LUBE-TECH

NO.9

EXTENDED DRAIN INTERVALS FOR CRANKCASE LUBRICANTS

INTRODUCTION

Recent advances in lubricant and engine technology have enabled significant increases in the potential for extension of service intervals, particularly in the Commercial Vehicle market where off-road time for servicing is required to be at an absolute minimum. In Europe, current drain intervals of 100,000 km. are now the benchmark for such vehicles. Several key Truck Manufacturers have introduced exacting new specifications for engine and transmission lubricants, the use of which are required in order to achieve new extended service intervals and are in some cases mandatory in certain extended warranty situations.

Passenger car manufacturers are also realising the marketing benefits associated with extended service intervals in today's highly competitive market, and most manufacturers are designing-in the potential for less frequent servicing. However, increasingly stringent emission regulations are an additional complicating factor. The resultant increased contaminant load upon the lubricant acts against the extension of drain intervals. Lubricant formulators and vehicle manufacturers are therefore endeavouring to achieve longer lubricant life by re-formulating the lubricant and by modifying the design of engine lubrication systems respectively. With regard to the latter approach, the most viable option appears to be the incorporation of some form of by-pass filtration system supplementing the normal full-flow filtration.

LUBRICANT CONTAMINATION

The primary contaminant of diesel engine crankcase lubricants is soot, the accumulation of which leads to thickening of the oil and an increase in the abrasive wear in critical areas such as valve cross-heads, rockers and cam followers. The need to meet increasingly stringent exhaust emission regulations has required modifications to engine design and operating conditions, such as the use of articulated pistons with steel crowns and high top rings, increased injection pressures, retarded injection timing and the use of exhaust gas recirculation. The last two items in particular directly contribute to higher contamination levels in the lubricant, particularly soot content. The size of primary soot particles is in the order of 20-30 nm, but these primary particles rapidly fuse together to form larger particles in the order of 0.2–0.3 μm. General opinion seems to indicate that the smaller particles are primarily responsible for oil thickening, whereas the larger agglomerates are responsible for wear. Earlier investigators reported that the presence of a certain concentration of fine sub-micron particles was in fact beneficial as they aided polishing of bearing surfaces over an extended period thereby reducing friction. Removal of particles down to 5 micron did not significantly reduce wear, whereas when the oil passed through a 1 micron filter there was a significant reduction in wear. Wear rates arising from the presence of particulate contaminants increase rapidly when the size of the particles exceeds running clearances between sliding surfaces.

Other contaminants include unburnt fuel, metallic particles, together with acidic by-products of fuel and lubricant combustion, etc. In general, it can be seen that the more stringent controls on emissions are leading to an increase in the contamination level in the lubricant.

The presence of even small quantities of metallic debris, such as iron, copper, lead, etc., can act as an oxidation catalysts which will degrade the lubricant. In the presence of oxygen at elevated temperatures, organic peroxides are formed by the removal of hydrogen atoms from the lubricant hydrocarbon chain, which results in the formation of free radicals, which then react with the oxygen to form peroxy radicals. These act as precursors for further oxidation, which ultimately result in the formation of a variety of organic compounds, including aldehydes, acids, ketones, which may then further oxidise and react with each other to form high-molecular weight polymers, such as varnish or sludge.

Water is another potential source of serious engine problems which conventional full flow oil filters are not designed to handle. A normal by-product of combustion, water enters the crankcase with piston ring blow-by gases and condenses when the engine is shutdown and cools. Water, oil and soot then mix to form sludge which insulates the crankcase and oil pan to reduce the engine's cooling capacity. Water in oil also promotes formation of corrosive acids. Sulphur and nitrogen compounds, when combined with water in a hot engine, can form sulphuric and nitric acids.

DEVELOPMENT OF LONGER-LIFE ENGINE CRANKCASE LUBRICANTS.

Most lubricant marketers have responded to the requirements for extended drain intervals by introducing new or upgraded product lines. A typical diesel engine product range would include, for example:-

1. Standard Engine Oil suitable for On and Off Road applications- Would meet basic industry requirements for diesel engines only. Little opportunity for extension of normal drain intervals, however. Suitable for the majority of the current on/off Road vehicle parc but not recommended for new design low emissions engines

2. Mixed Fleet product suitable for On and Off Road applications - diesel and gasoline engines. Meets "second tier" industry specifications for diesel engines, and "suitable for use" in gasoline engines. Suitable for mixed Van/Car fleets where there are some gasoline-engined vehicles. These products, however, would not usually meet the latest performance requirements for low viscosity fuel economy oils for gasoline engines. Meets some manufacturer specifications for moderate extension of drain interval in commercial diesel engines e.g. up to 30,000 kms.

