UP-TO-DATE OF AUTOMOTIVE LUBRICANTS

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Abstract

During the short time, automobile factories will strive achieve, two-fold increase in energy efficiency and ten-fold reduction in emission levels. On the way to achieving these task, automobile companies will be improving efficiency and emission of engines, while minimizing servicing requirements, as well as introducing new technologies and changing energy sourcing from oil, to gas, and possibly to hydrogen. Numerous supporting technologies, such as electronics, sensors, computers, fuels, lubricants, oil and others, is involved in contribution. The paper deal with expected improvements and changes in lubricant technology. There are up to date technologies, which will with novel surface technologies and engine design changes ,for example lead to fill-for-life engine lubrication, etc.

KEY WORDS: fuel economy, emission, extend drain, power train trends, coatings, lubrication research, additives

1. Introduction

During the next time, environmental protection, resource utilisation, and customer satisfaction will continue to be the main technology drivers in power train development. Automotive companies must continue to achieve higher fuel efficiency, reduction CO_2, CO, HC, NO_X and other emissions, and high customer satisfaction, and minimising servicing requirements [1]. During the last 30 years, automobile industry have decreased emissions tenfold, doubled fuel economy and removed about 500 kilos in weight from cars. On the way to achieving this, automotive industry have introduced unleaded fuel, to use polymers and other lightweight materials, electronic fuel injections, torque converter lockup, computer controls, after treatment of exhaust gases, fuel efficient engine oil, etc. In the next several years automobile industry must make another high technological leap: to achieve another tenfold reduction in emission levels and another twofold increase in energy efficiency. All this will require systematic approaches and introduction of new technologies, which might not currently exist. On the way to achieving these goals we will be witnessing development of new unconventional engine technologies as well as a frantic effort to improve the efficiency of internal combustion engines. We may also witness gradual changes in energy sourcing from oil to gas to hydrogen. It is our belief that this changes will bring the automotive and oil industries much closer to each other. IC engine system improvements can be achieved through changes in engine and emission system design and introduction of advanced electronic control. These improvements need to be supported by advancements in other technologies such as electronics, computers, fuel, catalysts, sensors, lubricants, etc. The most imminent are the first four challenges and, therefore, they are discussed below.

2. Fuel efficiency and emission system compatibility

Significant improvements in engine fuel economy through increasing engine oil fuel efficiency have been achieved since 1990. The last version of the fuel economy test imposes limits for fuel efficiency of both the new and used oil. This ensures that fuel efficiency benefits will be provided throughout average oil drain periods and during for example the American test. The test represents the current and near future engine population, using the roller follower valve train technology, which is less sensitive to boundary friction reducing additives and more to oil isometrics. Nevertheless, it is estimated that molybdenum friction reducing additives, which are widely used Japan [2], could provide as much as 0,3 % of fuel economy benefit in test. The limits selected for test, however, do not require the use of these additives. It appears that the limits can be met through the use of very high VI/low viscosity base oils, resulting in engine oils formulated at the lower and of low temperature viscosity range for a given viscosity grade, and ash less friction modifiers. This seems to be way by which the oil industry is approaching the formulation of oils. Some engine friction model estimates of power loss for oils of different viscosity illustrate positive effects of use of low viscosity oils mainly in the larger engine with a roller follower valve train. The benefits of effective reducing additives are apparent for the smaller engine with a sliding contact valve train. The use of low viscosity oils, however, could raise concerns with increase, oil consumption and durability since these could negatively affect fuel efficiency and catalyst performance. To minimise viscosity increase, it is imperative to reduce base oil volatility. The durability concern brought up by the use of low viscosity oils can be alleviated by proper selection of anti wear and friction reducing additive systems which extend the transition from hydrodynamic to mixed or boundary and, also, by component redesign. As can be see from loss estimates 1L engines with a bucket tappet sliding valve train is much sensitive to the use of a boundary friction additive (friction coefficient is 0,05) than a 3L roller follower engine. In the former case, friction-reducing additives can lower valve train friction nearly to the level achieved with roller follower valve train. Thus, application of this type of friction reducing additive could significantly improve the friction in engines where boundary friction represents a significant fraction of friction losses. Such engine technology is currently preferentially used in Europe. One shortcoming of currently used boundary friction reducing additives, such as molybdenum dialkydithiocarbamates, is their loss of effectiveness with studied the mechanisms of interactions of molybdenum with zinc and with oxidation products under conditions of oxidative degradation and concluded that the effectiveness of this additives can be extended by peroxide decomposing and peroxide radical trapping antioxidants and by base oil selection. The effectiveness of this friction reducing additives is also significantly affected by the presence and formation of polar compounds that presumably interfere with additive adsorption at the surfaces and with the formation of NOS2 directly in tribological contacts. Therefore, more work is necessary for development of practical additive systems that would effectively reduce boundary friction during extended oil drain intervals. One solution could be in the use of tri nuclear molybdenum, which are claimed to display outstanding performance retention in the fired engine environment [3].

