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THE NEW GENERATION OF MOTOR OIL FOR THE EMISSION DEMANDS

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Abstract: *Current and future concern for the environment, supported by stricter emission limits in automotive industry, resulting in the development of new engine designs and new engine lubricants based around new additive technology. Therefore, lubricant industry is undergoing a period of dramatic change. Changes in lubricant technology in the past as in the resent period are results the three main factors, each of which addresses an environmental concern. Those three main factors are: lower emissions, fuel economy and extended oil-drain.*
From this aspect this paper deal with new specifications of motor oil for Euro-4 emission demands. Also, it shows specifications of some engine manufacturers.
Keywords: *motor oil, new specifications, emission*

NOVE GENERACIJE MOTORNIH ULJA ZA NOVE EMISIONE ZAHTEVE

Rezime: *Sve stroživi emisijoni propisi u automobilskoj industriji vode do novih konstrukcionih rešenja motora koja kreiraju i nove generacije ulja. Zbog toga se industrija maziva nalazi u periodu drastičnih promena. Promene u tehnologiji maziva u proteklom kao i sadašnjem periodu su rezultat, uglavnom, promene tri glavna faktora, a svaki od njih je usmeren na zaštitu životne sredine. Ta tri ključna zahteva su: manje emisije, smanjenje ptrošnje goriva i duži interval zamene.*
Sa tog aspekta u radu su analizirane nove formulacije ulja čije performanse moraju biti u saglasnosti sa novim motornim tehnologijama. Pored toga, dat je pregled ACEA specifikacija kao i specifikacija nekih proizvođača vozila.
Kljucne reci: *motorno ulje, nove specificacije, emisioni zahtevi*

1. INTRODUCTION

Lubricant are important group of industrial chemicals. The current annual EU market volume is about 4.200000 t. The lubricant industry is facing some very serious challenges. The first is that lubricant industry to become sustainable. The second is the new chemical policy. Sustainable development has three dimensions, which have to be carefully balanced again each other: social aspects, economical aspects and ecology.

Rising fuel costs and the need to conserve fossil fuel led to an increased interest in the role of lubricants in improving fuel economy. Lubricant formulation can have a beneficial reduction of engine friction, thus improving fuel economy.

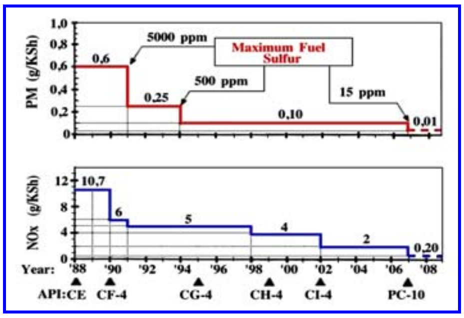

Figure 1: Stepped reduction in exhaust emissions with stepped increases in oil quality level

Engine design changes required to meet the latest emission regulation greatly impact on the engine oil degradation process and consequently, for each new emission regulation, a new engine oil specification is released (Fig.1).

2. THE FUTURE DEMANDS FOR AUTOMOTIVE LUBRICANTS

The future demands for automotive lubricants are (Fig.2):

- Improvement fuel economy,
- Reduced emission
- Extended drains interval and
- Biodegradability.

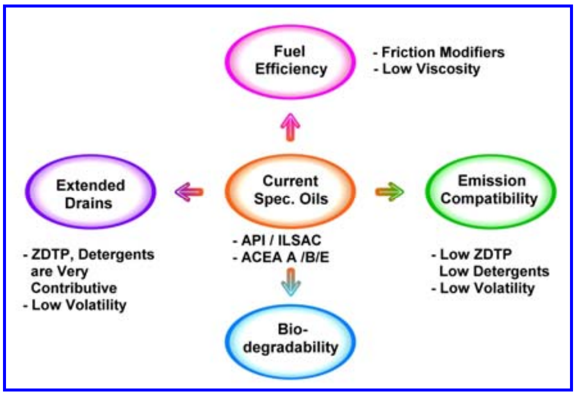

Figure: The major lubricant oils drivers

2.1 FUEL ECONOMY

The OEM's are under intense pressure to provide the most fuel efficient vehicle to respond to both the emission regulations and Kyoto protocol.