3. Super High Performance Diesel Engine Oil suitable for On Road applications - may have some gasoline engine performance. Meets several OEM and Industry "Long Drain" specifications typically used for long haul applications. Oil life can be between 45,000 and 60,000 kms depending on application. Also needed for some European Off Road engine designs.

4. Ultra High Performance Diesel Engine Oil "very long life" oils using new technology, synthetic base fluids, etc. Needed for latest engine designs where manufacturers are offering 100,000 kms + oil life and service interval.

Experience by some manufacturers who have evaluated synthetic oils to their limits show that engine oil life of 500,000 kms can be accomplished in the right type of operation. It is argued that if the total cost of lubrication of a vehicle is considered, rather than just the cost of the lubricant, it will be found that elements such as filters/labour/oil disposal can contribute far more to the cost of lubrication than the lubricant itself, By using a higher quality of oil the cost of lubrication can fall. However these exceptional results are not possible for many of today's vehicle parc - mainly due to a limited degree of sophistication of engine management systems and to the type of operating conditions experienced in practice.

ENGINE DESIGN

The simplest and most obvious way of extending oil change intervals by reducing the concentration of contaminants in the sump is to

(Continued on Page II)

enlarge the size of the sump, this approach having been adopted by some manufacturers of commercial trucks such as Mercedes. However, this should be seen as only a short term expedient in order to extend drain intervals when using existing designs with the minimum of manufacturing cost changes. The disadvantage of this approach, apart from the obvious increased cost of the lubricant, is the increase in thermal mass which will reduce thermal efficiency, also the increased weight of the unit.

BY-PASS FILTRATION

An alternative, or possibly complementary, approach, to extending lubricant drain intervals is the use of some form of by-pass filtration. This technique is becoming increasingly popular among many diesel engine-vehicle manufacturers and systems incorporating increasingly sophisticated combination barrier media full-flow and by-pass filter systems have been used for many years in Japan. Similarly, in the US and in Europe, by-pass systems have been used in a variety of vehicles; Scania, Renault, DAF and Mack for example currently use self-driven centrifugal by-pass filtration systems.

A conventional engine lubrication system will normally incorporate a mechanically-driven oil pump, an oil pressure relief valve, an oil cooler and a combination of oil filters. The oil filtration system normally consists of a full-flow barrier media type, possibly in conjunction with some form of by-pass filtration system.

The full-flow filter will normally have a pore size ranging from 15 – 50 µm, although differences often arise in the figures quoted due to confusion over the use of absolute vs. nominal filter ratings. Such barrier media filters are therefore normally only capable of removing the largest contaminant particles, and will not cope with accumulation of soot, the pore sizes being at least an order of magnitude larger in pore size than the majority of particles circulating in the lubricant. In order to provide a full-flow filter which would remove particulate debris of less than 1µm, the filter would need to be unacceptably large in order to obtain acceptable flow rates and pressure drops. However, if a small proportion, normally some 10%, of the lubricant is continuously diverted through some form of by-pass filter which is effective in retaining these very small particles, the lubricant will eventually achieve a high level of cleanliness if the filtration removal rate exceeds the generation rate of the small particulates, which is the case in practice.

BY-PASS FILTRATION - BARRIER FILTRATION

Barrier filtration of particulate material to the sub-micron level is possible, but the system suffers from a number of drawbacks. As the filter becomes progressively loaded with contaminant, the flow rate through the filter drops, falling to zero when the filter becomes completely blocked. However, before this stage is reached, the filter membrane may well rupture or channel at high inlet pressures, allowing unfiltered oil to pass through. Filtration Ratings of barrier media filters are expressed as either the Filtration Ratio β_2, or the Filtering Efficiency η.

$$\beta = C_{Up} / C_{Down}$$

Where C_{Up} = Concentration of particle entering the filter

C_{Down} = Concentration of particles leaving the filter

The particle count size is normally expressed as a subscript, e.g. a filter with a rating of "$\beta_2 = 100$" would allow one particle through for every 100 particles of size 2 µm entering the filter. The Filtering Efficiency η is defined as the Upstream - Downstream Particle Count of a given size (x) divided by the Upstream Particle Count, i.e.

