THE STUDIES ON LUBRICITY AND CONTAMINATION ANALYSIS OF THE PERSONAL CAR'S LUBRICATING OIL WITH TAKING OIL AGEING INTO ACCOUNT

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Abstract

In this paper, the results of researches on lubricity and content analysis of the personal car's engine oil are presented. The measurements of lubricity are made on the T02-U four-ball tester. The content analysis is made on the Spectroil Q100 spectrometer, which makes it available to measure the amount of 24 chemical elements. Due to this analysis, technical condition of the engine is possible to estimate. Tested oil is Shell Helix AV-L, which was exploited in the personal car, Volkswagen Touran, equipped with the turbo charged diesel engine, with the capacity of 2.0 litres. The samples for oil ageing characteristics were taken from the engine in the intervals approx. 3500 km. This research was performed as a result of the other studies on the dynamic viscosity characteristics. In the viscosity researches for this oil, was shown, that in the first period of the exploitation time, the viscosity decreases significantly. Detailed research on the additives and wear products content, as well as a lubricity characteristic, defines the reason of such a significant decrease of the oil properties. This paper is a part of a wider research on the oil ageing characteristics. It will support development to the new mathematical model of the lubricating oil viscosity changes during the exploitation time of the engine.

Keywords: *oil ageing, viscosity characteristics, ageing model, rheology*

1. Introduction

Research of the viscosity changes are the main subject of this article author's research. During his research, author noticed that the oil's viscosity for the one of the samples, in the first stage of its exploitation dropped down significantly, what is approx. 20-30%, depending on the temperature and shear rate. According to the references [2], viscosity's drop down of more than 26%, makes the lubrication not sufficient. Drop down of the oil viscosity during exploitation is a normal phenomenon, but in this case, the viscosity's drop down is so significant, that it has to be clarified.

There are many factors, which have an influence on the oil's viscosity. Some of them come from the internal processes of the engine and the other ones depends on the external conditions such as: grade of the oil's filter contamination, clearness of the fuel, the way of the oil's change. In order to identify the factor, which has a major influence on the oil ageing; many detail tests of the chemical elements content and lubricity as well as the simple simulations have been performed.

Oil, which was investigated, is Shell Helix AV-L, exploited in turbocharged diesel engine, with the capacity of 2.0 Litre. Each one of the oil samples were taken from the engine's syringe, every time after long distance drive, approx. between distances of 3500 km. By the oil viscosity research, performed on the Haake Mars III rheometer, occurred, that the new oil's viscosity does not correspond to the characteristic of all other next samples [4].

2. Experimental research

Both of the compared real and predicted characteristics, included in this paper, have been

performed according to the following plan:
- For the input values, ageing characteristics have been performed.
- From the ageing characteristics, the first measurement points, correlated to the first oil sample have been cut.
- For the secondary characteristics, the function approximation, according to the assumed exponential function [4], have been performed
- Difference between original and predicted for the mileage of 0 km characteristics, is a background for the reason analysis of the viscosity drop down in the first stage of exploitation.

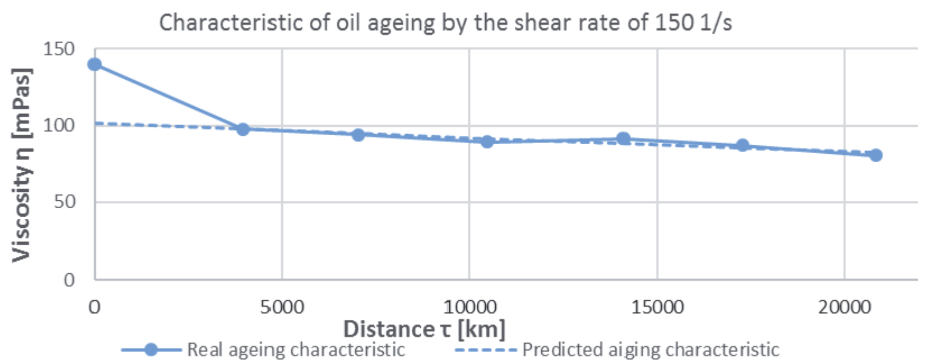

Fig. 1. Real and predicted ageing characteristics of the examined oil samples

Difference between real viscosity and predicted for the first measurement is 38.51 mPas. It means that in the first stage of exploitation, after distance of 3967 km, the oil has lost 27.5% of its viscosity properties.

The first possible reason which could have an influence on this situation, was the suspicion, that by the oil change, not whole amount of the oil was changed. Too short time between engine stop and the oil change and too short time for the complete oil leave from syringe could have caused, that a part of the used oil left in the engine and in the follow mixed with the new oil and worsened it's properties. In order to verify this suspicion, the viscosities of the new and used oil from the engine has been performed. Measured viscosities of the used oil, new oil and theoretical value for the shear rate of 150 1/s and the temperature of 20°C, are presented in Fig. 2.

