LUBE-TECH

NO.15

THE LUBRICATION OF OFF-ROAD VEHICLES AND EQUIPMENT

The adequate lubrication of vehicles and equipment used in a whole variety of off-road situations present the lubricant formulator with a number of challenges. In addition to ensuring the best possible lubrication in any given circumstance, there are increasing pressures to extend oil drain intervals, to reduce any environmental impact to the minimum, and, of course, there are the inevitable cost implications. Although there is a generalised categorisation of lubricants into those suitable for off-road use, the number of lubrication requirements in this category, which could include lubricants for diesel engine crankcases, for hydraulic systems, open gears, wire ropes, conveyor systems, etc., differ to such an extent that each individual category needs separate consideration.

However, in this generalised category, the lubricant formulator is likely to be faced with a number of common problems, i.e. the need to provide lubricants which will operate under harsh conditions, including high loads, extremes of temperature, variable speeds, reverse rotation and 24-hour operation. There are differences in requirements between pressure-fed systems, such as journal bearings in diesel engines, and non-pressurised systems, such as oil-bath gear lubrication.

However, in virtually all of these situations, the viscosity is of paramount importance. Oils of too low a viscosity may not have adequate film strength to prevent metal-to-metal contact, whereas oils of too high a viscosity may not be sufficiently pumpable on start-up at low temperatures.

The viscosity index, i.e. the rate of change of viscosity with temperature, is also important, since oils with low a viscosity index are only useable over a limited range of temperature.

The pour point of a lubricant is defined as the lowest temperature at which an oil will flow. However, this is misleading in that the user may incorrectly assume that the lubricant may be used at any temperature down to that of the pour point. In fact, a lubricant at a temperature approaching that of the pour point value will be far too thick to pump adequately. The oil pump will merely churn the oil, heating the oil locally but not producing any worthwhile flow to the bearings. Eventually, the prolonged churning will gradually heat up the bulk of the oil which may then start to flow, but during this significant time period, which may be 10 minutes or more, severe bearing damage may result from prolonged lubricant starvation.

The specific requirements of three of the more common applications are now considered separately.

HYDRAULIC SYSTEMS

Fluids intended for the hydrokinetic transmission of power are termed power transmission fluids; those intended for hydrostatic power transmission are termed hydraulic fluids. Fluids used in shock absorbing systems, used to suppress vibrations and as energy converters, represent a special case of hydraulic fluid. Properties required in hydraulic fluids can include viscosity, viscosity index, oxidation resistance, wear resistance, corrosion resistance, incompressibility, seal compatibility, air-release, anti-foam, filterability, shear stability, and possibly biodegradability.

Hydraulic fluids, particularly those used in off-road machinery and equipment, are normally based on mineral hydrocarbon oils (except biodegradable fluids, see below), but can also be based on water or a whole variety of synthetic fluids for more specialist applications.

The main problem encountered in hydraulic systems is contamination of the hydraulic fluid, this being the reason for some 70% of system failures according to some sources. Current trends towards higher operating pressures and speeds, the use of sophisticated electrical proportional control systems, coupled with tighter tolerances, smaller sumps, and extended drain intervals, result in more stress on the fluid and a greater sensitivity of the machinery to particulate contamination. During use, the hydraulic fluid can become contaminated with a variety of particulate materials, especially when operating in dusty environments such as mines where there can be as much as 7 to 8 mg. dust per cubic metre of air. Fluid systems are not always closed, and 'breathing' in the header tank vent due to normal ambient and operating temperature fluctuations can draw in dust from the atmosphere if the vent is not fitted with a filter. Also, dust can leak past cylinder seals. Such contaminants not only cause erosive wear in the equipment, but can also lead to premature deterioration of the fluid, accelerating oxidation causing thickening of the fluid and the possibility of sludge formation.

Traditional paper barrier filters will remove particles ranging from 15-50μ, but the harmful effects of particulate contamination can be due to smaller particles down to 5μ at which level the normal paper filter is not effective. However, the newer high-efficiency, synthetic fibreglass filters are much more efficient, removing particles down to 5μ on multi-passes.

Particulate levels can be quantified using the UK-made UCC CM20 optical particle counter, which counts the number of particles in a sample of fluid and rates the fluid against the industry standard ISO 4406. By sampling the fluids, a single particle counter can be used to monitor the fluid condition of a number of different items of equipment.

Many manufacturers of hydraulic machinery specify ISO standard levels of fluid cleanliness, and for maximum fluid and machinery life, the fluid should be regularly monitored and maintained at least at the ISO level specified by the manufacturer.