For example, in Japan, by the Year 2010, the fuel consumption of automobiles must be reduced by an overage of 22, 8 compared to 1995 [1].

In Japan, several automobile manufacturers have applied very low viscosity OW 20 oils to their factory fills. These low viscosity fuel – efficient oils are usually formulated with organic molybdenum compounds. They can provide a fuel economy benefit of as much as 2 to 3%.

In addition to the to the molybdenum friction – reducing additives, high quality Group III base oil also play a crucial role in the OW 20 oils. It has been painted out that the use of low viscosity oils could raise concerns about viscosity increasers and oil consumption, which could negatively affect the fuel efficiency and catalyst performance. From this aspect, the ILSAC GF-3 standard requires that oil volatility must be reduced to 15% NOACK, which is substantially lower than the previous 22% in GF-2. This change not only minimizes the viscosity increase but also is expected to reduce the oil consumption significantly. For low viscosity OW 20 oils, this can be achieved only through the use of very high viscosity index Group III base oil (Fig.3).

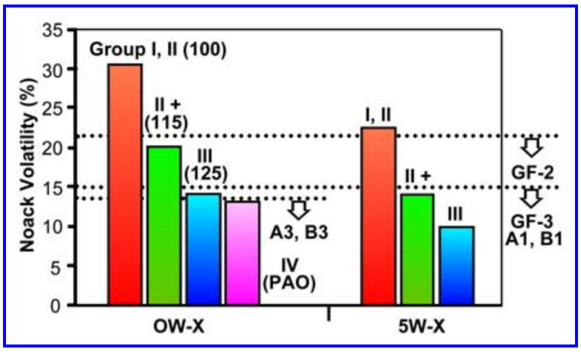

Figure 3: Noack volatilities of different base oil types vs. specification limits

Figure 4 show fuel economy benefits as result of the lower EHL friction of the VHVI Group III in compare with Group I base oils.

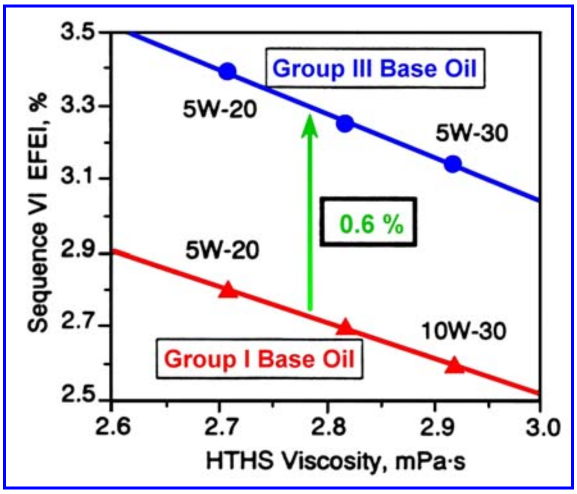

Figure 4: Fuel economy benefits obtained from VHVI Group III base oil

Typically, PAO based engine oils have a fuel consumption benefit of up to 3,4% relative to comparable mineral oils. In automotive transmissions the benefit is of the order of 10% of the power transmitted through the unit resulting in a fuel economy benefit of up to 2% in the driveline of a vehicle. This result is in on overall benefit of up to 5,4% in a vehicle [2]. In industrial transmissions, it is a possible to achieve a 10% reduction in energy consumption

by replacing mineral oil with equivalent PAO based oils.
This trend to improve fuel economy has led to the introduction of lower oil viscosity grades such as 5 W-30 and 10 W-30 grades that are now common place in the heavy-duty engines. Some of studies [3,4] indicate that synthetic diesel engine oil with a viscosity grade of SAE 15 W-40 can provide a 3 % fuel economy benefit compared to “convention mineral-based” or “premium SAE 15 W-40 mineral based oil”.

