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1979 Porsche 935, owned by Bruce Canepa, using 20W50 Non-Petroleum Racing Motor Oil to beneficial effect (Photo courtesy: Evolve Lubricants)

Power plants

Plant-based oils are not only good for the planet, they promise to offer enhanced engine performance. **Wayne Ward** reports

There has been a renewed focus in the past couple of years on the sustainability of many aspects of life, and motorsport is playing an increasing part in this. There is a rapid move to adopt fuels for combustion engines that emit less CO_2. There are two approaches to this – producing fuels that contain no carbon (ammonia or hydrogen are examples), or producing fuels that contain carbon which has been taken from the atmosphere, either by direct capture of CO_2 from air or by using organic matter which has naturally captured CO_2.

A much less prominent area of research is into renewable and sustainable lubricants. This not only gives the right 'message', but potentially offers technical advantages over traditional petroleum oils. This is by taking a different approach: not simply reproducing what we already manufacture from refined crude oil but assessing what might be the ideal properties for an engine lubricant in the modern era, and synthesising an appropriate product.

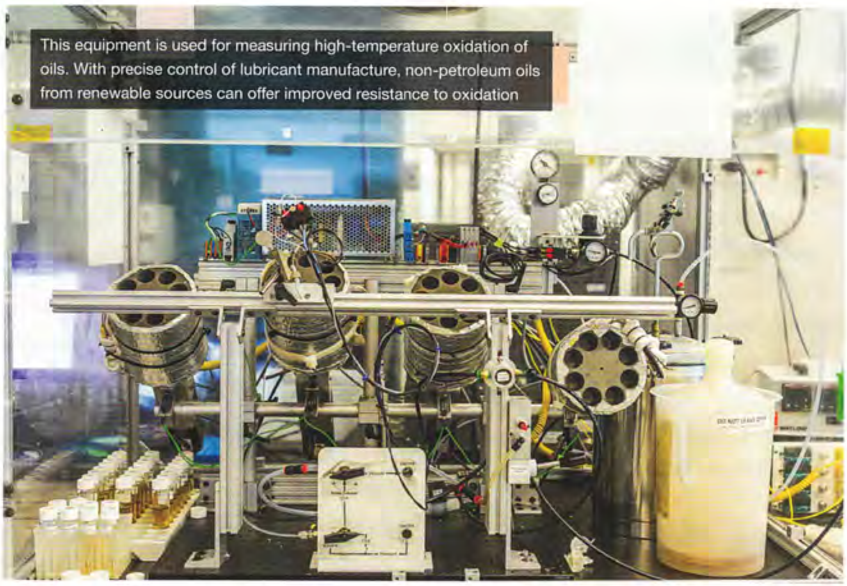
Modern lubricant requirements

In any engine or machine, we expect a lubricant to keep components in sliding contact apart, or to at least minimise the metal-to-metal contact in terms of time and area of contact. That is only part of the story though; we also have expectations that the oil – for our lubricants are almost always oils – will be able to operate over a wide temperature range for extended periods of time with limited degradation.

Almost as important as the requirement to lubricate, we also treat oil as a coolant. When we talk about race engines being water-cooled, we are simply referring to the fact that a water-cooling circuit is used. Very often a significant proportion of the heat transfer from the bottom-end components in an engine is through lubricants that commonly pass through an oil-to-air heat exchanger.

In 20-plus years of working on race engine design, I have yet to work on a bespoke engine that does not use sprayed oil to remove heat from pistons. I have seen simple jets fashioned from tube and repurposed carburettor jets through to the most complex machined components.