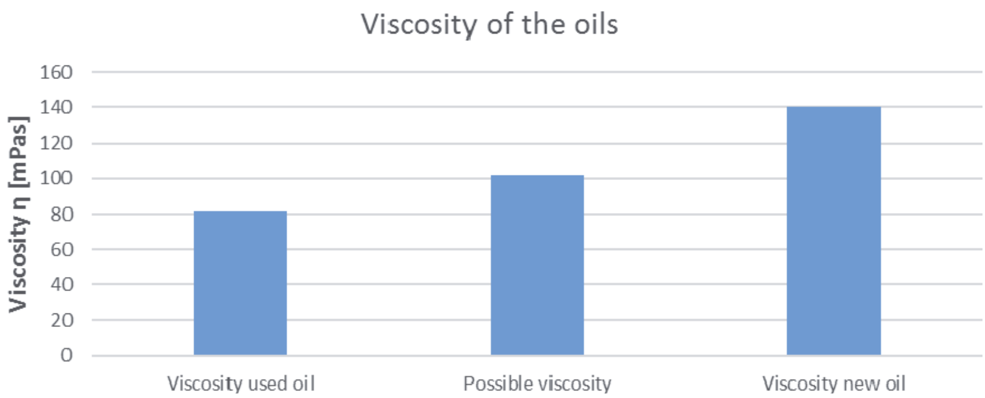

Fig. 2. Real and predicted ageing characteristics for contaminations

Using the method of proportion was calculated, that in this viscosity dependence for the new and used oil, in order to get a predicted oil viscosity, the new oil and the old one have to be mixed in the proportion of 34% of the new oil and 66% of the used oil. In the other words, if this suspicion were true, during the oil change, 2.5 litre of the used oil had to stay in the engine in order to get after mixing with the new oil the viscosity of 101 mPas. Such a fact is almost impossible, that is why the thesis of the not complete removal of the used oil from the engine was declined.

In consequence of the prior research, the decision to make a detail analysis of the chemical content of the oil and it's contaminations has been made. For this research the Spectroil Q100 spectrometer, which can specify content of 24 chemical elements in the examined oil. Results of this research are presented in Tab. 1.

Tab. 1. Chemical elements content in examined oil

Mileage [km]	Chemical elements content [ppm]										
	Ag	Al	B	Ba	Ca	Cd	Cr	Cu	Fe	K	Mg
0	0	8.669	0.378	0.372	1672.5	0.067	0.001	0.094	1.14	7.437	6.813
3967	0.004	50.088	2.219	0.513	1403.5	0.134	11.606	29.416	201.36	10.418	11.392
7032	0	49.669	2.280	0.448	1378.5	0.176	12.323	27.940	250.82	10.154	11.610
10471	0	49.272	2.188	0.436	1370.5	0.202	13.143	28.381	299.98	10.805	11.261
14117	0	51.983	2.421	0.440	1357.3	0.267	15.164	32.658	423.36	10.760	11.637
17291	0	51.723	2.443	0.455	1274.3	0.268	16.007	34.559	483.34	10.345	10.958

Mileage [km]	Chemical elements content [ppm]										
	Mn	Mo	Na	Ni	P	Pb	Si	Sn	Ti	V	Zn
0	1.277	2.944	4.817	0.336	698.42	1.638	15.526	0.001	0.414	0.132	828.02
3967	5.637	4.693	11.175	8.416	555.69	8.075	39.826	0.019	0.695	0.021	670.15
7032	6.588	4.644	8.634	8.868	505.15	9.049	40.516	0.261	0.745	0	668.15
10471	7.751	4.592	9.089	8.873	482.77	8.626	39.930	0.149	0.678	0.184	636.03
14117	9.728	4.863	8.999	9.472	474.44	10.299	47.790	0.425	0.749	0.228	633.18
17291	10.846	4.724	6.982	9.537	427.07	10.965	43.100	0.615	0.684	0.016	610.69

Analysis of the chemical elements content gives a view in the grade of the oil wear and also for the condition of the engine. Chemical elements, which are a content of the additives, are present in the new oil on a high level, which is getting lower during exploitation. Such a chemical elements are Zn, Ca, Mg, Ba, Mo, Cu, P, S [2]. Fig. 3. presents content of the major additive's chemical elements.