With increasing awareness of environmental matters, there is a growing demand for biodegradable hydraulic fluids, particularly when used in environmentally sensitive areas such as in forestry equipment or near watercourses. These fluids are intended to cause minimal environmental impact when natural or accidental losses occur from equipment in use. Such fluids are normally based on rapeseed oils and rapeseed oil esters and may also contain synthetic esters. Early experiences with rapeseed-based fluids were not favourable, in that users found that the fluids did not have the temperature capabilities needed for most off-road applications, gelling at low start-up temperatures, and oxidising at the upper operating temperatures. Oxidation caused polymerisation and the formation of sticky deposits which interfered with the operation of valves and other components. However, developments in improving the characteristics of the base fluids and in additive technology, and the use of alternative, synthetic fluids have not only overcome most of the original shortcomings, but have resulted with fluids of improved performance in some aspects compared with the non-biodegradable variety, albeit at a cost penalty. However, it must be emphasised that when such fluids are drained off for routine replacement, they should be disposed of in a responsible fashion as for any other waste oil, and not merely poured into a convenient

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landfill in the supposition that they will rapidly degrade. Also, they should not be disposed of into bulk storage tanks intended for the accumulation of used mineral oil collection, since their presence can adversely affect the potential for re-use of the mineral oil.

OPEN GEAR LUBRICANTS

Off-road equipment such as shovels, excavators and draglines make use of a variety of large exposed gear drives operating at low speeds and not normally manufactured to the high degree of precision and surface finish which characterises high speed enclosed gear systems. They often operate in hostile environments, being exposed to climatic extremes of temperature, also to abrasive dust and corrosive atmospheres. Lubricants need to be of high viscosity and adhesive in nature to resist product throw-off, but the amount of lubricant generally present is insufficient to provide a continuous hydrodynamic wedge between the gear teeth.

From the early 1900s, the majority of open gear lubricants were based on asphaltic products (high viscosity mineral oils containing a high level of asphalt or bitumen), diluted with chlorinated solvents (such as perchloroethane, 1,1,2-trichloroethane and 1,1,1-trichloroethane), and often containing lead-based extreme pressure additives and wax to better resist shock-loading and resist corrosion respectively. Although petroleum-based solvents were originally used, they were replaced by the non-flammable chlorinated solvents for safety reasons, since the presence of flammable solvents had historically resulted in a number of fires involving a variety of different types of off-road equipment. These types of products provided excellent protection to rolling and sliding contact surfaces, their inherent adhesiveness giving good anti-wear, anti-scoring and anti-scuffing properties, although they tended to become hard and brittle at low temperatures.




However, some asphaltic products are now suspected to be carcinogenic, chlorinated solvents are now banned as being ozone-depleting and lead based products are known to be toxic. The lubricant formulator was then presented with the problem of ensuring adequate lubrication of heavily-loaded open gear systems, operating at ambient temperatures ranging from $-50^{0}C$ to $+50^{0}C$ with products which would have minimal impact on the environment. Also, since the amount of lubricant delivered to the gears is not usually sufficient to provide a true hydrodynamic 'wedge', i.e. a separation of the sliding surfaces by a film of lubricant, open gears operate for much of the time under conditions of 'boundary' lubrication; in this situation the lubrication activity is due to chemi-adsorbed components on the gear teeth surfaces.

As a result, the earlier asphaltic products have now been largely replaced by grease-based products, initially diluted with solvents, but now mainly replaced by solvent-free versions due to environmental concerns.Semi-fluid greases have advantages in that they can be designed to be either thixotropic (shear-thinning) or dilatent (shear thickening) as required for the particular application. These products can be used as a multi-service lubricants which can lubricate both the open gears and also the bearings. Field experience also confirmed better housekeeping (less dripping), more easily cleaned off for gear inspection, and easier application.

Lead-based extreme pressure additives have now been substituted by sulphur/phosphorus and more recently, by bismuth/sulphur synergistic additive chemistries.

Also, because of the total loss nature of open gear lubrication, there is again a need for biodegradable products in certain situations. In these situations, the semi-fluid greases can be based on vegetable oils, although it may be necessary to substitute the vegetable oil-based products with more expensive versions based on biodegradable synthetic esters when operating at low ambient temperatures due to the generally poor pumpability of the former low temperatures.

However, because of the increasing importance of environmental concerns, designers of many items of off-road equipment are now re-evaluating much of their equipment with a view to eliminating the need for the use of exposed gears. Some reports suggest that some 25% to 50% of many items using exposed gears, admittedly mainly in non-off-road use, are candidates for retro-fitting of enclosed circulating oil lubrication systems. However, it is probable that such systems would not be practically or economically feasible in many off-road applications, and particularly where the use of total loss lubrication systems provide a necessary flushing action that carries away grit and dust.

