, thicker does indeed lead to enhanced protection. Straight base oils in such systems act as Newtonian fluids, which means their viscosity is constant irrespective of machine speed.

A simple modification to the base oil, such as the addition of a viscosity modifier, can make the formulation

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non-Newtonian. Under such circumstances, a small but beneficial effect of the now non-Newtonian fluid behavior is enhanced load-carrying capability through normal stress effects.

These effects are expansion forces acting at right angles to the general direction of lubricant shear in the bearing. The forces slightly enhance load-carrying capability by pushing surfaces apart and could allow for the use of a slightly thinner base stock to achieve the same degree of protection.

The same physical effect can be seen when a non-Newtonian polymer solution creeps up a stirrer against gravity. Such a load-carrying capability is not the primary purpose of a viscosity modifier, which is added to improve low-temperature cranking of an engine. However, we're not going to look a gift horse in the mouth.

But what happens in more extreme situations, where loads and pressures are much higher and no viscosity modifier is present? This would correspond to using a monograde oil to lubricate a point or line contact.

An extreme pressure additive could be added, but an often overlooked attribute of all base oils is that in extreme pressure lubrication, they can carry a load and keep surfaces apart by temporarily crystallizing to create a quasi-solid barrier between two surfaces.

Crystallization is an extremely transient phenomenon such as would be seen in line or point contacts of non-conformal surfaces, for example, during the short time when a cam lobe tip runs against its follower. This effect occurs during elastohydrodynamic lubrication and can be characterized by the pressure-viscosity coefficient or frictional coefficient of the base stock.

The chemical character of the base stock determines the magnitude of this effect. It does contribute to a transient higher friction in the base stock as a result of the temporary crystallization, as well as a higher load-carrying capability. However, the frictional effect is so small because of the timescales involved that, in the overall scheme of frictional losses that occur in engines, it is of no real concern. But the enhanced load-carrying capability is more than welcome.

Crystallization will occur in even the thinnest base stocks and is one reason why very thin base stocks can lubricate effectively. In fact, base stocks are far more limited by volatility constraints than by viscous constraints in terms of how thin they can be. As proof, refer to the recent SAE -12 and SAE-8 grade announcements.

For highly hydrogen saturated base stocks, which include all modern API Group II, III and IV base stocks, the differentiation of this effect seems to be determined by the paraffinic-to-naphthenic ratio. The most highly paraffinic stocks, like PAO, exhibit the lowest frictional increases due to transient crystallization. More naphthenic oil, like Group II, show the greatest frictional increase but the best increased load-carrying capability. The effect is also present in Group I stocks, but the drivers are less clear because aromatics, paraffinics and naphthenics are all quite variable depending on grade, crude source and processing scheme.

So, hopefully, it is clearer now how base stocks are more than just coolants or carriers for the additive package. □

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