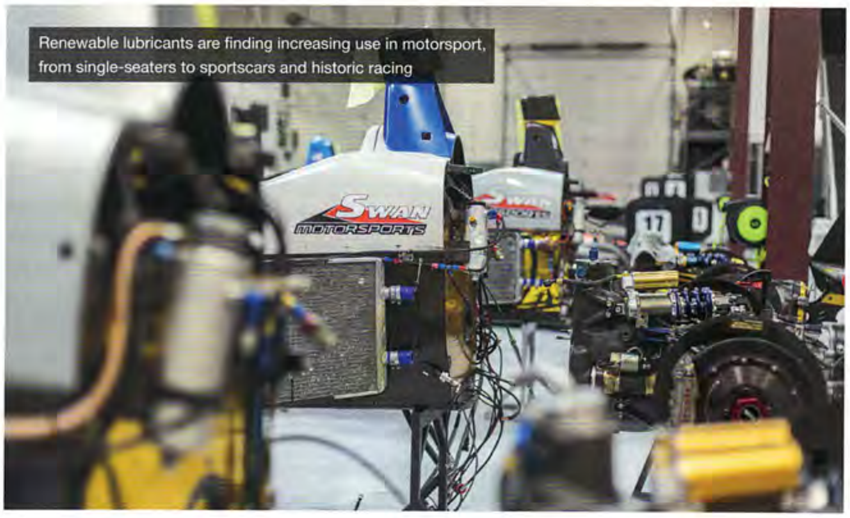
The same oil that we expect to form a protective, low-friction, sub-micron film of oil between cam and follower, or between valve and guide, is also required to behave well as a coolant when sprayed at the underside of a very hot piston. It is only through the performance and durability of lubricants, acting in their capacity as a coolant, that we have been able to advance so far in the development of engines for performance, efficiency and durability.


This equipment is used for measuring high-temperature oxidation of oils. With precise control of lubricant manufacture, non-petroleum oils from renewable sources can offer improved resistance to oxidation

Engine lubricants

Engine oils are a mixture of base oils and a specific package of additives for a given application. Our requirements as producers of race engines are similar to those of the automotive companies, and what benefits one group of engineers usually benefits the other.

Reduction in viscosity reduces friction in sliding contacts and the amount of work required to pump oil around the system. The 10W40 and 20W50 oils of old have given way to 5W30 in many applications, and are migrating to 0W20, 0W16 or 0W8 even as I write this. Driven by fuel economy legislation in recent times, much of the gains are a direct result of the lower frictional losses from lubricants.



Renewable lubricants are finding increasing use in motorsport, from single-seaters to sportscars and historic racing

Lubricant volatility is the tendency of an oil to evaporate as the lighter 'ends' of the hydrocarbon mixture evaporate off. This not only reduces the quantity of oil in the system, but naturally leaves behind the more viscous fractions of the oil, resulting in a tendency for friction to gradually increase. Because of this, low-viscosity engine oils with low volatility have always been difficult to achieve.

Renewable hydrocarbons and molecular design

The present route to producing renewable lubricants is to use non-petroleum natural oils of a type with a high polyunsaturated fatty acid content. These are derived from plant sources such as soy, palm, rapeseed, sunflower and peanut oils. By processing such raw materials, it has been shown that a lubricant can be produced which is both renewable and which has some very attractive properties for passenger car and race engines.

Traditional base oils are very often composed of a wide range of molecules, defined by the hydrocarbon molecule length and the position of side branches on the 'spine' of the carbon chain. Although these traditional base oils have served us well in the past, that is not to say they cannot be improved upon.

The claimed control over, and reduction of, branching from the spine of the lubricant molecules for renewables have positive effects on the thermal conductivity and specific heat capacity of the fluid, both of which are important in terms of the behaviour of the fluid as a coolant. When we think of the performance of a fluid as a coolant, we consider specific heat capacity, but thermal conductivity is the mechanism by which the rate of temperature increase of the fluid volume under consideration occurs.

Not all of a fluid volume is in contact with the boundary across which heat is being transferred. The primary mode of heat transfer of oils is along the carbon spine of the molecule.

Thermal conductivity in hydrocarbon molecules is enhanced by increasing chain length. Reduced side branching from the carbon spine, as might be observed in a renewable oil, also has a positive effect on thermal conductivity. For a similar molecular weight, a traditional base oil has a greater degree of side branching and lower thermal conductivity.

Cooling oils for EVs

The advantages of having precise control over the composition of fluids produced from non-petroleum raw materials are not only limited to engine lubricant characteristics – hydrocarbon oils can be used as dielectric (electrically non-conductive) fluids for cooling electric motors in hybrid systems and EVs. ▸

At least one hybrid system that has had success in top-level motorsport used engine oil as a motor coolant, with a shared engine lubrication and motor cooling system using the same fluid. Specific dielectric coolants are available of course, but the ability to lubricate effectively in arduous conditions should not be underestimated, particularly in motorsport.