Exhaust emissions limits will continue to become more stringent. In 2005 emission level is the same for cars and light trucks. Even more stringent supr-low-emission-vehicle standards are already on the horizon. Meeting these extremely low limits, particularly at high km, will require the emissions control system to operate consistently at very high efficiencies. This means that even very low levels of contaminants, such as phosphorus and sulphur, may cause the systems to fail. Phosphorus contamination comes from the zinc that are used as anti wear antioxidant additives in engine oils. Sulphur has come predominantly from the fuels, however, as sulphur levels in fuels approach levels 10 ppm, or less, the contribution of engine oil derived sulphur may not become significant. Baseline experiments demonstrated that the acid wash and catalyst stabilisation procedures did not alter catalyst performance significantly. The effects of the washing procedure on the performance of aged catalyst are attributable to removal of contaminants. Results for six catalyst systems obtained from three engine and vehicle types show significant improvements in catalyst performance. Tailpipe hydrocarbons were reduced by 5 – 55 %, after removal contaminants with the oxalic acid wash procedure. Carbon monoxide emissions were also significantly reduced, improvements ranging to 42 %, reductions in NO_X emissions ranged from 15 – 48 % [4]. Phosphorus collects primarily at the catalyst face with lesser amounts observed along the length of the catalyst. Presence of phosphorus was indicated by the curved light area at the surface of the wash coat near the inlet. The primary effect of phosphorus contamination on catalyst light off performance. Hydrocarbon conversation efficiency during the first 130 seconds of emissions testing for duplicate test before and after washing showed that the catalyst light off times were substantially shorter after contaminant removal. Phosphorus contamination can be the difference between passing and failing stringent emission requirement. Results of this study we can summarise as follows:

- Eliminating or greatly reducing emissions system contaminants or poisons is needed
- Phosphorus is a key player

Removal of phosphorus from aged catalysts means:

- Reduced HC emissions by 15 – 55 %,
- CO emissions by 8 – 42 %,
- NO_X emissions by 15 – 48 %, etc.

Reducing the amount of phosphorus from engine oil that reaches the catalyst can be addressed by reducing oil consumption and by reducing the amount of phosphorus in engine oils. Reducing the amount of zinc, a very effective anti wears and antioxidant additive, however, raises some concerns.

3. Extend drain and high temperature capability

Old drain periods for example in Europe and USA differs significantly. While in Europe is a trend to extend oil drain intervals to 50.000 km, in USA the goals are much more modest (15 – 25.000 km). The driving force behind these trends is reduction in maintenance and cost of ownership, reduction in phosphorus contamination of catalyst, and environmental considerations. From a technical point of view, extension of oil drain periods could also have negative effects, which are consequences of oil deterioration and contamination during service. The extent of these negative effects, of course, depends on oil quality and customer usage and cannot be predicated from number of km on the oil only. The only robust solution to these problems the use of oil changes monitoring systems, as we know them at the present time, in combination with real oil quality sensors. Development of such sensors, however, is not a simple task since deterioration of several oil parameters needs to be monitored to cover several possible modes of oil failure [5].

