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Why are there so many oils?

by John S Evans, B. Sc.

There are thousands of oils to choose from.

There is a common misconception that ‘oil is just oil’ and this simply is not the case. Consider the many types of machines that need lubrication and that these machines can operate in many different environments doing many different jobs. There are also dozens of different oil suppliers who can supply thousands of different oils based on viscosity and additive chemistry which dictate their function. This is why there is such a variety of oils in the market place. This technical bulletin will look at the different classes of oils (liquid lubricants) and why they are different.

The basic functions of an oil are to:

- Reduce friction
- Reduce wear
- Dissipate heat
- Remove wear particles
- Remove external contaminants
- Act as a structural material
- Seal
- Protect surfaces

These basic functions can be modified by the addition of additives. The

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base oil is responsible for the typical properties of the lubricant, while the additives determine the actual performance by influencing:

- Anticorrosion properties
- Emergency lubrication properties
- Emulsibility
- Oxidation stability
- Stick/slip behaviour
- Viscosity-temperature behaviour
- Wear protection
- Wetting behaviour

Basically, oils can be placed into one of three very broad categories - engine oils, hydraulic oils and gear oils. The ISLS (International Standard Lubrication System - refer Wearcheck Technical Bulletin #8, *How to read a can of* *oil - Part 2)* breaks this down further into the following classes of lubricant:

- Hydraulic oil
- Hydraulic oil suitable for wide ranges of operating temperature
- Fire retardant hydraulic fluids
- Heat transfer oils
- Electrically insulating oils
- Air or process gas compressor oils
- Refrigeration compressor oils
- Turbine oils
- Engine oils suitable for petrol engines
- Engine oils suitable for diesel engines
- A wide variety of automatic transmission oils
- Automotive gear oils
- Industrial gear oils
- Steam cylinder oils
- General industrial circulating oils

The functioning of each of these classes of lubricant is determined by the additive package that the oil company blends into the oil, and each class can have subtle sub-sections to cater for highly specific applications and environments. The base oils can be either mineral or synthetic and they can come in a wide variety of viscosity grades to suit every possible application. Industrial oils can generally be obtained in one of 18 different viscosities, automotive engine oils have eight basic viscosity grades plus a variety of multi-grade products, and automotive gear oils come in six different flavours, also with a variety of multi-graded products.

It would be impossible to discuss every oil on the market, so the ISLS categories listed above will be considered along with the attributes these oils must have in order to do their jobs. Even within a highly specified product there can be differences, and price is one of them. No reputable oil company produces 'bad' oil. However, all oil companies produce 'cheap' oil and all companies produce 'expensive' oil. You get what you pay for.

You get what you pay for.

A typical bottom of the range mineral engine oil might cost as little as R10 per litre, a top quality mineral engine oil might be double that and a top of the range synthetic product could cost over R100 per litre. However, they all do the same basic job.

That is why there is no answer to the question: 'What is the best oil for my car?' It depends what you want to do with it. Michael Schumacher will definitely be using a different oil from what the man in the street puts in his ten year old Nissan Sentra. This fact has recently been recognised by a number of oil companies who now market a range of forecourt products to cover the likes of taxis, older vehicles, diesel bakkies and high performance cars.

HYDRAULIC OILS

The primary function of a hydraulic fluid is to transmit power but, in terms of lubrication, the following attributes are desirable.

Correct viscosity

The viscosity of the lubricant is extremely important, the pump design usually being the determining factor. Too low a viscosity leads to internal leakage or 'pump slip' with a consequent loss of efficiency and lack of adequate lubrication. Too high a viscosity can lead to cavitation, overheating and power loss.

Viscosity stability

The oil should retain its original viscosity during use. An increase in viscosity due to oxidation, or a reduction in viscosity due to shear, would result in a decrease in the efficiency of lubrication and pump performance.

High viscosity index

The viscosity index is a measure of an oil's resistance to 'thinning out' at elevated temperatures. Due to the fact that the lubricant will have to function over a wide range of temperatures, it is desirable that it has a relatively high viscosity index. This will prevent slug-

Seal compatibility is of great importance.

gish operation at low temperatures and jerky operation as the temperature increases and the viscosity decreases.

