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MONITORING OF CHEMICAL ELEMENTS DURING LIFETIME OF ENGINE OIL

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Abstract

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Awareness of engine oil condition is a valuable indicator for assessing the state of degradation of the lubricant. The article deals with monitoring of chemical elements, especially metals and additives, during lifetime of commercially distributed automobile engine oil Castrol Magnatec 10W–40. Engine oil was regarded as a Newtonian fluid. The passenger car Renault Scenic I with petrol engine (four pistons, volume 1,600 cm^3) was used to the observed. Lifetime of automobile engine oil has been stated by car and lubricants producers in interval 15,000 km. The samples of automobile engine oil have been taken in suitable intervals – 1,500 km. Only first sample of used engine oil was taken with raid 20 km. The seasons of monitoring were spring and summer. The spectrometer Spectroil Q100 has been used to monitoring of chemical elements in automobile engine oil. Increase contents of metals and decrease contents of additives were observed. The results were modelled using mathematical models with given the values of coefficient correlation *R*. Linear function as a mathematical model with the lowest number of degrees of freedom was used. Created mathematical models can be used to predict of conditions of engine oil in the same or similar petrol engine aggregates.

Keywords: chemical elements, metals, engine oil, lifetime, spectrometry

INTRODUCTION

The effective tool to monitoring engine condition is analysing its engine oil. With increasing number of taken samples of engine oil, increase the accuracy of analyses. The main emphasis is placed to the sampling apparatus – extraction injection, containers, etc. Selection of sampling point and interval of sampling is very important too. This area is described in the following publication (Vališ *et al.*, 2013).

The engine oil lifetime extended and cylinder volume downsizing (with increasing power) is a new trend in these times in automobile industrial. The lifetime extension is tempting for customer, but for tribotechnic this is the large problem (Sroka, 2012).

The publication (Lake *et al.*, 2004) is mentioned that downsizing is not problem for kinematic viscosity, density, and shear stress of engine oil, but in used oils there are many of metal particles and other contaminants, which pile up in engine oil during lifetime. It can cause malfunction of the engine or even crash the entire system (Smith and Cheng, 2013).

The most of the friction places are made from several metals. The most of them there are treated iron containing other metals, aluminium and copper components, some portion coated with a surface layer of another metal in order to increase the surface hardness and improve sliding properties, improved corrosion protection, etc. Therefore, it must be also interested in other metals (except iron only), such as aluminium, copper, chromium, lead, tin, nickel, silver, etc. (Kumbár and Dostál, 2013).

The other chemical elements, which must be monitored in engine oil, these are chemical elements contained in oil additives. These are detergents, dispersants, friction modifiers, viscosity modifiers, anti-freeze agents, antioxidants, substances affecting the freezing point, anti-abrasion additives, lubricating ingredients and some others. In most cases these are the elements molybdenum, phosphorus, boron, calcium, zinc, magnesium, etc. Similar theses have been stated in publications (Valach *et al.*, 2013) and (Meng and Huang, 2011).

MATERIALS AND METHODS

The passenger car Renault Scenic I with gasoline engine has been used. This car have gasoline engine with 1,600 cm^3 cylinders capacity and the power 79 kW. The year of made is 1999. Commercially available automotive engine oil Castrol Magnatec 10W-40 (ACEA A3/B3) has been used. The lifetime interval of this engine oil is 15,000 km (according to the manufacturer's recommendations). The samples of used engine oil have been always taken after 1/10 of lifetime interval of engine oil – thus means 1,500 km. The season was spring and summer. The exact intervals of samples taken are reported in Tab. I.

Spectrometry

With the chemical analyses it has been founding metals and additives in the new and used engine oils. Determining the chemical composition of oils has been measured using Spectroil Q100, which is a completely solid state spectrometer, specifically designed for the analysis of oil samples. With this spectrometer it can be measured trace levels of elements dissolved or deposited as fine particles in mineral or synthetic oil-based products using long established and reliable technique with rotating disk electrode. The device meets the requirements of ASTM D6595 standard method for the determination of wear metals and contaminants in used lubricating oils and hydraulic mixtures. Increase metals content and decrease additives content have been modelled using linear function as in publication (Kumbár *et al.*, 2013).

