LUBE OIL CONSUMPTION'S IMPACT ON ENVIRONMENT

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Abstract

The problem of lube oil consumption has been the point of interest of scientists for years, first because of economy and later – because of stringent standards of environment protection.

From the point of economy lube oil consumption is not a problem of modern engines. On the other hand even a brief look proves that there is a quite wide range of admissible consumption from negligible values up to even 1 litre per 100 km. The question is why this range is so wide. Possible answer is that engine manufacturers leave so wide margin taking into consideration situations of very short trips, mainly in towns, when engine runs not fully warmed up with greater clearances, especially within the piston-cylinder assembly. Any oil consumption results in emission of particulate matter, which conveys a weighty number of hydrocarbons of which the most manifest serious hazardous properties, mainly carcinogenic ones.

Nowadays, standards of environment protection require for instance the use of diesel particle filters and the excessive oil consumption could lead to the premature damage of these devices. Correct operation of the DPF could be disturbed not only by the excessive oil consumption but also by the use of improper oil, i.e. the non-low ash one. Certain additives that improve oil properties could produce ash as a result of oil combustion, which could clog filter irreversibly.

***Keywords**: lubricating oil consumption, particulate matter, diesel particulate filter*

1. Introduction

The quantitative lubrication oil consumption of modern automobile engines does not make any problem from the economic point of view. However, even a brief analysis of admissible oil consumption given by engine producers shows that the range is quite wide from practically negligible values up to even one litre per 1000 km mileage. One could wonder why this range is so wide. One of the causes could be short trips until the engine reaches thermal balance which could happen in urban traffic. The need, for limitation of oil consumption, even in the described circumstances, outcomes from the ecologic effects relative to lube oil consumption and introduction of constructional solutions to modern IC engines that facilitate meeting stringent standards limiting the environmental pollution.

2. The phenomenon of lubricating oil consumption

The most important source of lube oil losses is the "piston-pin-rings-bore" assembly. The clearance between valve stem and valve guide is another possible direction of oil passage to the combustion chamber and contribution of inlet valves in this process is the dominant one. Moreover, loss of oil can be caused by improperly operating movable and stationary sealing.

The prime goal of lube oil presence on the surface of cylinder bore is the lubricating of the piston-cylinder liner group in order to minimize friction losses generated in this area during engine operation. Alas, even under the conditions of correct lubrication these losses could reach as much as half of the entire friction losses generated by the engine.

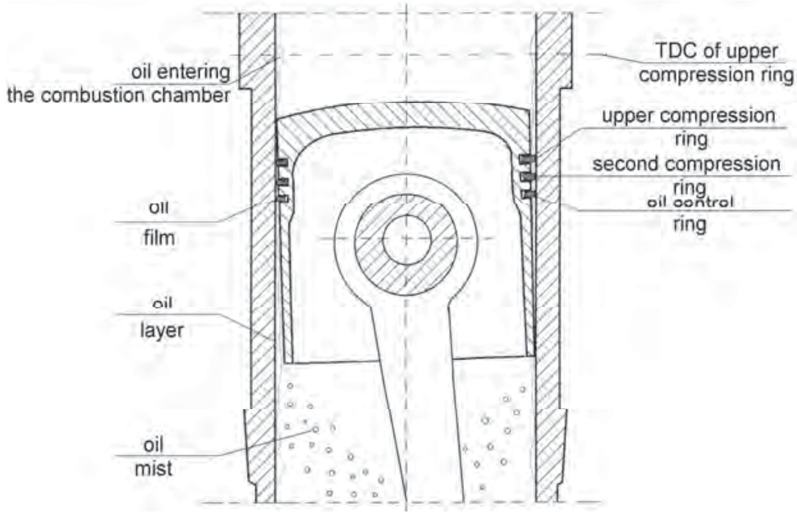

Fig. 1. Sketch of lube oil penetration towards combustion chamber

3. Methods of lube oil consumption measurement

Various measuring methods could be applied in order to evaluate the lubrication oil consumption beginning with the weighing the engine before and after the trial, weighing the oil pan located outside the engine, through the method of continuous oil additions and finishing with nowadays used method of automatic measurement based on the principle of connected vessels.