ENCLOSED GEAR LUBRICANTS

The massive size and extreme operating conditions of some of the enclosed gears used in large off-road machinery have again posed particular problems for the lubricants formulator. For example, the critical hoist gears on a large rope-shovel, with 46" centre to centre dimensions, and running at 1,160 rpm with a stalling motor torque of 19,000 ft. lbs, used a common lubricant for both the gears and the pinion support bearings.

Lubricants such as full-synthetic 75W-90 API GL-5, which performed well on the roller bearings, were inadequate for the gear lubrication. Thicker lubricants, such as an ISO 1000 gear oil, were, conversely, satisfactory for the gears but resulted in bearing failures.

The best compromise in practice was found to be the use of a grease-thickened fluid, using aluminium complex soap or polymers as thickeners. Such fluids have rheology characteristics which favour this type of application in that they cling to the gears and do not slump off when the gears are idle, nor leak from gearboxes. However, they are sufficiently thixotropic to shear-thin during use to provide adequate lubrication for the bearing systems.

David Margaroni

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BLF CHALLENGED BIKE MAGAZINE OVER THEIR ARTICLE 'FIND THE RIGHT OIL'

Keen motorcyclist and BLF Technical Officer David Margaroni was surprised to read what he considered a rather confused maintenance tips article in a recent BIKE Magazine issue. We decided to act to seek modification, so that bikers could be helped to understand how to correctly lubricate 4-Stroke motorcycles. On behalf of the BLF David discussed our concerns with their Editor and provided him with a written explanation of our concerns. The outcome promised by BIKE's Editor was to correct the errors in a future issue.

The following Is a transcript of the BIKE Magazine June 2000 Page 189. 'Find the right Oil'

Confused by the vast range of four-stroke engine oils? Choose the right one, or you could end up with a knackered engine or an empty wallet. Or both.

IT'S EASY TO ASSUME that the most expensive oil is the best oil for your bike but that's often not the case. A high-specification oil is designed for a high-specification, hot-running engine built to close tolerances. That same oil in, say, a well-worn commuter bike won't take up the engine's much larger tolerances and it will be more likely to emulsify (the white 'mayonnaise' you sometimes see in cam covers).

And. in case you're wondering, car oil often isn't suitable for bikes because it's not designed for the wet (ie oil-bathed) clutches that most bikes have. So, with a range of motorcycle oils in front of you, what should you look for? First check its type:

Mineral oil: conventional multigrade for low-revving engines that are rarely subjected to long motorway journeys and never taken to the track

Part-synthetic: sometimes known as synthetic fortified. Good enough for almost any type of bike (the wide tolerances of a Harley requires a thick mineral oil. though), but best avoided if you regularly thrash your bike hard. or use it for track days

Semi-synthetic: the best choice for supersports bikes that are ridden hard, and often used for motorway journeys and track days.

Fully synthetic: ideal for racing and track days. An unnecessary expense for all but the most highly-tuned road bikes.

Then make sure the grade is correct, according to the maker's recommendations in your manual the grade will be SAE 10W-40 or similar: SAE is the American Society of Automotive Engineers, which set the original standards for the viscosity (or thickness) of oil. The first number is the viscosity of the oil during 'winter' use, actually tested at 0°C it will usually be five, 10, 15 or 20. The second number is the viscosity at normal working temperatures, tested at 100°C. That's likely to be 40 or 50. Getting an oil that is too thin will increase wear and engine noise, while an oil that is too thick will sap power and may cause clutch drag.

Finally, check the quality grading of the oil, which will be, for example. API SD/CC. API is the American Petroleum Institute rating standard that defines the quality of the oil. The S of SO in the example above is for 'spark ignition' i.e. petrol engines, while the D is the quality of the oil Those two letters could be SA - a straight mineral oil, the most basic lubricant - while multigrades go from SB to the high quality SG. Expect any decent bike oil to be SG.

The last part of the API code (CC in the example above) always has a C in it. The C is for 'compression ignition' which means diesel. so we won't mention that again.

Two-stroke oils are another matter- we'll cover them in a future issue........"

BIKE magazine

THE BLF Email to BIKE Magazine

'Find the right oil'

Article on page 189 of June Issue 'Bike'.

The article has some useful pointers for your readers, but is very much out of date in some areas as well as containing a number of factual errors. I have detailed the following notes, which you are welcome to use in any way you think appropriate.

GENERAL

It has long been a matter of concern for myself and many others that the lubricant requirements of the modern motorcycle, and particularly those of the higher-performance 4-str variety, have never been properly recognised. Oils habitually used for motorcycles were primarily designed for passenger car engines, the design of which has developed and become more and more different from motorcycle engines and drive trains as both types of unit have become progressively more tailored for their respective purposes.

For example, a primary consideration for car engine oils is to assist in the improvement of fuel consumption. This calls for the incorporation of a type of additive known as a 'friction modifiers' in the lubricant, the purpose of which is to reduce internal friction in the engine by making the internal surfaces in the engine, e.g. the surfaces of bearings and bores etc., more slippery.