2.2 EXTEND DRAIN INTERVALS

Against the background of maintaining vehicle performance there has also been a strong trend to extend drain intervals because of customer convince and ecological considerations. In addition to this trend, there are different factors that lead to an increased stress on the engine oil, like higher oil sump temperatures, smaller volume of oil available, smaller engines with higher power output and the like. These different factors were combined to lead to an oil stress factor. To withstand those stresses over a long period of time significant changes have been made in oil-formulation, leading to superior long drain oil with higher content of synthetic (more stable) base oils and higher amounts of performance additives. Table 3 demonstrates the significant changes in typical drain intervals over the recent past.

Table 1. Typical drain intervals over the recent past

Typical oil drain	1995 Years	2003 Years
PC	10 000 (km)	30 000 (km)
HD	40 000 (km)	100 000 *(km)*

As oil drain- intervals increase, more severe aging of the oil by thermal and chemical stress, eg. By EGR- components, unburnt fuel, acids, and blow-by, can happen. The ageing of the oil during use has the most dramatic influence on fiber media stability.
Extending oil drains increases ash and soot levels. If soot is not adequately dispersed by the engine oil, it can cause:

- sludge to from on rocker and front engine covers,
- bearings to fail,
- valve bridges and fuel injection links to wear,
- filters to plug.

The durability of the lubricant and additive system in relation to the ability to disperse soot and maintain a regime of reduced wear has led to significant changes in additive formulation.
Extending the oil drains allows maximum up time for hauling freight and reduces costs for fresh oil, filters, mechanics labor, and used oil and filter disposal.

2.3 EMISSION REDUCTION

In the current industry climate emissions reduction has been the most significant driver of lubricant quality and the concept of lifetime of reduction of emissions is of fundamental importance. Enormous steps have been made in for example the reduction of particulate during the lifetime of typical diesel truck (Fig.5).

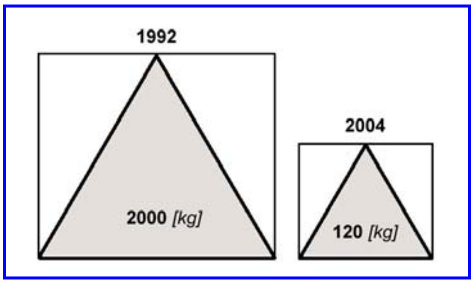

Figure 5: Typical truck particulate emission

Contribution of lube oil in engine emission depends on engine design features as well as on lube oil characteristics. The most important lubricant characteristics are contents of **sulfur, sulfate ashes- metals**, **aromatics, viscosity/density and volatility** (Noack).
Results we obtained with testing [5,6] fossil and synthetic oils show (Fig.6) that former produce 8% higher **NOx emission** than the latter. In addition to this fossil oils contain more sulfur (0, 8%) than the synthetic ones (0.6%).

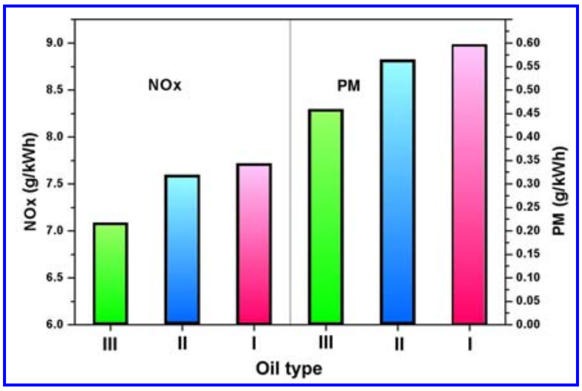

Figure 6: Specific emissions of the mineral and synthetic engine oils

Increased contents of aromatics in oil results in higher NOx emissions due to increased combustion temperature.
Some other investigations [7-10] show that synthetic oil produces 5% [7], or 7-9% [8,9], lower NOx emission than fossil oils.
As particulate emission, oil contribution is mostly manifested in organically soluble fraction as well as in PAH emission.
Our tests [5,6] show that synthetic oils produce approximately 20% lower particulate emission which is in good correlation with results obtained by Goodier [7].
Results obtained by BP Chemicals UK [12] show that 5W40 synthetic oil produces lees particulate emission by 35-55% than 15W40 or 5W40 mineral oil respectively. Other investigations [7,9-11] show 5-22% reduction of particulate emission with 5W-30 synthetic oil compared with 15W40 fossil oil.

