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RESEARCH

Monitoring Lubricant Performance in Field Application

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ABSTRACT

The paper presents the physical chemical tests in the analysis of oils that are used for the assessment of his condition.

Furthermore the results of experimental research of physical chemical characteristics engines oil was sampled from engines of PUCH 300 GD, Pinzgauer 710 and Ikarbus IK 104 P vehicles, which were in use. The research results are originating from the research of the paper authors. Investigations it was realized that there is a change of physical chemical characteristics of oil for lubrication in the engines vehicle. These changes are in direct dependence on the state of all elements tribomechanical engines system, and depending on their functional characteristics.

1. INTRODUCTION

The basic role of lubricants i.e. lubrication is to reduce friction and hence prevent the wear of material surfaces whose relation is conditioned by relative mutual movement. However, it is essential that the lubricant also has other functional properties that will ensure its efficient application. These are above all good oxidation and thermal stability, corrosion protection property, compatibility with different materials, low foaming and ability to release air, good detergent-dispersant properties, good deemulsification, and the like. The use of a lubricant inevitably leads to the impairment of its performances. These negative changes are most usually caused by thermal load and/or influence of different kinds of pollution, to which lubricants are exposed during service.

Thermal loads may be generated as a result of high mechanical loads or prolonged exposure to increased temperatures. Different kinds of pollution are also a frequent cause of lubricant degradation. Gaseous combustion products, air, water, glycol, fuel, various process media, wear products, and other pollutants, may be the cause of a serious impairment of the condition of the lubricant, but also of the device itself.

That is why it is necessary to monitor changes in lubricant's performances, based on which one may determine a timely change of lubricant, thus prolonging the lubricant's service life and preventing any major failures of or damages to the system.

In application, oils change their properties through [1]: contamination by combustion products and metal wear particles, consumption of additives which is chemical and bears impact on important oil functions and base oil oxidation.

The primary role of engine oil is the lubrication of moving engine parts and reducing friction and wear of metal surfaces which provides the good engine performance and its long life. In order to provide a defined quality of engine oils during production and for final products to meet the product specifications we need to know the physical chemical characteristics of engine oils.
Certain physical-chemical characteristics which are significant for the quality of engine oils are achieved by adding additives to base oils. The most frequent additives are for: improving of viscosity index-improvers, reducing pour point-depressants, maintaining engine cleanness-detergents and dispersants, preventing oxidation-antioxidants, preventing corrosion-corrosion inhibitors.

2. LUBRICANT SERVICE LIFE AND ANALYSIS

To know analytical properties of lubricants is the base to make a decision in development, production and application of lubricants. The lubricant classifications and approved system specify many performance characteristics and analytical tests. The analytical tests are classical and instrumental.

Instrumental technical have the advantages in small quantity of the sample and rapid analyze. As a part of the common proactive strategy of the hydraulic systems maintenance, concept of on-line monitoring is introduce in practice, recently [2], [9], [10], [11], [12]. It is a combination of the measurement procedures, by which sample of fluid is to be analysed is taken directly from the system and the results of the measurements are showned continuously. On-line monitoring considering, first of all, control of cleanliness classes (according to ISO, NAS, SAE), control of humidity, viscosity, permittivity (acid), temperature...

The following tests are the most used in condition monitoring: Spectrometric analysis, Analytical Ferrography, Rotrode Filter Spectroscopy (RFS), Infrared Analysis (FT-IR), Viscosity, Total Acid Number (TAN), Total Base Number, Water and Particle Count.

Spectrometric analysis is a technique for detecting and quantifying metallic particulates in used oil arising from wear, contamination and additive packages. The oil sample is energized to make each element emit or absorb a quantifiable amount of energy, which indicates the element's concentration in the oil. The results represent the concentration of all dissolved metals and particles. The equipment for spectrometric analysis is the standard equipment for oil analysis laboratories today. It provides information on technical system, contamination and wears condition relatively quickly and accurately. Spectroscopy is more-or-less blind to the larger particles in an oil sample, more precisely, to particles greater than 10 μm in diameter, which are more indicative of an abnormal wear mode [3].

Analytical ferrography is a technique which separates magnetic wear particles from oil. Those particles settle on a glass slide known as a ferrogram. Microscopic examination enables to determine the wear mode and probable sources of wear in the technical system. Analytical ferrography is an exceptional indicator of abnormal ferrous wear and it is inadequate for nonferrous wear.