Seal compatibility

The lubricant should not cause deterioration of the oil seals which could result in oil leaks and subsequent wear and power loss. At normal temperatures most mineral oils are compatible with most seal materials. However, at elevated temperatures, chemical reactions may take place between the oil and the seal. Careful selection of the lubricant base, additive chemistry and seal material can prevent this happening.

Foam resistance

The oil should resist the formation of foam due to air entrainment during operation but if foaming does occur, then it should collapse rapidly.

Wear resistance and load carrying capacity

The lubricant must not only prevent metal to metal contact at normal loads and rubbing speeds, but also under extreme conditions of shock loading. The oil should also possess the necessary characteristics to prevent wear of close tolerance components found in hydraulic pumps and valves.

Non-corrosiveness

It is important that the lubricant does not chemically react with metal hydraulic components.

Frictional characteristics

For the lubrication of journal and anti-friction bearings, it is desirable that the coefficient of friction between the lubricant and the bearing material be as low as possible so that drag on the bearing can be minimised.

FIRE RESISTANT HYDRAULIC FLUIDS

Fire resistant or retardant hydraulic fluids are to be found in environments where an oil leak may pose a risk to equipment and personnel through fire. The hydraulic systems of earthmoving equipment carrying slag pots or systems that open and close furnace doors in foundries are examples. All the desirable characteristics of a normal hydraulic oil are required, as well as:

High flash point

An oil's flash point is the temperature at which the oil will momentarily support combustion if an ignition source is present. Oils with high flash points are less likely to pose a fire risk than oils with low flash points.

Good emulsibility

A characteristic of nearly all oils is good *de*mulsibility as water is a highly destructive contaminant. However, with fire retardant oils, one of the ways of achieving the desired properties is to form an emulsion of oil with water or glycol. This oil must behave as hydraulic oil first and foremost, so the emulsion must be stable.

Low environmental impact

Emulsified fire retardant oils are effective at doing their job. However, the concentration of water or glycol present needs to be monitored and maintained closely. Synthetic fire retardant lubricants are an alternative but can be toxic or form toxic compounds should they come in contact with very hot surfaces. These oils need to be formulated to minimise environmental impact should a leak occur. With these synthetic oils, seal compatibility is of great importance.

HEAT TRANSFER OILS

The function of these oils is not to lubricate but to act as a medium for transferring heat from one place to another.

Low volatility

In the refining process, the high volatility fractions need to be removed. As the oil will be permanently subjected to high operating temperatures, highly volatile fractions could evaporate, changing the characteristics of the oil.

Transformer oil is used as an insulator.

Good oxidation resistance

Temperature has a pronounced effect on the oxidation of the base oil - for every ten degree increase in operating temperature the rate of oxidation doubles and hence the lifetime of the oil is halved. These oils need to resist oxidation effectively.

Low carbon and sludge forming tendency

Because of the high operating temperatures encountered, the oil must resist the tendency to carbonise or form sludge, as this severely degrades the oil's ability to transfer heat, and the presence of carbon could block coolers and heat exchangers.

High flash and fire points

For the same reason given earlier for fire retardant fluids, a high flash point is desirable.

Low viscosity

The lower the viscosity, the more easily the fluid can flow and the more efficient the heat transfer will be. Low viscosity oils tend to be highly volatile so these two properties need to be finely balanced.

INSULATING OILS

Insulating oils are used in transformers and switch gear to isolate electrical components. As with heat transfer oils, the primary function is not to lubricate.

High dielectric strength

A high dielectric strength means that the oil is a very poor conductor of electricity which is what the oil is supposed to be. The oil must be kept scrupulously clean and free from moisture, as any contaminant present will aid in the conduction of electricity and decrease the dielectric strength.