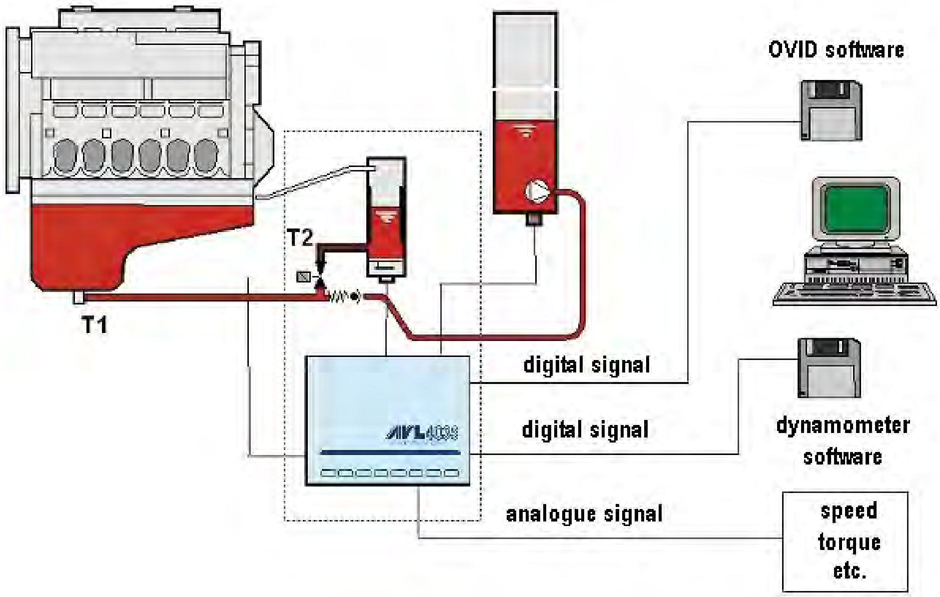

Fig. 2. Sketch of the AVL403s oil consumption measuring device

All the methods mentioned have one serious disadvantage, namely they are very time consuming and at the same time burdensome and expensive ones. Due to that at numerous R&D centres efforts have been made to develop a computer model of the piston-cylinder group elements collaboration that could determine a lot of operational parameters including lube oil consumption. A positive experimental verification of such model entitles to make use of obtained results to define suitable values of parameters describing the proper collaboration of piston-cylinder assembly elements.

The computer model of piston-cylinder group used for computations assumes that correct collaboration between ring face and bore securing possibly low oil consumption looks like the case

(a) in Fig. 3. The oil film covers then only a part of ring face. On the other hand, both case (b) and (c) mean an increased oil consumption resulting from ring tilt (first) or too thick oil layer in front of ring (second) that lead to the oil scraping towards the combustion chamber.

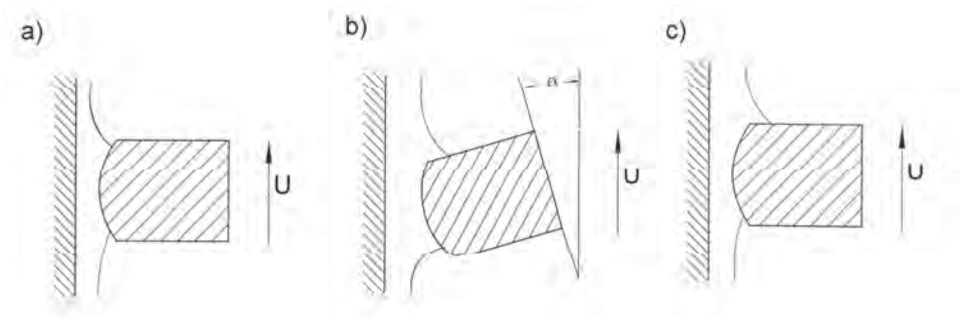

Fig. 3. Three cases of ring-to-bore collaboration

4. Ecological effect of lube oil consumption

As one can conclude from the previous description, the lubricating oil is being supplied to the bore surface in order to diminish mechanical losses which inevitably lead to its combustion and consequent emission of the hazardous compounds to the environment. So called particulate matter is the most serious toxic compound of emission, result of oil combustion in engine.

There is no explicit definition of particulate matter that is a constituent of emission gases. The particulate matter contains soot, sulphuric and metallic compounds, inorganic particles and heavy fraction of lubricating oil and fuel originated hydrocarbons.

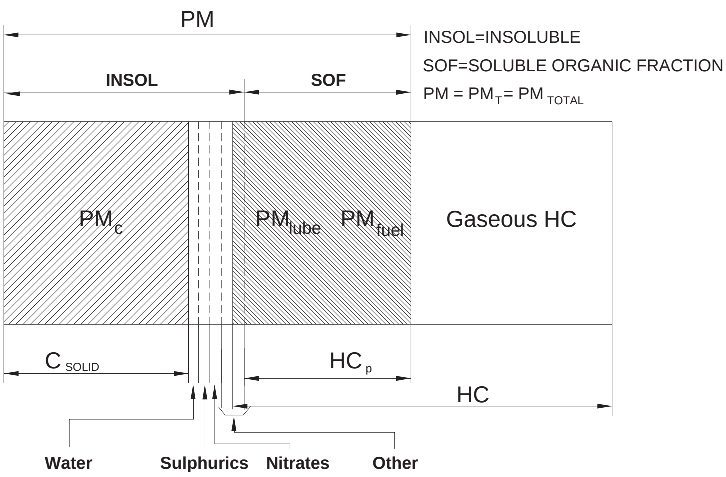

Fig. 4. Structure of particulate matter [4]

When measuring the toxic compounds emitted by combustion engines the term of "particulate matter" means all solid and liquid matter, organic or inorganic ones that is trapped on a absolute filter (of 99% efficiency, seizing particles not smaller than 0.3 μm in diameter) after passing a flow of exhaust diluted with air at the temperature of 52 deg C [5].