2.4 BIODEGRADABILITY

The quantity of used lubricating oil in the world is about 4 x10^7 t/y, and 10% which is environmental poisoning additives. It is our vital responsibility to protect the environment by eliminating the environmental poisons of the lubricating oils.
The need to comply with environmental legislation has enhanced the demand for environmentally acceptable technologies and designs which would help abate the adverse effects of chemicals and products such as lubricating oils an air water and soil.
One of the available preventive measures to reduce the environmental contamination is the use of easily biodegradable lubricating oils
Typical results for a number of base oils are shown in figure 7.

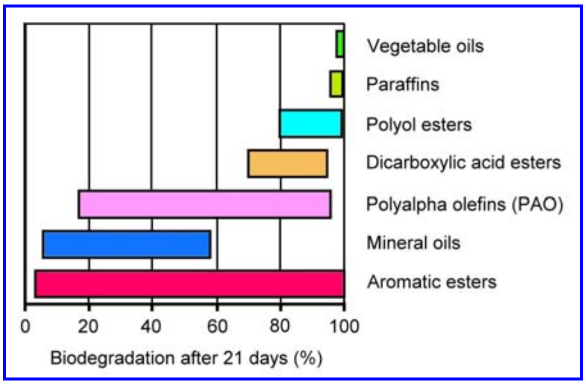

Figure 7: Biodegradation of various base oils in the CEC L-33-A-93 test

3. CURRENT EURO-4 SPECIFICATIONS

Global environmental regulations aimed at drastically reducing automotive emissions will require vehicles to be equipped with exhaust after-treatment systems. The durability and efficiency of that device, overlong periods must be good. Lubes and fuels contain elements such as sulfur, phosphorus and ash-forming metals (Fe, Ca, Zn) that can adversely impact on after-treatment systems. New engine oil specifications are being introduced that restrict the level of sulfated ash, phosphorus and sulfur (SAPS) as a way of minimizing the impact on the efficiency of the after-treatment system [14].
Table 2 shows ACEA C3-04 specifications/13/ for high HTHS oils and specifies a higher level of protection against wear and bore polishing than A3/B4-04. This specification also includes a fuel economy requirement which is at lower level of fuel economy improvement than either C1 or C2 /13/. C3-04 is stable, stay-in-grade oil intended for use as catalyst compatible oil in vehicles with DPF and TWC in high performance car and light van diesel and gasoline engines.
Current European engines emit approximately 1,5 to 3, 0 mg/kWh oil ash (corresponding to 8 to15% of total particulate for Euro IV/V), and proclaimed target is a maximum value on 0,5 mg/kWh (corresponding to 2,5 of total particulate for Euro IV/V).
The demands on automotive lubricants have never been greater in terms of their technical requirements.
From that aspect, low viscosity synthetic motor oil is expected to dominate in vehicles in the next decades.
Especially, for the sake of lowering NOx and particulate emissions of heavy-duty diesel engines they need low emission lubricants. The key elements used in lubricant formulation today and future are: **sulfur, sulfated ash and phosphorus.** These elements in lube oil are going to cause compliance problems as emission limits fell.
Stable, stay-in-grade oil in E6 quality (tab.3) providing excellent control of piston cleanliness, wear, soot handling and lubricant stability is recommended for highly rated diesel engines, especially for engines fitted with SCR NOx reduction and PDF. E6 quality is designed for use in combination with low sulfur diesel fuel (<50 ppm).