However, the use of friction modifiers, whilst benefiting fuel utilisation efficiency in car engine applications, caused problems in certain areas of the drive train and associated components of motorcycles, such as the clutch, back-torque limiter, starter mechanisms, all of which depended upon a certain degree of controlled friction for satisfactory operation.

To address this problem, preparatory work was initially carried out by a motorcycle-working group, under the engine oil subcommittee of the Japan Automobile Manufacturers Association (JAMA). This included a survey of existing specifications for four-stroke cycle engine oils and the engine test procedures and reference oils used. This was followed by an evaluation of four-stroke cycle engine oils with actual engine tests. After this preparatory period, the 'Motorcycle four-stroke cycle engine oil subcommittee' was set up in April 1996 under the motorcycle technical committee of the JSAE, comprising representatives from academia, motorcycle manufacturers, oil companies and

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additive suppliers. The subcommittee started by establishing a standard that specified test procedures to properly evaluate the quality of four-stroke cycle engine oils for motorcycles. This was followed by the definition of a classification standard based on the test procedures. During the standardisation work, existing hardware and evaluation procedures were, as far as possible, incorporated into the standard test procedures. In addition, the principle was to establish specifications that were suitable for four-stroke cycle motorcycle engine oils currently on the market (or to be developed in the future).

As a result, specifications for suitable oils and test procedures were developed and came into force on 1 July 1998.

The important item to note is that oils intended for 4-str use would be classified according to existing specifications such as the API system, but that they would be additionally subjected to a friction determination test and be further classified into two further groups, MA and MB. Oils, which had 'normal' frictional characteristics, i.e. which did not contain the problematical friction modifiers, would be categorised as MA group oils.

It is therefore important that your readers are alerted to this, and to ensure that lubricants, which they purchase, are identified as MA-type oils. All of the major lubricant manufacturers currently supplying oils specifically for motorcycle use have evaluated their lubricants and have identified them as being MA classification where appropriate.

ARTICLE SPECIFICS

Mineral Oil

Many developments have recently taken place in the refining of mineral oil, and some of the latest base mineral oils, now known as 'unconventional base oils' (UCBOs) are approaching the performance of certain synthetic fluids. It is therefore not necessarily correct to imply that all mineral oil products are of limited application.

Part-synthetic, Semi-synthetic

There are a number of terms used in marketing literature, which are used to describe oils, which contain a certain proportion of synthetic fluid to boost the performance aspects of lubricants based on basic mineral oils. There is no quantitative significance in the terms used, and it is not correct to imply that a product labelled as semi-synthetic is superior in performance to one labelled part-synthetic.

Full synthetic

Not necessarily an unnecessary expense since there can be other benefits such as improved fuel consumption and longer engine and drivetrain component life for lesser-tuned road bikes.

Viscosity grades

The first number (followed by a 'W') is determined, not at 0°C as stated, but at –25°C for 5W oils, at –20°C for 10W oils, and at –15°C for 15W oils.

It is not necessarily the case that a thin oil will lead to increased wear, since it is the film strength, which is important. A high-quality thin oil with a higher film strength can result in less wear to the engine and other drivetrain components than a lower-quality thicker oil with a lower film strength.

API grades

The API grades mentioned are very much out of date. API was introduced in 1968 and API SG, which you describe as 'high-quality' was introduced in 1989 and has since been superseded, the current API category being API SJ which was introduced in 1996. The next category, which will be API SL, is currently under development.

The prefix 'S' stands for Service (petrol engines) and 'C' for Commercial (diesel engines) not for Spark and Compression as you describe, although this is admittedly a useful way of remembering the different types of application.

SUMMARY

As might be expected, lubricant developments have not stood still over the years. The performances of such products have improved rapidly with time, particularly in recent years, and bear no relation to earlier products.

Although bike manufacturers may recommend certain API grades of lubricants, which are now, obsolete but still available, it must be remembered that the latest and most sophisticated lubricants are not available in many third world-countries where these bikes are being sold.

For bike owners who value their vehicles, and want to ensure that they can expect an extended working life with the minimum of mechanical problems, the latest category of lubricant should always be used, which is currently API SJ (with the additional MA!)

The whole subject of lubricants and their specifications is admittedly extremely complex, and is understandably not readily understood by the average vehicle user.

The British Lubricants Federation has therefore recently made available a give-away 'Fact Sheet', which assists motorists in choosing the right oil for their car. The demand has exceeded all our expectations, and we are now on our third print run.

We are now considering issuing a similar 'Fact Sheet' for motorcycle owners; if this materialises we would very much welcome your assistance in publicising its launch

David Margaroni
Technical Officer - BLF