RESULTS AND DISCUSSION

By the spectrometry was determined the chemical composition of samples of the new and used engine oil. The samples of used engine oil have been compared with samples of new engine oil same specification. It is important to the finding of the on-going state of degradation (Moritani and Kawai, 2006).

The Fig. 1 is showed increase contents of metals during lifetime of engine oil. The content of metal is presented in unit $mg.kg^{-1}$, respectively in *ppm*. The Fig. 1 shows the little increase of all observed metals. The biggest increase of metals contain in engine oil is from copper (Cu) and iron (Fe). These two elements are usually use as construction material of engine. Contain of copper increases from 1 $mg.kg^{-1}$ to the 5 $mg.kg^{-1}$, and contain of iron increases from the 2 $mg.kg^{-1}$ to the 7 $mg.kg^{-1}$. These are not high values of content, which is according publication (Černý, 2006).

The Fig. 2 is showed decreases of some chemical elements using as oil additives. Manganic (Mn) and molybdenum (Mo) decrease slowly with raid but boron (B) decreases quickly with raid. Boron contains in anticorrosion additives.

The Fig. 3 is showed elements phosphorus (P) and zinc (Zn). Phosphorus is usually contained in oil additives and zinc is usually used as construction material of engine.

The increasing and decreasing of metal and chemical elements has been modelled using linear function with general formula:

$$y(x) = A + k.x, \quad (1)$$

for example iron (Fe) can be calculated by formula:

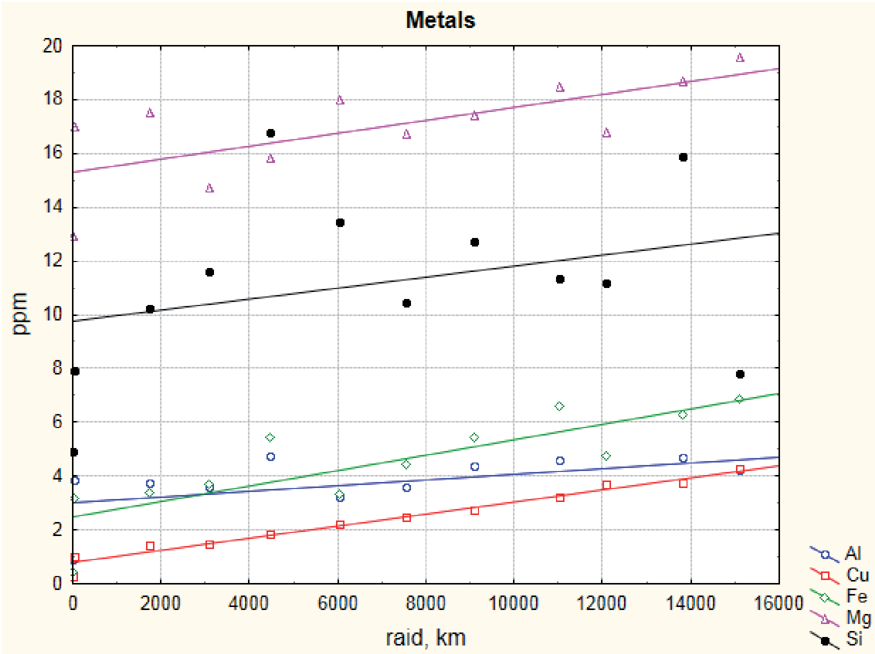
$$contain\ of\ Fe = 2{,}4714 + 0{,}003.raid\ [ppm; km], \quad (2)$$

where it must be respected the lifetime of engine oil 15,000 km, respective and maximal 30,000 km.