Table 2: ACEA C3-04 specifications

TEST NAME	TEST CRITERIA DESCRIPTION	UNITS	LIMITS
SAEJ300	No restriction except as defined by shear stability and HT/HS requirements. Manufacturers may indicate specific viscosity requirements related to ambient temp.		
Shear stability	Viscosity at 100°C after 30 cycles	cSt	All grades to be stay in grade
HTHS viscosity	Viscosity at 150°C and $10^6 s^{-1}$ Shear rate	cP	≥3.5
Evaporation loss	Maximum weight loss	%	≤13
Sulphur		% wt	≤0.3
Phosphorus		% wt	0.070≤ ≤0.090
Sulphated ash		% wt	≤0.8
Chlorine		% wt	Report
TBN		mgKOH/g	≥6
RE1 Elastomer compatibility	Hardness Volume Tensile Strength Elongation at Breakage	points % % %	-1 to +5 -1 to +5 -40 to +10 -50 to +10
RE2-99 Elastomer compatibility	Hardness Volume Tensile strength Elongation at Breakage	points % % %	-5 to +8 -7 to +5 -15 to +18 -35 to +10
RE3-04 Elastomer compatibility	Hardness Volume Tensile strength Elongation at Breakage	points % % %	-22 max 22 max -30 to +10 -20 to +10
RE4 Elastomer compatibility	Hardness Volume Tensile strength Elongation at Breakage	points % % %	-5 to +5 -5 to +5 -20 to +10 -50 to +10
AEM (VAMAC)	As per Daimler Chrysler		
Foaming tendency	Tendency - Stages I / II / III Stability - Stages I / II / III	ml ml	0 / 50 / 1C 0
High temperature foaming tendency	Tendency - Stage IV Stability - Stage IV	ml ml	

Table 3: ACEA E6-04 specifications

TEST NAME	TEST CRITERIA DESCRIPTION	UNITS	LIMITS
SAEJ300	No restriction except as defined by shear stability and HT/HS requirements. Manufacturers may indicate specific viscosity requirements related to ambient temp.		
Shear stability	Viscosity at 100°C after 90 cycles	cSt	stay in grade
HTHS viscosity	Viscosity at 150°C and $10^6 s^{-1}$ Shear rate	cP	≥3.5
Evaporation loss	Maximum weight loss after 1h at 250°C	%	≤13
Sulphated ash		% wt	≤1.0
Phosphorus		% wt	≤0.080
Sulphur		% wt	≤0.3
RE1 Elastomer compatibility	Hardness Volume Tensile Strength Elongation at Breakage	points % % %	-1 to +5 -1 to +5 -50 to +10 -60 to +10
RE2-99 Elastomer compatibility	Hardness Volume Tensile strength Elongation at Breakage	points % % %	-5 to +8 -7 to +5 -15 to +18 -35 to +10
RE3-04 Elastomer compatibility	Hardness Volume Tensile strength Elongation at Breakage	points % % %	-25 to +1 -1 to +30 -45 to +10 -20 to +10
RE4 Elastomer compatibility	Hardness Volume Tensile strength Elongation at Breakage	points % % %	-5 to +5 -5 to +5 -20 to +10 -50 to +10
AEM (VAMAC)	As per Daimler Chrysler		
Foaming tendency	Tendency - Stages I / II / III Stability - Stages I / II / III	ml ml	≤10 / 50 / 10 0 / 0 / 0
High temperature foaming tendency	Tendency - Stage IV Stability - Stage IV	ml ml	≤200 50

The Mercedes Benc service fill specification 229.31(tab.4) is only applicable for 0W-XX and 10W-XX multigrade high performance passenger car engine oil. It is the only

Table 4: MB 229.31 specification

TEST NAME	TEST CRITERIA DESCRIPTION	UNIT	LIMITS
Sulphated ash	Content	% wt	≤0.80
Phosphorus	Content	% wt	≤0.08
TBN	ISO 3771	mgKOH/g	≥6.0
Sulphur	Content	% wt	≤0.20
Chlorine	Content	% wt	≤0.0050
Pour point		°C	≤-36
Evaporation loss	Noack max weight loss, 1h/250°C	%	≤12
HTHS viscosity	Viscosity at 150°C, 10^6 s^{-1}	cP	≥3.5
NBR 34 Elastomer compatability	Hardness Volume Tensile Strength Elongation at Breakage	points % % %	-8 to +2 0 to +10 ≥-20 ≥-35
AK6 Elastomer compatability	Hardness Volume Tensile Strength Elongation at Breakage	points % % %	-5 to +5 0 to +5 ≥-50 ≥-55
ACM E7503 Elastomer compatability	Hardness Volume Tensile Strength Elongation at Breakage	points % % %	-2 to +6 -3 to +10 -2 to +6 ≥-50
EAM D8948-200 Elastomer compatability	Hardness Volume Tensile Strength Elongation at Breakage	points % % %	-5 to +10 -5 to +15 ≥-35 ≥-50

specification for engine oils use in BR 600 series diesel engines that are fitted with DPF.
The MB service fill specification 228.51 (tab.4) is applicable for high performance multigrade diesel engine equipped with DPF meeting Euro 4 (also in Eu 3, Eu 2, Eu 1) emission standards.