Rotrode Filter Spectroscopy (RFS) was first introduced in 1992. This spectrometric technique detects coarse wear metals and contaminants in a used oil sample. Diameter of those particles is up to 25 μm, but it excludes all additives. The coarse particles are especially important. They are the first indicators of abnormal wear situations.

Fourier-Transform Infra-Red Spectroscopy is a spectrometric technique for detecting organic contaminants, water and oil degradation products in a used oil sample. It monitors lubricant degradation (oxidation, nitration, sulfation, additive depletion) and liquid contaminants (water, glycol, fuel dilution).

Viscosity is the resistance of a fluid to flow and the most important lubricant physical property. The fluid is placed in a "viscometer" (a calibrated capillary tube for precise flow measurement between two pre-marked points on the tube) and pre-heated to a given temperature in a "viscosity bath" (which is usually oil-filled). After the oil reaches the desired viscosity temperature, gravity-influenced flow of the oil is initiated in the viscometer and timed between two calibrated points. This time becomes the determinant for the result.

Total Acid Number (TAN) is a neutralization number intended for measuring all acidic and acid-acting materials in the lubricant, including strong and weak acids. It is a titration method designed to indicate the relative acidity in a lubricant. The TAN is calculated from the amount of KOH consumed. The acid number is used as a guide to follow the oxidative degeneration of oil in service.

Total Base Number (TBN) is a neutralization number intended for measuring all basic (alkaline) materials in the lube (acid-neutralizing components in the lubricant additive package). The converse of the TAN, this titration is used to determine the reserve alkalinity of a lubricant. The TBN is highest when oil is new and decreases with its use. Low TBN normally indicates that the oil has reached the end of its useful life.

Water can be detected visually if gross contamination is present. Excessive water in a system destroys a lubricant's ability to separate opposing moving parts, allowing severe wear to occur with resulting high frictional heat. There are several methods used for testing the moisture contamination (crackle, FT-IR water, centrifuge, Karl Fischer) each with a different level of detection (1000 ppm or 0.1 % for first three methods and 10 ppm or 0.001 % for Karl Fischer method).

Particle Count is a method used to count and classify particulate in a fluid according to accepted size ranges, usually to ISO 4406 and NAS 1638 [4]. There are several different types of instrumentation on the market, utilizing a variety of measurement mechanisms, from optical laser counters to pore blockage monitors. The wear mechanism of a tribological lubrication system consists in the wear of contact surfaces, and lubricant consumption. If there is wear of the contact surfaces, there are wear particles present.

Regardless of the availability of numerous methods for diagnosing the physic-chemical changes of lubricants, in order to create a true picture of the condition of lubricants from the user system, it is of importance to satisfy the precondition of the possibility to obtain a representative sample. That is why it is extremely important to take the sample in a proper way.

Every sample has to be accompanied by documentation containing all relevant data, such as user name, lubricant name, sample label, date of sampling, date of sample delivery, type of device, lubricant quantity in the system, oil change date, refill data, number of operating hours, operating temperature, reasons for sample supply, and possibly other pieces of information that may be of use for an easier understanding of the actual problem in question and final interpretation of the obtained analysis results.

These data, along with the obtained analysis results, are the basis for the final lubricant condition interpretation, and hence also the evaluation of its further usability, possible maintenance intervention in order to resolve the problem, if any, and – in case of complaints – their justifiability determination.

3. THE TRIBOMECHANICAL SYSTEMS

The central component of the tribomechanical system is the lubricant, whose most significant function is the lowering of friction and wear appearing in the contact of two surfaces in relative motion. As a subsystem, tribomechanical systems are integrated everywhere into the technical systems. Apart from more significant applications in internal combustion engines, transmission, and hydraulic systems, there are also a large number of further applications.

By recognizing the function of the tribomechanical system and through a rich development of materials, equipment and methods, it seemed that all the problems associated with lubrication have been resolved. However, lubrication engineering still remains active. The goal is to develop tribomechanical systems that will be less environmentally harmful, while at the same time having high technical performances. Development of technical products is dependent on a number of both general and specific requests.