$$\eta_x = (1 - 1/\beta_x) \times 100$$

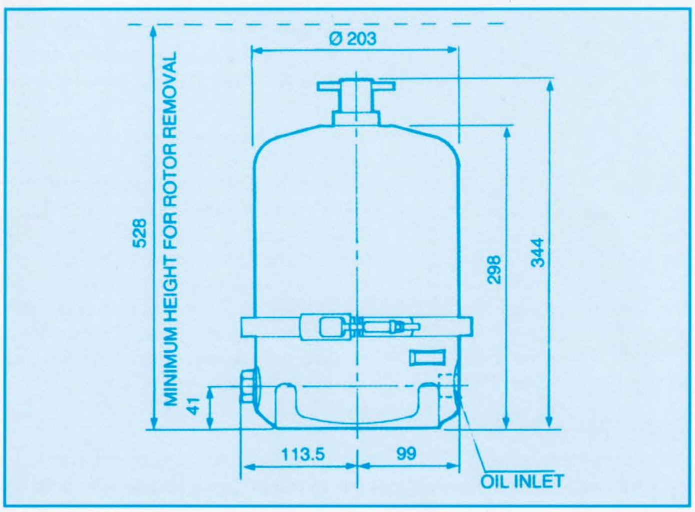
One such type of by-pass barrier filter, developed and proven in the US using technology based on human blood dialysis, diverts a small continuous stream of engine oil (5%-7%) through a specially designed filter element that uses a machine wound string of cotton/cellulose fibre. As it cleans the oil, the filter traps particulates down to 3 microns and removes water. This system claims to overcome channelling by using computer controlled winding machines that control both weave and tension of the wind to produce woven filter elements. These are wound on a stainless steel core resulting in a varying density filter progressing from a 40 micron weave at the outer diameter to a 1 micron capability at the core. The weave is designed so that there is an equal resistance to flow throughout the filter. With no shortcuts available, the oil must pass completely through the filter element.

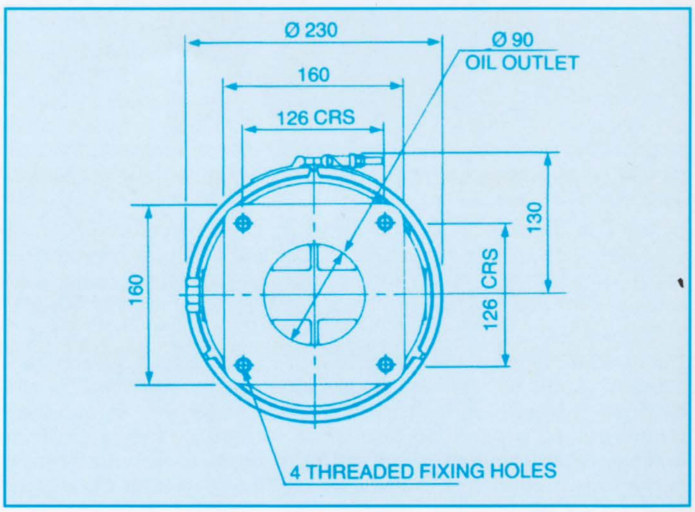
This system is also claimed to remove water as a result of an 80% cotton content in the makeup of the filter element which retains moisture in suspension within the individual fibres until it reaches saturation. This compares with the paper/wood cellulose, glass or synthetic fibres used in conventional full flow filters which are virtually ineffective in absorbing water.

This system has been extensively trialled in the US, where the tripling or even quadrupling of oil life has been claimed.