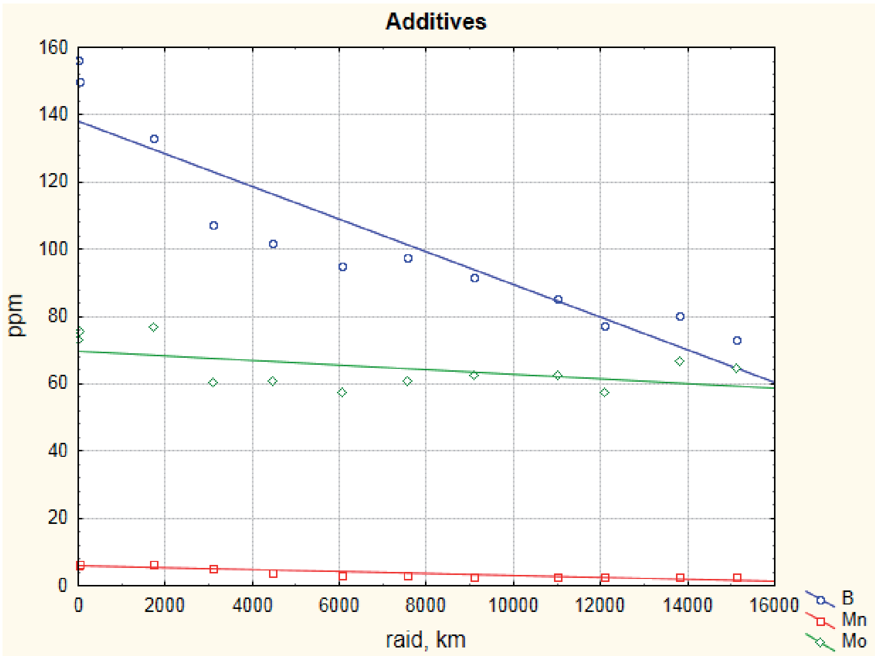
Correlation coefficients R achieve high values from the 0.79 to the 0.98. Similar values of correlation coefficient achieve authors in publications

I: *Intervals of collect samples of engine used oil*

Number of sample	Date of sample taken	Raid of oil, km	Raid of car, km
1	3. 3. 2012	0	171.790
2	4. 3. 2012	20	171.810
3	16. 3. 2012	1.737	173.527
4	28. 3. 2012	3.097	174.887
5	7. 4. 2012	4.462	176.252
6	23. 4. 2012	6.053	177.843
7	9. 5. 2012	7.550	179.340
8	28. 5. 2012	9.104	180.894
9	13. 6. 2012	11.027	182.817
10	27. 6. 2012	12.079	183.869
11	12. 7. 2012	13.815	185.605
12	25. 7. 2012	15.108	186.898



1: *Increase contents of metals in engine oil*



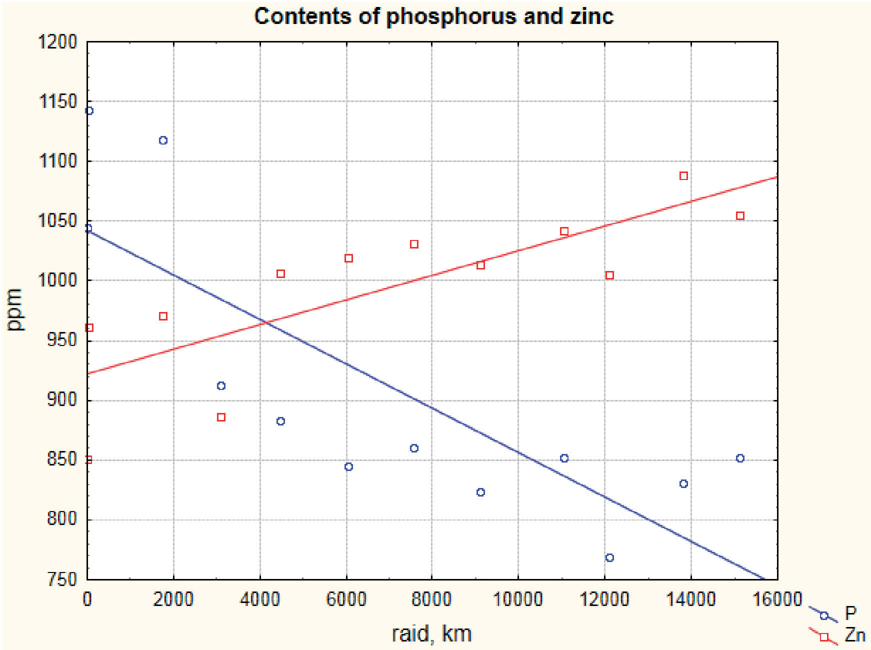
2: *Decrease contents of additives in engine oil*