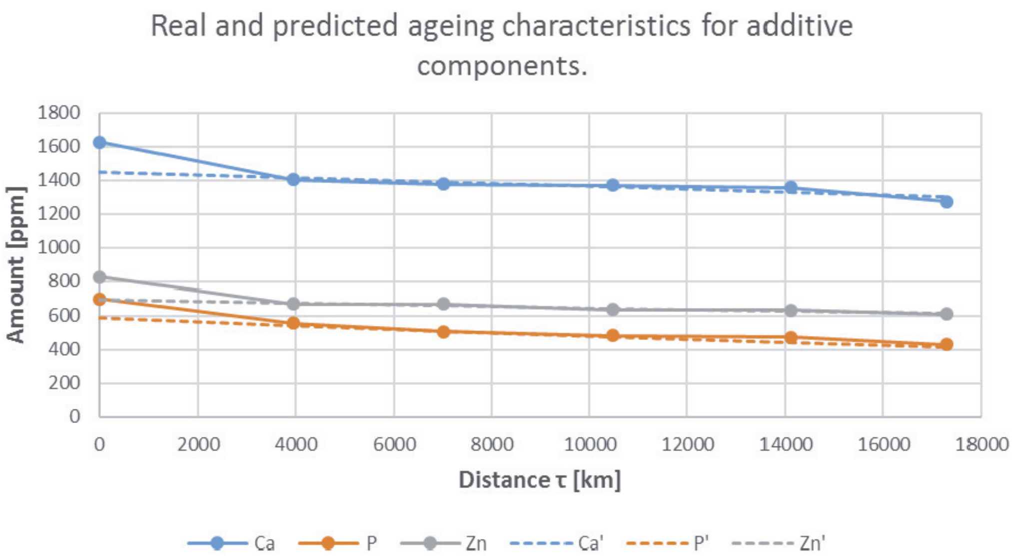

Fig. 3. Real and predicted ageing characteristics for contaminations

By the analysis of the amount of the chemical elements, which are content of the additives, was noticed, that in the first stage of the oil exploitation, the difference between real and predicted characteristic is 11% for Ca, 16 % for P and Zn.

Chemical elements, which are present in the new oil on the very low level and their content grows in the exploitation time, are a content of the contaminations. Such an elements are e.g. Fe, Cr, Al, Mo, Pb, Sn, Cu, in case of the contamination from the engine's construction and Na, V, Al, Si, which come from the fuel and combustion process [1]. Resulting from analysis of the data collected in the Tab. 1, was assumed, that for the further research, only those chemical elements, which are on the lowest level, should be taken into account. Such an elements are: Cr, Cu and Pb. Content of this elements in the new oil is on the very low level, what means, that they are not a content of the additives and their presence represents directly grade of the oil's wear. Fig. 4. presents the ageing characteristics for the contamination of engine's wear products.

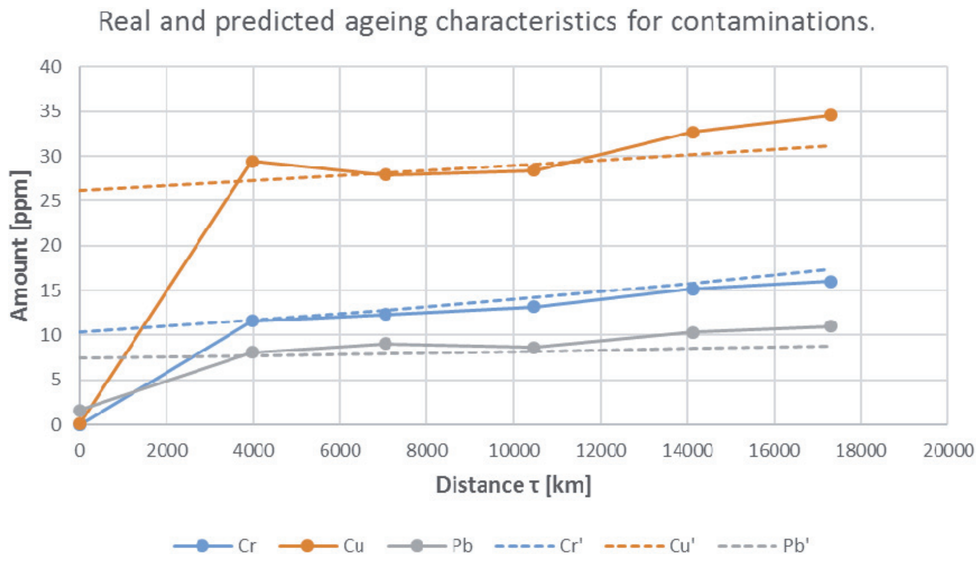

Fig. 4. Real and predicted ageing characteristics for contaminations

Form the Fig. 4 is possible only to estimate, in which grade the engine was contaminated directly after oil change. Presence of the metal contamination in the engine is impossible to avoid, because they are collected in every corner of the lubrication system, just after first start of the engine. Fresh oil has a high cleaning and resolving properties, what causes that collected in the whole lubrication system metal particles are easy to resolve. Based at the level of the contamination is not possible to determine the reason of the oil's viscosity drop down on the first stage of exploitation after change.