Low viscosity and fluidity at low temperatures

Formulating an insulating oil is a tricky business, as a number of the desirable properties are normally achieved with additive technology. Unfortunately, additives conduct electricity. Low viscosity and low pour point (the minimum temperature at which an oil will flow) are desirable for cooling and operation at low temperature, especially for transformers working outside in cold climates. This is achieved in the refining process to ensure the base stock has the desired properties without the need to resort to additives.

Good oxidation and carbon forming resistance

Because there is a possibility of arcing and sparking which produce transitory high temperatures, the oil must resist oxidation and carbon formation. Once again this is achieved by a very high level of refining so that additives do not need to be used.

Good heat transfer properties

For the same reasons that oxidation and carbon forming resistance are desirable, these oils must also be good conductors of heat.

Inhibited oils

Insulating oils are generally referred to as uninhibited oils as they do not contain any additives. However, in certain low voltage applications, additive technology is permissible. These are known as inhibited oils and may contain anti-oxidants.

AIR COMPRESSOR OILS

Generally, all the properties that are desirable for hydraulic oils are required for oils lubricating compressors that work with air or other process gases. Other particularly desirable properties are:

Good demulsibility

Due to the fact that gases, which may contain moisture, are being compressed, the possibility of water contamination is high. The oil needs to be able to separate from entrained water easily and rapidly.

Good oxidation and carbon formation resistance

Gas discharge temperatures in excess

of 150°C are possible so the oil must be able to resist oxidation at these elevated temperatures. Carbon formation in compressors represents a fire and explosion hazard.

Low gas solubility
If the gas being compressed becomes entrained or dissolved in the oil then the viscosity of the oil will decrease which will, in turn, degrade its load bearing capacity. The oil needs to be formulated so that the compressed gas has a low solubility in it.

Good sealing characteristics
Sealing is achieved in a number of ways and various seal technologies are employed in air compressors. Often it is the oil that completes the seal within the system.

Refrigeration compressor oils must flow at very low temperatures.

REFRIGERATION COMPRESSORS
Every characteristic that applies to hydraulic systems and air compressors also applies to refrigeration compressor lubrication. However, special considerations are needed to cope with the low temperature operation encountered with refrigeration systems.

Low pour point
Low temperatures are encountered in refrigeration systems and the oil must be able to flow at these low temperatures. A low pour point is essential and this can be achieved either in the refining of the base stock, the addition of additives or the use of a synthetic lubricant.

Good refrigerant solubility
The refrigerant must be compatible with the oil (soluble) and when it is carried by the oil it must also be able to readily give it up in the separator.

Low floc point
Related to the previous two items is the floc point of a refrigeration compressor oil. The floc point is the temperature at which a flocculent collection of wax crystals first appears when a solution of refrigerant in oil is cooled under prescribed conditions.

TURBINE OILS
Once again, all the attributes that are important to hydraulic oils are important to turbine oils, including the following:

Good demulsibility
Because there is a fairly good probability of steam condensate being present in steam turbine oils, they must readily separate from entrained water.

Good resistance to rust and corrosion
As water is likely to be a common contaminant, the oil must be fortified against rust and corrosion of metal components.

Resistance to thermal and oxidative breakdown
High speeds and temperatures are typical operating conditions for turbines so the oil must be able to resist thermal and oxidative degradation.

Long trouble-free life
Turbines tend to have very large sump capacities, sometimes running into the tens of thousands of litres. Ideally, the oil should give trouble-free performance for many years, which is why the previous three attributes are so important.

Good filterability
Because long, trouble-free lubricant life is a requirement, the oil needs to have good filterability to keep it clean and free from contaminants that could cause wear and degrade the oil.

This is the last of the oils that fall into the broad category of hydraulic lubricants. The next category that will be looked at is the gear oils.

INDUSTRIAL GEAR OILS
The general functions of gear oils are to:

- reduce wear on gears and adjacent moving parts
- reduce friction and consequently

Most gear oils contain extreme pressure (EP) additives to reduce wear.

increase power
- dissipate heat
- reduce noise, vibration and shock between gear teeth
- remove contaminants and act as structural material, i.e. the lubricant is a factor in determining the resistance of gears against breakage, pitting and welding.