BY-PASS FILTRATION - REFINERS

A further development of the barrier filter incorporates a heating chamber, the purpose of which is to remove water, unburnt fuel, acids, antifreeze and other low-boiling contaminants from the lubricant on a continuous basis. These systems, known as 'refiners',





have also undergone extensive trials, and lubricant lifetimes in excess of 800,000 miles have been claimed in commercial diesel engines. In practice, the lubricant first passes through a fine filter, of a type similar to that described above, after which it passes into the heated evaporation chamber in the form of a thin film, where, after heating to temperatures ranging from 100 to 150°C, the subsequent pressure drop to atmospheric assists the rapid removal of the lower-boiling contaminants described above. The vented contaminants are directed back into the induction system and subsequently consumed during the combustion process. In practice, it was found that an operating period of some 10,000 miles was necessary for the refiner to clear the lubricant of contaminants, regardless of whether the engine was new or old, although, once cleared, the lubricant remained virtually free of harmful solids and liquids. For reasons which have not been satisfactorily explained, it is claimed that the lubricant which has been subjected to cleaning-up treatment by such a refiner is claimed to have an improved film strength compared with the original, which results in decreased wear of engine components.

Again, for reasons which are difficult to comprehend, tests have shown that the emission levels of NOx, carbon monoxide, particulates and smoke are reduced when such a refiner is incorporated into the lubrication system, following an initial acclimatisation period.

These systems would be most beneficial when used in vehicles subjected to intermittent use with frequent need for cold starts, e.g. school buses. It is this pattern of use which is most likely to result in the problem of fuel dilution of the lubricant. If the lubricant becomes excessively thinned by fuel dilution, the hydrodynamic barrier which separates the moving parts within a bearing becomes thinner and less durable, with the consequence that the smaller particles within the oil become effectively more abrasive. This problem would be most readily overcome by using a refiner to evaporate off the lower-boiling fuel. Such refiners are also effective in eliminating 'acid-pitting', which is caused by an accumulation of acidic by-products in the lubricant.

BY-PASS FILTRATION - CENTRIFUGAL SYSTEMS

By-pass centrifugal oil cleaners may be externally powered or self-powered. The latter type are generally much smaller, and can be used in a variety of fixed (e.g. cleaning of quench oils and hydraulic oils) and mobile (e.g. commercial vehicles) applications. In a typical example, the centrifuge cleaner will consist of a body with outer casing and a central spindle around which a rotor revolves at high speed. The oil, which is under pressure, enters the centrifuge body and continues to the cleaning chamber of the rotor via the centre spindle. Having passed through the cleaning chamber, the oil exits at the base of the rotor via tangentially opposing nozzles. The oil exiting from the rotor causes the rotor to revolve at high speed, i.e. up to 10,000 r.p.m. Thus creates a centrifugal force within the rotor which can exceed 3000g, which causes separation of contaminants which differ in density from that of the oil. They migrate outwards, forming a dense 'cake' on the inside surface of the rotor wall. The rotor may then be either cleaned out or replaced with a new unit at the appropriate time. For optimum performance, it is essential that the oil entering the centrifugal filter is as hot as possible, so that the density and viscosity are at their lowest which will facilitate the migration of contaminants. Also, the oil should be delivered at high pressure, so that high centrifuge speeds are obtained, generating high centrifugal forces. The ideal positioning for the centrifuge cleaner is therefore immediately downstream of the oil pump. It is also necessary to ensure that oil drainage route from the cleaner, normally directly back into the sump, is free of any obstruction so that no flooding of the rotor can occur which would reduce its speed.

The basic principles involved are fairly basic and simply explained. Consider the case of a spherical contaminant particle of diameter d_p and density ρ_p suspended at a radius r in a fluid with density ρ_0 and dynamic viscosity μ_0. If we then assume that the fluid and the contaminant particle are both rotating about a vertical axis at the same angular velocity ϖ, then the centrifugal force acting on a particle would be:

$$f_c = m_p r \varpi^2$$

Opposing this force is the effect of the viscous drag upon the particle (f_d) which is a function of the Reynolds number and the particle drag coefficient. If we assume that Stoke's law will apply to the migrating rate of the particle, then the time taken τ for the particle to travel a distance r to the rotor wall is:

$$\tau = \frac{18\mu_0 \ln((r + \dot{r})/r)}{d^2_p \dot{p} \varpi^2}$$

where $\dot{p}$ is the difference in density between the contaminant particles and the oil $\rho_p - \rho_0$.)

From this last equation, it follows that separation of the particles is more rapid the lower the viscosity of the oil, as would be expected. Also, the shorter the distance that the particle has to travel under a given set of throughput conditions, then the smaller is the size of particle which can be removed.