(Božiková and Hlaváč, 2013) and (Trávníček *et al.*, 2013). Tab. II is showed constant values *A* and *k* for all of used chemical elements.

CONCLUSIONS

In this part of the paper it can be stated that using method (spectrometry) is as one of the basic oil analyses very suitable. The suitability rises when the samples of used engine oil are compared with the sample of new (unused) engine oil with same specification.

Using spectrometry has been determined chemical composition of all samples of engine oil. It has also been quantified individual chemical elements in the new and used engine oil. With graphs it can be seen increasing trends polluting elements (metals) and decreasing trends of oil additives (detergents, dispersants, friction modifiers, viscosity modifiers, anti-freeze agents, antioxidants, substances affecting the freezing point, anti-



3: *Contents of P and Zn*

II: *Constant values A and k*

Chemical elements	Constant A	Constant k
Al	3.0318	0.0001
Cu	0.7738	0.0002
Fe	2.4714	0.0003
Mg	15.2793	0.0002
Si	9.7779	0.0002
B	138.0036	–0.0049
Mn	5.8424	–0.0003
Mo	69.5518	–0.0007
P	1041.6257	–0.0186
Zn	922.0322	0.0103

abrasion additives, lubricating additives and some other).

All trends have been modelled using linear function. Linear function is basic mathematical model, which there can be used. But linear function is very accurate, if it be used it properly. Coefficients of correlation *R* have achieved high values – from the 0.79 to the 0.98.

Created mathematical models can be used to prediction changes in lifetime of engine oil fill in same or similar petrol engine.

SUMMARY

The main goal of this article deals with monitoring of chemical elements during lifetime of commercially distributed automobile engine oil Castrol Magnatec 10W-40. The passenger car Renault Scenic I with petrol engine (four pistons, volume 1,600 cm^3) was used to the observed. Lifetime of automobile engine oil has been stated by car producer in interval 15,000 km. The samples of automobile engine oil have been taken in suitable intervals – 1,500 km. Only first sample of used engine oil has been taken after raid of 20 km. The spectrometer Spectroil Q100 has been used to monitoring of chemical elements in automobile engine oil. Increase contents of metals and decrease contents of additives were especially observed. The results were modelled using mathematical models with given the values of coefficient correlation *R*. It can be stated that used method (spectrometry) is as one of the basic oil analyses very suitable. The suitability rises when the samples of used engine oil are compared with the sample of new (unused) engine oil with same specification. Using spectrometry it has been determined chemical composition of all samples of engine oil. It has also been quantified individual chemical elements in the new and used engine oil. With graphs it can be seen increasing trends polluting elements (metals) and decreasing trends of oil additives (detergents, dispersants, friction modifiers, viscosity modifiers, anti-freeze agents, antioxidants, substances affecting the freezing point, anti-abrasion additives, lubricating additives and some other). All trends have been modelled

using linear function. Linear function is basic mathematical model, which can be used. But linear function is very accurate, if it be used it properly. Coefficients of correlation *R* have achieved high values – from the 0.79 to the 0.98. Created mathematical models can be used to prediction changes in lifetime of engine oil fill in same or similar petrol engine.

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