Ability to overcome friction and resist wear

Wear and loss of power will result unless friction is minimised by interposing a film of oil between the sliding surfaces. This may be a full fluid film and hydrodynamic lubrication will therefore exist. Often in gear lubrication, opposing surface asperities touch, and boundary lubrication is the norm. In this situation, where metal to metal contact results, there are high frictional losses and wear takes place. Under these conditions a gear oil containing extreme pressure additives is required to prevent excessive wear occurring. These additives react with the high spots in the metal under the prevailing high pressures and temperatures and form anti-weld coatings.

Good film strength

The oil must have sufficient film strength to prevent metal to metal contact otherwise scuffing and rapid wear will take place.

Good power of adhesion

While both film strength and adhesion are related to viscosity (the more viscous oils are stronger and more adhesive), the quality and composition of the lubricant is of even greater importance. Some gear oils have greater 'wetting' powers than others, and some have an affinity for metal surfaces and the ability to adhere strongly (oily lubrication under boundary conditions). Gear oils are given this desirable property by compounding them with small proportions of fatty acids or additives of a polar nature.

Ability to resist corrosion

When gear systems get hot, the oil expands. When the system cools down, air (containing moisture) is drawn into the gear casing through the breather, i.e. the system breathes. The oil must be able to counteract the detrimental action of corrosion that the water will cause. At high temperatures, as the oil is churned into mist by the rotating gears, it is in the ideal state for intimate mixing with air in the gear case, which further accelerates the corrosion (oxidation) process.

Ability to dissipate heat

One of the major requirements of a gear oil is that it must act as a coolant. The combination of high pressure and sliding teeth can be so intense that very high temperatures can be reached. To counteract this, cooling is effected by ensuring copious quantities of oil are available. In some cases the gear teeth are sprayed with jets of oil.

Correct viscosity

Low viscosity oils cool best but do not damp noise and vibration effectively. A high viscosity oil has increased load bearing capacity, but too high a viscosity will result in the oil flowing sluggishly. The range of operating temperatures for gear applications is not as high as is the case with engines and hydraulic systems but the correct viscosity oil with a moderately high viscosity index must be selected.

Correct additive chemistry

The most important additives are the extreme pressure (EP) compounds. These additives are mainly organic compounds containing phosphorus and sulphur which react with the gear tooth surface at high temperatures. They form metallic sulphides and phosphides which are more readily fusible than the metals and prevent tearing of metal particles.

AUTOMOTIVE GEAR OILS

Ability to withstand shock loading and extreme pressures

All the attributes desirable in an industrial gear oil are required in automotive gear oils. Automotive gear systems tend to be subjected to more and heavier shock loads than industrial drivetrains and experience higher sliding speeds, particularly in highly offset hypoid systems. By nature, industrial gear systems are fixed. Their environment does not change and operation is generally constant. By contrast, automotive systems have continually changing environments and operating conditions which put them under more severe conditions than industrial systems.

STEAM CYLINDER OILS

Steam cylinder oils need to reduce wear and friction, have good film strength and adhesive properties, protect against corrosion and cool. In particular, they need to have:

A high viscosity

Steam cylinder oils tend to be straight mineral oils because a number of the additives used in oils would react with the super heated steam that these oils will come in contact with. These oils are said to be un-compounded. In order to have good adhesive properties to allow the oil to stick to the cylinder walls, high viscosity oils are used.

Have excellent demulsibility

Because the oil continually works in a wet environment and is generally carried to the cylinder walls by the steam, it must be able to separate from water easily and rapidly, which is partially achieved by being un-compounded. Compounded steam cylinder oils do exist but the level of compounding is low and these lubricants are used in milder conditions.

GENERAL INDUSTRIAL CIRCULATING OILS

These oils are almost a 50:50 cross between general hydraulic and gear oils and usually require the base oil properties of a gear oil and the additive chemistry of a hydraulic oil. They come in a wide range of viscosity grades with an anti-wear additive package but no extreme pressure compounds. They are used under mild operating conditions.