Table 5: MB 228.51 specification

TEST NAME	TEST CRITERIA DESCRIPTION	UNIT	LIMITS
Sulphated ash	Content	% wt	≤1.0
Phosphorus	Content	% wt	≤0.08
TBN	ISO 3771	mgKOH/g	≥7.0
Sulphur	Content	% wt	≤0.3
Chlorine	Content	% wt	≤0.0050
Pour point		°C	≤-27
MTU deposit test	Result 1,2,3 and Average	mgKOH/g	Rate and Report
Evaporation loss	Noack max weight loss, 1h/250°C	%	≤12
HTHS viscosity	Viscosity at 150°C, 10^6 s^{-1}	cP	≥3.5
NBR 34 Elastomer compatability	Hardness Volume Tensile Strength Elongation at Breakage	points % % %	-8 to +2 0 to +10 ≥-20 ≥-35
AK6 Elastomer compatability	Hardness Volume Tensile Strength Elongation at Breakage	points % % %	-5 to +5 0 to +5 ≥-50 ≥-55
ACM E7503 Elastomer compatability	Hardness Volume Tensile Strength Elongation at Breakage	points % % %	-2 to +6 -3 to +10 ≥-30 ≥-50
ACM D8948-200 Elastomer compatability	Hardness Volume Tensile Strength Elongation at Breakage	% % % %	-5 to +10 -5 to +15 ≥-35 ≥-50

Table 6 shows Man M3477 specification which is applicable to high performance diesel engine oil meeting SAE 0W-XX, 5W-XX or 10W-XX.

An oil meeting this specification is suitable for MAN diesel engine equipped with after-treatment devices.

Table 6. MAN M 3477 specification

TEST NAME	TEST CRITERIA DESCRIPTION	UNIT	LIMITS
HTHS viscosity	Viscosity at 150°C, 10^6 s^1	cP	≥3.5
Shear stability Viscosity after shear	xW-30 xW-40	cSt cSt	≥9 ≥12
Evaporation loss	Noack	%	≤12
Flash point	Cleveland open cup (COC)	°C	≥215
Pour point	5W-XX or 0W-XX 10W-XX	°C °C	≤-40 ≤-30
TBN	Basicity	mgKOH/g	≥10
Phosphorus		% wt	≤0.08
Sulphated Ash		% wt	≤1.0
Sulphur	Total from additive only	% wt	≤0.3
Foaming Without option A	Tendency - Stages I / II / III Stability - Stages I / II / III	ml ml	≤10 / 50 / 10 0 / 0 / 0
MTU Deposit test	Turbocharger and intercooler deposits	mg	≤120
PDSC	Oxidation stability	min	≥100
SRE - NBR 34 (DIN 53521) Elastomer compatibility	Hardness Volume Tensile Strength Elongation at Breakage	points % % %	-10 max 0 to +10 -20 max -30 max
AK6 (DIN 53531) Elastomer compatibility	Hardness Volume Tensile Strength Elongation at Breakage	points % % %	-5 to +5 max -2 to +5 -30 max -40 max

4. CONCLUSIONS

1. New emission regulations demand new engine oil formulations.
2. Contribution of engine lubricant oil to exhaust HC, CO, NOx and particulate emissions is obvious and depends on both engine and oil characteristics.
3. The most important oil physic-chemical characteristics affecting engine emissions are: content of sulfur, aromatics, sulfate ashes, i.e. metal, viscosity and volatility.
4. Synthetic oils produce less HC, NOx and particulate Emissions than mineral lubricant oil.
5. To produce engine emissions, and in order to save environment, it is necessary not only to use low sulfur fuel but also lubricant oil containing low contents of sulfur (0,2-0,4%), sulfate ashes (1,0%), phosphorus (0.05%) and having low rate of volatility (< 15%) and low viscosity.

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