Many dielectric fluids can only be used for cooling, as they are not effective lubricants. If it is possible to use a fluid that does double duty as a lubricant and dielectric coolant, it becomes possible to use the coolant to lubricate bearings and so on. In an electric machine, that can mean significantly enhanced reliability if replacing greased-for-life sealed bearings, or being able to combine lubrication and cooling circuits.

Factors defining useful end of life

Several factors can define the end of a lubricant's life. One can be acid formation, so any lubricant that resists this tendency can lead to longer life without degradation and longer drain intervals.

The control over the raw material, and in particular the lack of petroleum, is important in this respect. Sulphur in petroleum oils oxidises to sulphur dioxide and trioxides, both of which are soluble in water, forming sulphurous and sulphuric acids respectively. Oil produced without sulphur cannot later produce these acids, which can cause corrosion in an engine.

Another important factor that can be considered to lead to end of life in a lubricant is high-temperature oxidation, which can cause piston ring deposits.

Volatility is an undesirable trait in any lubricant, but especially in one used at elevated temperatures. The desirability of increased engine efficiency and lower emissions is supported by legislation; this provides the incentive to use lower-viscosity oils, which are proven to reduce frictional losses.

However, less viscous petroleum base oils are also more volatile: there is a correlation between hydrocarbon chain length or molecular weight and the temperature at which the oils evaporate. Lower-viscosity oils are prone to high volatility because they contain a greater proportion of low-viscosity, lighter hydrocarbons.

Many historic racecars are still raced hard, and their irreplaceable engines require a high degree of protection by lubricants. Longer lubricant life, low tendency to form acids and oxidation resistance shown by some renewable lubricants are important factors to consider

CASE STUDY: EVOLVE LUBRICANTS

Rick Lee, CEO of Evolve Lubricants, reports that his company has "not simply reproduced what we already manufacture from refined crude oil". Instead, he says, it has looked at what might be the ideal properties for an engine lubricant in the modern era, and has synthesised a renewable/sustainable product accordingly.

Lee says that Evolve's (undisclosed) production process gives precise control of molecule length and the position of side branches, as well as control over the location of any double carbon-carbon bonds (which are beyond the scope of this article).

He adds that such precise processing of plant-based oils gives a more predictable composition, resulting in lower viscosity and reduced volatility. Low volatility helps maintain a more consistent performance through the life of the oil. Its lifetime, as measured by the drain interval in an engine, is also impressive, Lee tells us.

He adds that the renewable oil produced by Evolve has a high viscosity index. That means there is a relatively small change in viscosity with temperature, and film thicknesses are maintained over a wide range of operating conditions.

He also talks of impressive ongoing lubricant performance, with more consistent film thickness and oil viscosity over its lifetime. Moreover, he reports that in testing, the renewable oil from Evolve has shown improved oxidation behaviour compared to a number of base stocks.

Testing a high-performance Porsche road engine using Evolve's oil exhibited a 2.7% performance increase compared to one used with a 'standard' oil. Of course, such gains are not promised in every engine, but this is impressive, especially given that the main aim of the test was to get Porsche's approval for the oil to be used in this application for 30,000 km (18,640 miles)/2-year service intervals (1).

Volatility in oils

The Noack volatility test is standardised as ASTM D5800, and measures the weight fraction lost under controlled test conditions when oil is heated to 250 C with a specific constant airflow over a constant surface area. High losses of weight indicate oils with a high fraction of lighter and more volatile molecules. The part that has not evaporated is therefore composed of less volatile, heavier molecules, which are more viscous. For a typical modern top-tier engine oil this Noack value will be about 11-13%.

In the case of an operating engine, an oil that loses weight over time and leaves an increasingly viscous fluid in the engine contributes to increased pumping work to circulate that fluid, and greater shear losses in the bearings. We measure this on the dyno as a loss of performance for a given flow rate of fuel, which equates to a loss in efficiency.

In a passenger car, that means greater emissions over a drive cycle or in day-to-day driving. References 2 and 3 both find correlations between oil volatility and viscosity and oil consumption. It stands to reason that the lightest fractions are most quickly evaporated and lost from the engine, so the degradation happens quickly and is permanent.

For a given grade of oil, there is a wide range of volatilities depending on the quality and composition of the base oil, with better quality oils having less variation over their lifetime.