Real systems are complex tribomechanical systems. Conditions of the elements of tribomechanical system are very complex and determinate great deal by the adequate characteristics of lubricants. Complexity of conditions is determinate by:

- Temperature of elements in contact and temperature of lubricant,
- Outer load (specific pressure in contact zone),
- Dynamic character of making contact and power and motion transmission.

Vehicle as a technical mean is a set of complex tribomechanical systems composed of range of subsystems that are also complex tribomechanical systems. They are composed of elements that participate in power transmission, (moment of force from the motor, over transmissions (power transmitter, differential and other systems), to executive organs of a vehicle.

If the engine assemblies are considered from the aspect of tribomechanical systems (e.g. assemblies piston-piston ring-cylinder, cam-valve lifter, bearing-journal bearing) defined by tribological processes, it can be shown that the determination of the content of wear products, content of contaminants, state of lubricants and lubrication conditions have a significant influence on the implementation of maintenance of these systems.

We should emphasize the importance of monitoring oil for lubrication of tribomechanical engine assemblies, which provides that in the early stages of the functioning of the system identification of potential causes and phenomena that lead to damage and failure. Prognostication and detection of potential and/or current damage and failures in the system, checking the functionality of oil and determination of usage life are the main factors of the implementation of monitoring oil.

Vehicles are very complex technical systems which endure intense and different exploitation conditions. New vehicles are equipped as moving laboratories which do not lack data (in number and kind). Vehicles have gained OBD systems (On Board Diagnostics) because of ecological reasons. When some other information is added, there are conditions for forming of FSS (Flexible Service Systems) [5].

Diagnosis of tribomechanical system can provide validation, working capacity and the functionality of the system, and to point out the place, form and cause of failure. Through the detection of symptoms to determine the value of the characteristic parameters and their comparison with the limit values it is possible to diagnose the system.

Diagnostics of tribomechanical systems in motor vehicles is part of the overall process of managing maintenance. It provides an opportunity for the user to predict the damage and/or failure, and thus prevent delay in the work and extend usage life of motor vehicles.

The essence of diagnosis is based on the prognostication (recognition) of damage and/or failure through the characteristic diagnostic parameters. This allows prevention of the occurrence of delays, and increase reliability, economy, and usage life.

Confirming the basic causes of failures and their elimination, control of certain phenomena, is defining proactive maintenance, as a new method that reduces maintenance costs and prolongs the life of assets.

Modern trends of diagnosis in recent years go to the affirmation of the monitoring of oil, which has resulted in growth of interest of producers and users of oil. The reasons lie primarily in increasing the reliability, effectiveness, economy, and recently more and more present protection of the environment.

4. THE RESULTS OF OIL ANALYSIS AND DISCUSSION

In this part are presented the results of oil analysis examination during application in four-stroke engines by physic-chemical methods in order to evaluate possibilities of engine condition monitoring by oil analysis. This part presents the results of experimental research of physic-chemical characteristics of engines oil which was sampled from engines of PUCH 300GD (Table 1), Pinzgauer 710 (Table 2) and IKARBUS IK 104P vehicles (Table 3) [6], [7] and [8].

Table 1. Technical data for Mercedes-Benz engine, type OM 617.931 (vehicle PUCH 300GD).

Engine Mercedes-Benz, type OM 617.931	
Engine type	four-stroked, diesel
Number and spacing cylinders	5, linear
Cylinder bore, mm	90,9
Engine capacity, litre	2,998
Compression ratio	21 : 1
Nominal output, in 4000 min^{-1}, KW	65
Maximum torque, in 2400 min^{-1}, Nm	172
Minimal number of revolutions idle stroke, min^{-1}	750
Rated speed, min^{-1}	4500
Pressure motor oil (Rated speed), bar	3,5-5
Pressure motor oil (idle stroke), bar	0,5
The amount of oil with filter, liter	7

Table 2. Technical data for STEYR PUCH 712 engine (vehicle Pinzgauer 710M).

Engine Steyer Puch 712	
Engine type	four-stroked, Otto
Number and spacing cylinders	4, linear
Cylinder bore, mm	92
Engine capacity, liter	2,499
Compression ratio	7,5 : 1
Nominal output, in 4000 min^{-1}, KW	64
Maximum torque, in 2000 min^{-1}, Nm	180
Pressure motor oil (Rated speed), bar	4,5
Pressure motor oil (idle stroke), bar	1,5
The amount of oil with filter, liter	7

Table 3. Technical data for RABA engine, type D10 UTSLL 160 (vehicle Ikarbus IK 104P).