Emission and fuel economy related design actions are expected to drive oil temperatures, in bulk and also in individual lubricated contacts, to higher levels or to longer residence times at higher levels. It is probable that the temperature reached will require unconventional oil and additive formulations.

4. Future engine oils, coatings and new materials

Reviewing lubricant wants in four major areas where improvements are desired, as described above, results in a series of conflicting requirements that significantly reduce lubricant design space. From the point of view of base oils, it seems that synthetic hydrocarbon and very high VI base oils could fulfil the needs in all four areas in the future. However, additive technology is facing very challenging times. Replacing phosphorus and sulphur in conventional formulations by other chemistries, having an even greater range of efficiency and providing even longer life than current additive systems, will be a very tough task requiring significant research effort and breakthrough technologies. This is not only a great challenge; it is also a great opportunity. The task ahead of us is to consider the lubricant to be one parameters in designing lubricating systems, the parameter which is intimately related with lubricated surfaces and tribological design. Such a systems approach could lead to a breakthrough design of lubricated systems and eventually to an ultimate goal of having, in the engine, lubricant-for-life.

Several technologies for coatings and surface treatments are now concept-ready for automotive applications. These coatings run the range from very thin diamond like carbon films that impart hard, smooth surface characteristic capable of withstanding very high unit loads, to thick molybdenum-intensive spray coatings that can reduce friction in moderately loaded contacts. Coating will find increasing mainstream applications in future power trains, as loads and temperatures increase in lubricated contacts and weight or cost reduction efforts intensify, if they can be cost-effective in mass manufacturing [6].

Simultaneously, new materials such as aluminium and magnesium are being deployed in engine components; some of these materials may need durable coatings for friction, scuffing and wear resistance. Engine oils, which have been developed and optimised for ferrous lubricated contacts may need to be formulated for effective lubrication of other surfaces. For example, many low friction coatings offer significant friction reduction in dry sliding, but little incremental benefit in realistic oil lubricated engine contact. However, some cylinder bore coatings do demonstrate considerable friction reduction with current engine oils, and more so in presence of oils with effective friction reducing additives which was discussed above [7]. These examples further underscore the need to integrate the lubricant into the design of lubricated systems, since engine oil technology may have to be tailored to effectively lubricate diverse materials and coatings in future engines [8].

5. Power train future

Changes in engines and transmissions will affect automotive lubricants as well. While IC engine powered by diesel or gasoline will probably remain the dominant power plant over the next few decades, it will witness evolutionary transformations aimed at improving fuel conversation efficiency, reducing parasitic losses in the engine and transmissions, and frictional losses in the drive line. Several of these changes described below will impact on lubricant performance [9].

Cooling-on-demand involves the use an electric water pump or flow control mechanism in the engine cooling system to supply coolant based on engine metal temperature, rather than on speed. By throttling down coolant flow at start up, this system can achieve a rapid engine warm up and significantly reduced friction due to higher metal surface temperatures. Some fuel efficiency gains can also be derived from reducing coolant flow to operate at higher surface temperatures at idling and part-load conditions. Such a system will result in the engine oil being exposed to higher operating temperatures over a larger portion of its use with possible implications on oil volatility and degradation.

Direct Injected Spark Ignition (DISI) engine technology offers significant promise for improved fuel efficiency, through some exhaust after treatment challenges remain to be solved. These efficiency improvements are largely possible due to higher fuel energy conversion rates (DISI 26 % and conventional gasoline engines 19 %). Gasoline wall wetting with resultant localised continues to be a problem with several DISI combustion chamber designs. Formation of deposits in intake system, combustion chamber EGR passages is another serious concern also involving the lubricant. Lubricate issues with low sulphur gasoline may impact high-pressure pumps and injector nozzles in these engines, while this is not a lubricant issue; it is nevertheless a lubricant problem.