In a result from the lack of definitive reason of oil viscosity drop down in the first stage of exploitation, was decided to make an researches on lubricity of this oil. This research leads to estimation of the influence of all of the researched values on the tribological properties of the oil and its exploitation properties [1].

Lubricity of the examined oil has been tested on the four-ball tester T-02U, according to the polish standard PN-76/C-04147 and the procedure elaborated by the ITEE institute in Radom. In this research, the critical pressure of seizure is to be found for each of the oil samples. Tab. 2 presents the critical seizure load for each sample and maximal scuffing load.

Tab. 2. Lubricity parameters for the tested oil

Parameter	Distance of the oil's exploitation [km]						
	0	3967	7032	10471	14117	17291	20837
Scuffing load, P_t [N]	1700	1900	1800	2200	2200	2200	2200
Limiting seizure load, p_{oz} [N/mm^2]	102.96	120.33	126.91	135.89	143.41	165.02	186.36
Critical pressure of seizure, P_{oz} [N]	2200	2200	2100	2300	2400	2400	2300
Average diameter of the flow, d [mm]	3.33	3.08	2.93	2.97	2.95	2.75	2.53

For the real and predicted lubricity, the characteristics have been made and presented in Fig. 5.

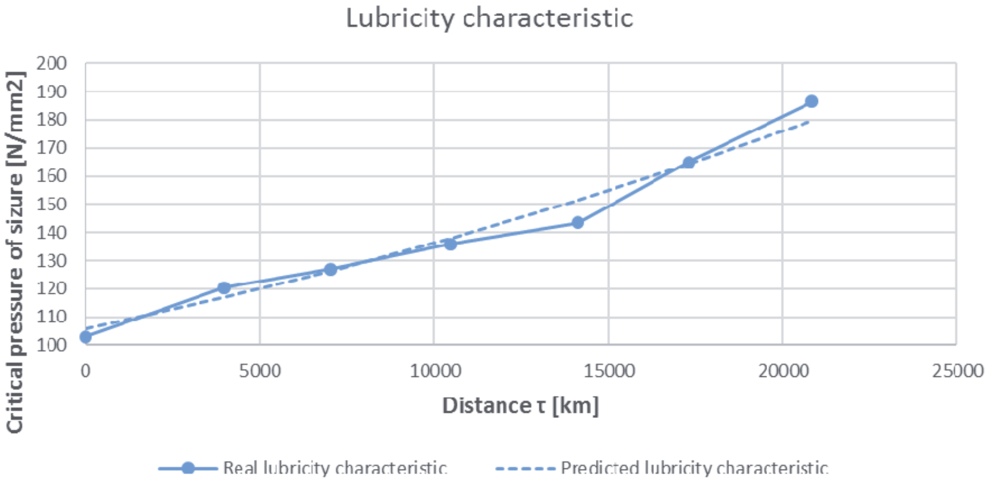

Fig. 5. Lubricity characteristics for the examined oil

As it is shown in Tab. 2, as well as in Fig. 5, the lubricity properties have increased in the period of exploitation time. Difference between real and predicted characteristic is only about 3%, so the drop down of the oil viscosity in the first stage has no significant influence into lubricity of the oil, which is the most important tribological parameter in this study [3]. As it is shown in Fig. 5, the lubricity has increased in the exploitation time of the oil in about 81%. This fact may be caused by increasing of the Cu content in the exploitation time, as shown in Fig. 4. [2].

3. Conclusions

Analysis on the oil parameters such as viscosity and chemical elements content did not resulted in a final answer for the reason of the viscosity changes in the first stage of the exploitation period of the oil. As it is shown in this study, neither viscosity nor chemical elements content changes have a negative influence on the lubricity of this oil, what is more important from the tribological point of view.

In order to better recognition of the oil ageing processes in the first stage of exploitation, next researches, for more engines and higher frequency in the first stage of exploitation. Conduct of such a researches will help with the better modelling of the oil ageing characteristics.

References

[1] Frycz, M., *The Effect of Magnetic Particle Concentration on the Ferrofluid Lubricity*, Tribology, No. 4 (244), pp. 59-65, 2012.

[2] Krupowies, J., *Analysis of Changes in Operating Parameters of Lubricating Oils of Marine Auxiliary Engines,* Scientific Papers of Szczecin Maritime University, No. 1 (73), pp. 411-422, 2004.

[3] Młynarczak, A., *Investigation of the Influence of a Surface Active Agent on Lubricating Properties of Oil Used in Marine Diesels,* Tribology, No. 4 (244), pp. 175-181, 2012.

[4] Sikora, G., Miszczak, A., *The Influence of Oil Ageing on the Change of Viscosity and Lubricity of Engine Oil*, Solid State Phenomena, Vol. 199, pp. 182-187, 2013.