AUTOMATIC TRANSMISSION OILS

Automatic transmission fluids (ATF’s) are exposed to high temperatures, pressures and sliding speeds. In addition, different manufacturers require different frictional characteristics and use different friction materials and rubber components with which the fluid must be compatible.

From the above it can be seen that there is no such thing as a universal automatic transmission fluid and the type of fluid recommended by the manufacturer should be the only fluid used in the transmission.

ATF’s can be broadly divided into two categories: friction-modified and non-friction-modified fluids. The two categories are similar in requirements for thermal and oxidation resistance, low temperature fluidity, seal compatibility, foam control, corrosion control, and anti-wear properties. They differ in frictional properties, reflecting needs caused by transmission design factors and shift-feel preferences.

Different ATF’s should not be mixed.

All fluids have similar frictional properties at high sliding speeds. However, as these speeds approach zero (clutch lock-up), some transmissions require a decrease in friction (more slippery) for a smooth, jerk-free shift. Others have fewer clutch plates and higher working pressures. These need an increase in friction (less slippery) at low sliding speeds to assist the clutch lock-up and prevent slippage under load.

There is no standard classification for these oils and it is important to check that the brand and type of ATF used is approved by the transmission manufacturer. It is also important that different ATF’s are not mixed.

Some transmissions call for an engine type oil. Once again it is important to follow the manufacturer’s recommendations, taking the temperatures and working environment into account.

When engine type oils are recommended for use in automatic transmissions, it is preferable to use monograde oils as multi-grade oils tend to 'thin down' with use. The viscosity index improvers used in these oils (this is discussed further under 'Engine Oils') are broken down by the high shearing forces experienced in automatic transmissions.

ENGINE OILS

The third and final broad category of lubricants is engine oils. The processes that take place in an internal combustion engine are varied and complex, therefore engine oils tend to contain the greatest variety of additives and have the most varied properties. The reason for this is because, not only does the oil have most of the characteristics of gear and hydraulic oils, but it also has to contend with the by-products of combustion which tend to be highly aggressive.

Engine oils contain the greatest variety of additives.

A list of engine oil additives used by all major suppliers is given below:

- Anti-oxidants - to prevent varnish and sludge formation
- Anti-corrosives - to retard attack by acidic combustion gases
- Detergents - to keep metal surfaces clean
- Dispersants - to keep contaminants in suspension in the oil
- Anti-wear agents - to reduce friction and wear
- Rust inhibitors - to prevent corrosion
- Metal deactivators - to pacify or prevent catalytic attack of metal surfaces
- Pour point depressants - to ensure fluidity at low temperatures
- Viscosity index improvers - to lower the rate of change of viscosity with temperature
- Foam inhibitors - to inhibit foam formation

These additives are chosen for their suitability and with full knowledge of their nature, compatibility and 'additive response' when blended into a specific base oil. This precise knowledge is necessary to ensure that the resultant blend of additive oil will perform satisfactorily in service and meet performance tests and specifications.

This technical bulletin has looked at examples of oils using the ISLS classification and their desired properties. However, this only scratches the surface as there are many other specialised products. They include such things as food grade lubricants, metal processing fluids, and open gear and wire rope compounds. The important thing to remember though, is that oil is more than 'just oil'.

John Evans is the diagnostic manager: mobile equipment for the Wearcheck Division of Set Point Technology.

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Produced by the Wearcheck Division of Set Point Technology

KWAZULU-NATAL
9 Le Mans Place, Westmead
P.O. Box 15108, Westmead, 3608.
Tel: (031) 700-5460
Fax: (031) 700-5471
E-mail: support@wearcheck.co.za

GAUTENG
25 San Croy Office Park,
Die Agora Road
(off Brabazon Road), Croydon.
P.O. Box 284, Isando, 1600
Tel: (011) 392-6322
Fax: (011) 392-6340
E-mail:
jhbsupport@wearcheck.co.za

INTERNET SITES :
www.wearcheck.co.za
www.setpoint.co.za