Compression Ignition Direct Injection (CIDI) technology has diesel engines operating at up to 35 %

fuel conversion efficiency, with the potential to achieve 40 % which could match today’s best fuel cell efficiency. These gains make diesel engines compelling candidates for light duty applications, particularly in hybrid vehicles, to achieve a two or threefold increase in vehicle fuel economy. While diesel engines are enjoying increased market penetration in Europe and elsewhere, customer acceptance in the USA is likely to be limited to niche vehicles, owing to fuel pricing and concerns over particulate emissions.

Variable Valve Timing (VVT) is now in use in several production engines. In the near future, this feature could be used to manipulate the IC engines Otto cycle to achieve further fuel efficiency gains. Other cycle engine, for example (Miller), uses VVT to obtain an extended cycle with a truncated, energy conserving compression cycle. Other cycle engines (Otto-Atkinson) achieves thermal efficiency by delaying the exhaust valve closing under certain load conditions. The increased use of engine oils to assist engine performance features such as VVT, hydraulic lash adjustment and perhaps variable compression devices integrates it more tightly into the engine design – oil viscometrics will need to be within a narrow range over the oils entire service life for optimal engine performance.

The camless valve train is nearing production-ready status with several automakers. Using electromechanical or electrohydraulic valves, this technology will not only change cylinder head and lubrication circuit design, it will also effect lubricant design. With minimal lubrication required in the cylinder head, lubrication can be tailored to better perform lubrication and head rejection in the engine block. This may reduce the overall impact of friction reducing additives, but may open the horizon to new, more fuel-efficient lubrication techniques for engine as a whole. Cylinder deactivation will become standard with camless valve trains, with potential lubrication and wear problems in the cylinder bore or ring contact under transient conditions.

Integrated starter or alternators coupled with 42 V vehicles electrical systems are likely to become in the next decade. This technology achieves some of its fuel efficiency potential through instant stop-starts, such as at traffic light stops. In such features are implemented, to engine will experience greater transient friction conditions than in current operation, with thinner films and higher incidences of mixed lubrication conditions in bearings and cylinder bores.

The hydrogen engine is emerging as a possible challenger for the fuel cell, with the potential of high conversation efficiency. Hydrogen has the advantage of being very clean burring, and requiring a very simple engine control system, through formidable infrastructure, onboard storage and power density problems remain to be surmounted. Injector wear characteristics will need to be improved with hydrogen operation. Research must also be direct towards efficient cylinder bore lubrication since hydrogen could react with unsaturated and aromatic components of current lubricants. Since water is the main combustion product, engine oil must have the capability to tolerate water particularly under could or short trip-driving conditions. Hydrogen fuel cells represent the highest technological risk, and greatest technological challenge. But fuel-cell vehicles also represent the greatest opportunity for achieving a true zero-emission vehicle. The first production fuel-cell vehicles will probably reform their hydrogen from gasoline or methanol, creating the need to invent low-cost, onboard reformers. The fuel cells with direct oxidation of gaseous and liquid hydrocarbon fuels, solid-oxide fuel cells, are also being developed. These fuel cells do not require complicated reforming of hydrocarbons but they produce CO_2 and water. Unfortunately for tribologists, there is no need for engine oil in fuel cells.

6. Conclusions

Further progress in fuel efficiency and emission control of internal combustion engines can be achieved only through improvements and changes in many other supporting technologies. One such technology is lubricant technology that on the way to reduce friction must meet many other requirements dictated by engine technology, emission control and customer wants. This paper illustrates that some of these requirements are quite demanding, many are contradictory, and others cannot be met without a breakthrough. This paper also illustrates that there are many tribology issues to be solved to successfully meet future emission and fuel economy requirements and that there is an urgent need for extensive and systematic lubrication research to meet future technological challenges and competitive pressures [10].

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