This type of cleaner will not separate out unburnt fuel, but does have other advantages compared with barrier type filters in that the cleaning efficiency remains constant throughout, also particles smaller than those which may pass through many barrier filters may be separated out. In practice, primary soot particles below 1 μm, which are responsible for oil thickening, may be separated out using centrifugal systems. The benefits of the centrifugal by-pass filtration system in reducing wear values can be quantified by measurement of the increase in iron levels in the lubricant. It has been shown that the rate of increase in lubricant

(Continued on Page IV)

(Continued from Page III)

iron concentration levels in an engine equipped with a centrifugal filter is only about half of that in an engine operating without the benefit of a centrifugal filter.

SUMMARY

The ultimate aim of fleet operators and environmentalists, albeit for different reasons, is the concept of the fill-for-life lubricant. However, other environmental issues such as exhaust emission levels have in the meantime predominated with the introduction of mandatory emission limits covering a number of exhaust gas constituents. This has slowed the progress towards the extended life-time lubricant since strategies for reducing exhaust emission levels such as exhaust gas recirculation, piston geometry changes and retarded injection timing all have the unfortunate effect of adding to the contamination level in the lubricant. Nevertheless, the technologies are still moving forward with the result that longer and longer drain intervals are now being realised, the result of advances in lubricant formulations and changes in the design of vehicle lubricating systems.

The use of new lubricant basestocks, either unconventional severely hydrocracked base oils, or synthetic fluids, has resulted in the introduction of a new range of lubricants with enhanced resistance to oxidation enabling prolonged operation at elevated temperatures throughout their working life.

The adoption of new technology sophisticated by-pass filtration systems has enabled the lifetime of the oil to be prolonged by ensuring that levels of accumulated contaminants in the oil are maintained at sufficiently low levels that the functional properties of the lubricant are not adversely affected, and that wear rates in the engine are kept at low levels.

By suitable combination of engine design, lubricant formulation and by-pass filtration systems, very high lubricant operating mileages are now achievable in practice. The concept of a fill-for-life lubricant can therefore be contemplated, although the overall operating economics and even a proper environmental life-cycle analysis may not necessarily favour such an option.

The concept of extended drain intervals is not necessarily attractive to manufacturers and marketers of lubricants, since sales volumes will inevitably be adversely affected as a consequence. Nevertheless, increasing pressures from customers and environmentalists to reduce operational costs and minimise environmental impact respectively are factors which cannot be ignored.

David Margaroni

"RESPONSIBLE CARE™" FOR BLF MEMBER COMPANIES

The Federation held a conference in Manchester on 9th March at which member companies present were offered the opportunity to join the BLF s programme of Responsible Care™".

Vice President Operations and Logistics, Simon Hayles of Castrol UK has together with a small Task Group been spent many hours working to create the BLF's scheme, with the blessing and considerable help of the Chemicals Industry Association.

Members who take up this opportunity to commit their company to the BLF's "Responsible Care™". programme, will be able to claim formal recognition by publicising to their customer and the public at large that they are in compliance with the scheme. It should be stressed that most aspects of the scheme are already covered within the BLF's Code of Ethics (COE). One aspect not included in the BLF's COE is a requirement to provide information on 'Key Performance Indicators'. These will form the backbone of indices included in a new Annual Report on the UK Lubricants Industry's continuous improvement progress on Safety Health and Environmental (SHE) issues. BLF "Responsible Care™". will be based on the following principles: -

GUIDING PRINCIPLES

BLF members must comply with all legislative requirements and should conduct their operations in accordance with government and industry guidance and codes of practice as they apply to the lubricants industry.

Members are committed to:

- ensure that any activity carried out by or for the company will not present and unacceptable risk to employees, contractors, visitors, customers, neighbours, the public or the environment
- to document the company's SHE policies and procedures and to ensure that the commitment to RC™ is reflected as an integral part of the business strategy
- provide relevant SHE information on the company's products and activities to all employees, contractors, customers and, where applicable to statutory bodies and the public
- ensure all employees are aware of the commitment to RC™ and provide the training necessary to enable them to achieve the SHE objectives
- establish and maintain and appropriate emergency response system
- support and participate in those activities that will influence the continuous improvement in SHE issues of the company's operations and report indices of performance annually
- maintain an awareness of and respond to local community concerns, which relate to their activities
- conform with all legal regulations and requirements, which apply to their business activities.

If your company is a member of the Federation and wasn't present at the Conference but you would like to learn more about the scheme please contact the Secretariat.

Rod Parker