Engine RABA, type D10 UTSLL 160	
Engine type	four-stroked, diesel
Number and spacing cylinders	6, linear
Cylinder bore, mm	121
Engine capacity, liter	10,35
Compression ratio	-
Nominal output, in 1900 min^{-1}, KW	160
Maximum torque, in 1400 min^{-1}, Nm	928,2
Pressure motor oil (Rated speed), bar	3-4
Pressure motor oil (idle stroke), bar	0,8-1,4
The amount of oil with filter, liter	-

The research was carried out in two vehicles PUCH 300GD (PUCH-1, PUCH-2), two vehicles PINZGAUER 710M (PINZ-1, PINZ-2) and two vehicles IKARBUS IK 104P (IK104P-1, IK104P-2).

The research was conducted through periodic sampling oil from engine vehicles listed above. Apart from the fresh oil ("zero" sample), samples are taken after 1.000 km, 2.000 km, 3.000 km, 4.000 km and 5.000 km for vehicles.

The physical-chemical characteristics of oil in accordance with standard methods are examined, shown in Table 4.

Table 4. Implemented tests and methods for examining the physic-chemical characteristics of oil.

Characteristic	Method
Kinematic viscosity, mm^2/s	SRPS B.H8.022
Viscosity Index	SRPS B.H8.024
Flash Point, °C	ISO 2592, ASTM D 92
Pour Point, °C	ISO 3016
Water Content, mas. %	ASTM D 95
Total Base Number (TBN), mgKOH/g	ASTM D 2896
Insoluble substances in pentane, %	ASTM D 893
Insoluble substances in benzene, %	ASTM D 4055
Fe Content, %	ASS
Cu Content, %	ASS

The analysis was done on the fresh (new) oils and oils that are used in the engines of vehicles. During the sampling of oil choice of the sampling were conducted carefully according to the actual oil usage, which enabled each sample as representative one.

Allowable values of deviation limits of individual characteristics of the oil are conditioned by the type of oil, working conditions and internal recommendations of the manufacturer of lubricants and users. Limited value characteristics of oils that condition the change of oil charging from engine are given in Table 5. They represent the criteria for the change of oil charge. Deviation of only one source changes characteristics of oil charge, no matter of what a characteristic is about.

Table 5. Allowed values deviation of physico-chemical characteristics of new and used oil.

Physical-chemical characteristics oil and products wear	Maximum allowed variation
	Motor oil
Viscosity at 40 °C and 100 °C, mm^2/s	20 %
Viscosity Index, %	± 5 %
Total Base Number (TBN), mg KOH/gr	The fall to 50 %
Flash Point, °C	20 %
Water Content, %	0,2 %
Products wear – Content Fe, ppm (μg/gr)	100 ppm
Products wear – Content Cu, ppm (μg/gr)	50 ppm

Used engine oil in examined vehicles is shown in Table 6. Characteristics of zero samples of motor oil are shown in Table 7, and the results used oil samples in Table 8.

Table 6. Used engine oil in examined vehicles [6]

Engine oil from engine of PUCH 300 GD vehicles		
SAE classification	API classification	Manufacturer
SAE 15W-40	API SG/CE	FAM Krusevac
Engine oil from engine of PINZGAUER 710 M vehicles		
SAE classification	API classification	Manufacturer
SAE 30/S3	-	GALAX Beograd
Engine oil from engine of IKARBUS 104 P vehicles		
SAE classification	API classification	Manufacturer
SAE 15W-40	API SG/CE	FAM Krusevac

Table 7. Results of zero samples of oil from the engine [6]

Characteristic	Type of motor oil	
	FAM SAE 15W-40	Galax SAE 30/S3
Color	3,0	3,0
Density, gr/cm^3	0,881	0,902
Viscosity at 40 °C, mm^2/s	104,81	104,63
Viscosity at 100 °C, mm^2/s	14,12	11,67
Viscosity Index	—	—
Flash Point, °C	230	240
TBN, mg KOH/g	10,5	9,8

The viscosity index is an empirical number which shows how the viscosity of some oils changes by increasing or reducing the temperature. High viscosity index shows relatively small tendency of viscosity to change upon influence of certain temperature, as oppose of low viscosity index which shows greater viscosity change with temperature. During the exploitation it is desired that the viscosity changes as lesser as possible with the change of temperature. If during work temperature modes are changeable and cause major changes of viscosity that may cause disruptions in the functioning of the system, which is a manifestation of increased friction, wear and damage.