The way particulate matter forms itself differs according to the type of engine: diesel or gasoline one.

The emission of particulate matter from gasoline engine is a minor one. There are different classes of particulate matter depending on major compound that could be organic compounds or metal particles originating from engine elements wear or from lube oil additives purposed for better oil properties like ability to carry loads, e.g. Zinc Dialkyl-Dithio-Phosphate (ZDDP). Because of the lower speed of thermal decomposition of gasoline its susceptibility to soot formation is low. The hydrocarbon part of particulate matter (PM_{SOF}) originates mainly from combustion of lubricating oil and to very limited extent is being formed as a result of fuel incomplete combustion on that type of engine.

Tab. 1. Evolution in standards of admissible contents of toxic compounds in combustion engine exhaust

Emission standard	Particulate matter (PM) [mg/km]		Nitric oxides (NOx) [mg/km]		Hydrocarbons (HC) [mg/km]	
	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline
Euro 2 ('96)	80-100	–	–	–	–	–
Euro 3 ('00)	50	–	500	150	–	200
Euro 4 ('05)	25	–	250	80	–	100
Euro 5 ('09)	5	5	180	70	–	100
Euro 6 ('14)	5	5	80	70	–	100

When an engine is being fuelled with unleaded gasoline only liquid organic particles are emitted and this emission does not excess 20 mg/km for an engine without a catalytic converter. Because of soot presence in exhaust the level of particulate matter is far higher on diesels than on gasoline engines.

On diesel engines the level of particulate matter emission is higher than on gasoline engines due to the presence of soot which is the product of incomplete combustion, characteristic for this type of engine. Soot emitted by the diesel is a complex of pure carbon particles with adsorbed products of incomplete combustion (see Fig. 5). Depending on conditions in combustion chamber these products could be compounds of oxygen (mainly aldehydes) or polycyclic aromatic hydrocarbons (PAHs) like benzopyrene, pyrene or anthracene.

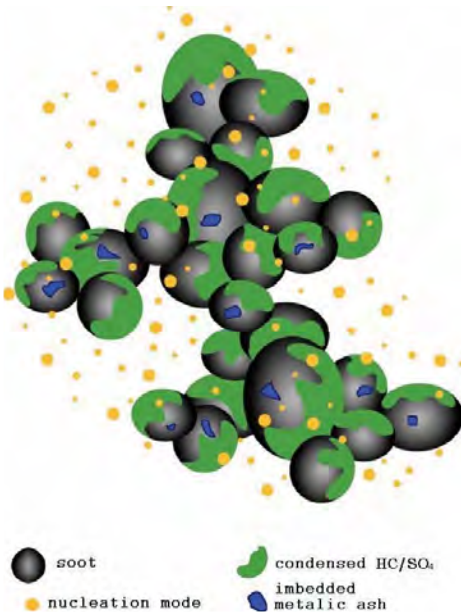

Fig. 5. Artist's conception of diesel PM [3]

The composition of particulate matter collected from diesel's exhaust system is as follows: oil (both from fuel and lube oil) – 40%, soot – 30%, sulphuric and confined water – 14%, unburned hydrocarbons – 1%, unidentified reminder – 8%.

Formation of PM occurs at the first stage of condensation of fuel and oil-like substances created as a result of oxidation or pyrolysis. Products obtained as result of these processes contain various unsaturated hydrocarbons, particles of acetylene, higher derivatives of $C_{2n}H_2$ and PAHs.

Reactions of condensation of these compounds lead to formation of soluble (SOF) and insoluble (INSOL) fractions.

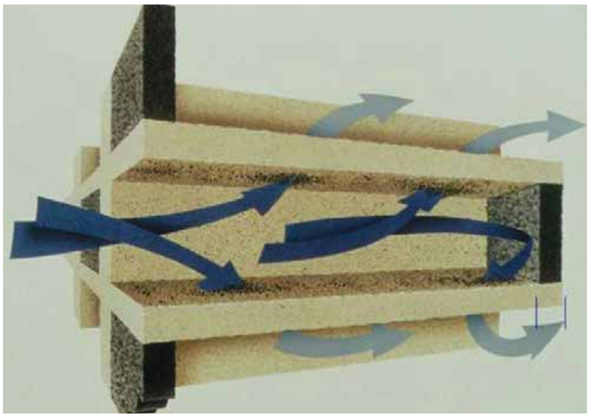

Fig. 6. Structure of DPF (Diesel Particulate Filter) [3]