A summary of this testing was presented by Lee at the 2022 Baden Baden Engine Congress. It was conducted on a Porsche MA203, a 2981 cc six-cylinder horizontally opposed, direct injected turbocharged unit using a POSK E25 reference quality fuel. The test was performed on behalf of Porsche by engine test authority APL (Automobil-Pruftechnik Landau) at its facilities in Landau, Germany.

The test procedure called for the engine oil to be pre-aged before testing and subjected to a piston ring wear test on a dynamometer. After that it was subjected to simulated high-performance and race track conditions to generate high-temperature ring groove conditions using worst-case fuel scenarios and including hybrid drive periods with significant oil dilution. No oil was to be added throughout the 100 hour test.

The Evolve oil tested was an SAE 0W40 using the EcoSyn formulation. It is described as having a non-petroleum or renewable base stock together with a combination of additives to address the high-performance requirements. The lubricant is formulated such that the cold cranking viscosity (CCS)/Noack volatility characteristic produces lower viscosity engine oils with improved wear, as well as increased engine power without compromising low speed pre-ignition (LSPI), which can be particularly damaging in direct injected engines.

The oil is also designed to produce a more consistent film thickness under a wider range of operating conditions producing a higher performance base oil for a given viscosity grade. The lower Noack volatility results in a higher flash point than an equivalent grade of PAO oil, and consequently improved heat transfer from higher thermal conductivity and heat capacity for even lower viscosities.

An alternative approach to sustainable lubricants

'Re-refining' is a term that, as the name suggests, is a process of taking previously used oil and extracting the useful parts of it for reuse while discarding the waste products – oxidised oil, water, acids, 'spent' additives, solid contaminants and so on.

There is of course a huge amount of waste oil drained from passenger cars, goods vehicles, industrial engines and machinery each year. These processes can produce a significant quantity of new base oil from old oil, with the remainder being diesel and bitumen.

However, the base stocks thus produced are at the lower end of the spectrum, being equivalent to Groups I, II and III. They are possibly not going to be able to reproduce the properties of a typical very high quality racing oil and are unlikely to confer the same benefits as the approach of synthesising tailored molecules.

Re-refining can only selectively take what remains after use. However, as a way to reduce the consumption of crude oil, it is a very valid process for producing lower-grade lubricants. The worldwide capacity to re-refine oil is already high and is likely to increase, but it remains to be seen whether re-refining very high quality used oil made from Group IV base stocks can viably produce 'new' racing lubricants.

Test results

Piston ring groove widening severe oxidation and wear test

Aged Oil under High Performance racetrack conditions, worst case fuel E25 with a boiling point up to 230°C, high piston groove temperatures up to 280°C.
Typical failures include broken first ring, excessive aluminium wear and groove widening.
Result: No issues with Evolve renewable motor oil

Oil dilution versus viscosity change test

Causes: High torque at rated power with longer injection duration, cold cycles, short range and hybrid vehicles
Effects: Oil viscosity drop and increased wear, oil oxidation/ blowby create piston deposits, oil additive dilution or degradation.
Result: Low viscosity change at high dilution rate.

Piston groove deposit tests

Causes: Oil oxidation, soot wear or damage to piston rings or ring grooves, fuel dilution.
Effects: Oil degradation and wear to the piston rings.
Results: Evolve oil below limit on all cylinders.

Other deposits and wear testing

Cylinder liner wear – no harm
Filter blocking hydraulic valves – no harm
Turbocharger variable turbine sticking – no harm
Turbocharger sealing ring sticking – no harm
Tappet surface DLC – no harm
Tappet wear outlet small lift DLC – no harm
Tappet wear inlet big lift DLC – no harm
Cam wear outlet DLC – no harm
Cam wear inlet small lift DLC – no harm
Cam wear inlet big lift DLC – no harm
Piston ring sticking – no harm

Horsepower and torque maximum test

The published maximum horsepower for the Porsche MA203 engine is 443 hp @ 6500 rpm.
Result: the maximum full load power output is 455 hp @ 7000 rpm, a positive variance of 12 metric horsepower.
Based on these test results it is reasonable to expect that the Evolve EcoSyn 0W40 engine oil satisfied the test requirements of the Porsche engine oil validation system. We look forward to further evidence of the potential of renewable/sustainable lubricants from this company and from others developing renewable/sustainable lubricants.

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