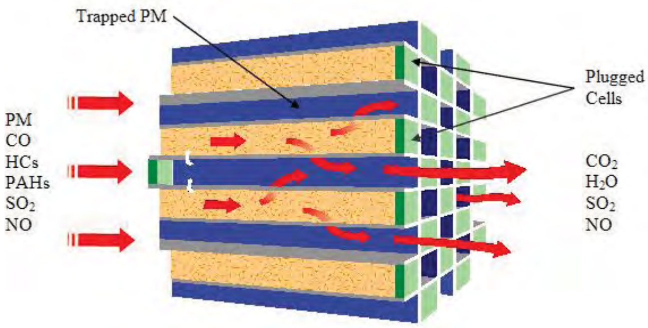

Fig. 7. Principle of DPF (Diesel Particulate Filter) operation

Moreover, particulate matter serves as carrier of PAHs while the presence of soot plays a substantial role in emission of PAHs. Soot has a highly developed specific surface (at the flame temperature it can exceed 100 sqm/g) which determines its absorbability. Despite that differences in growth of PAH and PMT can occur as a result of different circumstances accompanying formation of these substances (temperature, in particular). For example, temperature rise causes the decline of atomic relation H/C of soot (it stabilizes at temperature of 1300 K). So an increase of PAH at constant PM proves about the course of pyrolytic processes at lower temperature (bigger contribution of PAH formation process at very temperature below 1300 K than formation of soot „carbon framework" which occurs at higher temperature). Moreover, formation of PAH and PM can also occur in other regions of combustion chamber [4].

The insoluble fraction of particulate matter could originate from unburned particles of metals. These metals can be the products of engine elements wear but they can also derive form lube oil additives purposed for the increase in oil load capacity – it could be calcium or zinc (added in form of ZDDP – zinc dialkyldithiophosphates) [1]. The zinc additive is particularly significant because on the one hand its presence in lube oil dedicated to diesels should be very desirable in higher loaded engine while on the other hand such engines are often equipped with diesel particulate filters (DPF) and removing particles of metallic origin is impossible. Due to that lubricating oils dedicated to engines with DPFs should be so called "low-ash" oils. It should be added here that insoluble particulate matter that leaves car exhaust system are hazardous to man's and animals' health because they deposit in lungs and could cause chronic and often lethal diseases.

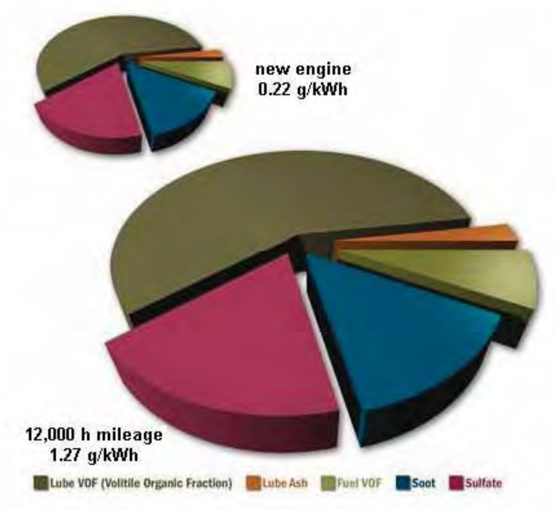

Fig. 8. Projected increase of particulate matter emission resulting from engine increased wear

5. Conclusions

New solutions aimed at lowering the level of soot emission for almost unchanged content of trace metals in fuels and lubricating oils could lead both to an increase in metal to soot ratio in emitted particles and to intensive formation of nanoparticles rich in metal through creation of crystal nuclei. Metals in these nanoparticles could originate from dirt in fuel, products of engine elements wear and also from lube oil consumption or fuel additives added in order to purify DPFs. Microscopic dimensions of nanoparticles make that they easily enter lungs which could lead to health problems of human population. Therefore the limitation of lube oil consumption is one of the essential steps towards the reduction of automotive environmental pollution.

References

[1] Barnes, A. M., Bartle, K. D., Thibon, V. R. A., *A Review of Zinc Dialkylditiophosphates (ZDDPs) Characterization and Role in the Lubricating Oil*, Tribology International 34, pp. 389-395, 2001.
[2] Key, W. S., *Lube Oil Contribution to Emissions.*
[3] Matti Maricq, M., *Chemical Characterization of Particulate Emissions from Diesel Engines, A Review*, Journal of Aerosol Science, 38, pp. 1079-1118, 2007.
[4] Merkisz, J., *Ekologiczne problemy silników spalinowych*, Politechnika Poznańska, T. 1, 1998.
[5] Serdeckiego, W. (red.), *Badania silników spalinowych – laboratorium*, Politechnika Poznańska 1998.