Change of engine oil Viscosity Index is shown in the Fig. 1. The decrease in the Viscosity Index oil is evident for all vehicles, exceeding the limit of 5 % (Table 5).

Table 8. The results of testing samples of used oil from engines examined vehicles [6]

Sample		PUCH –1	PUCH –2	IK104P –1	IK104P –2	PINZ –1	PINZ –2
Viscosity at 100 °C, mm^2/s	0	14,1	14,1	14,1	14,1	11,6	11,6
	1	14,6	14,2	13,7	13,6	10,9	10,5
	2	15,4	15,0	12,8	13,5	10,3	10,4
	3	16,0	15,6	12,4	13,2	9,96	10,1
	4	16,6	16,1	12,3	12,9	9,3	9,6
	5	17,5	17,0	12,2	12,6	8,7	9,0
Viscosity at 40 °C, mm^2/s	0	104,8	104,8	104,8	104,8	104,6	104,6
	1	111,0	110,4	96,9	104,4	100,4	100,9
	2	113,5	111,8	96,2	101,9	94,4	96,1
	3	119,4	113,8	92,3	97,1	86,3	88,6
	4	126,4	115,9	90,8	94,8	79,1	82,2
	5	132,7	127,5	90,2	93,1	75,9	76,9
Viscosity Index	0	135	135	135	135	100	100
	1	129	131	132	133	96	97
	2	122	126	130	131	93	95
	3	119	123	125	127	89	91
	4	116	120	122	124	84	87
	5	112	115	119	121	82	84
Flash Point, °C	0	230	230	230	230	240	240
	1	220	215	217	212	196	193
	2	208	210	214	210	186	177
	3	205	204	213	202	168	159
	4	197	202	210	193	154	143
	5	192	188	189	184	136	128
TBN, mgKOH/g	0	10,5	10,5	10,5	10,5	9,8	9,8
	1	9,1	9,4	8,8	8,1	9,6	9,4
	2	7,2	8,9	8,7	7,7	9,1	8,4
	3	6,5	8,7	8,4	7,2	8,3	7,8
	4	6,1	8,1	7,9	6,8	7,6	6,6
	5	5,2	7,6	7,3	6,4	7,1	6,2
Fe Content (ppm)	1	98,4	27,4	30,1	20,5	19	17,9
	2	123	59,8	32,5	46,3	19,8	40,9
	3	137,1	71,2	35,6	57,6	38,3	86,7
	4	149,4	71,4	37,5	62,8	54,3	132,8
	5	165,3	86,8	38,5	69,6	105,4	261
Cu Content (ppm)	1	4,9	2	1,5	3,2	3,5	3,3
	2	5,9	3,4	1,9	5,1	4,1	3,8
	3	6,7	3,7	3,2	6,3	5,3	6
	4	7,3	3,9	4,4	7,7	6,9	8,1
	5	7,9	5,4	4,9	9,1	8,7	9,7

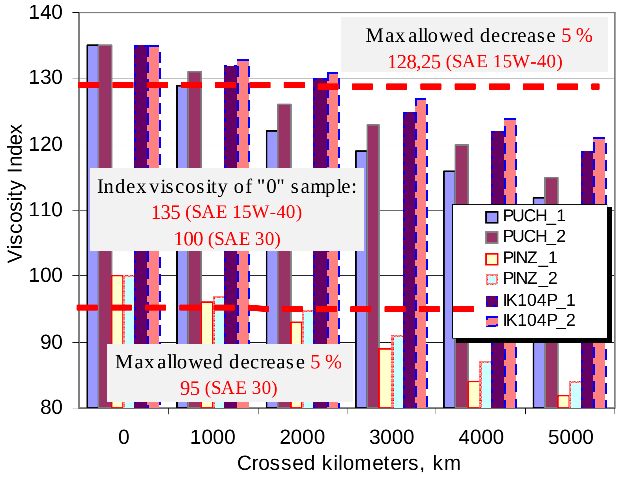

Fig. 1. The change of Viscosity Index [6].

The most important engine oils characteristic is the viscosity defined as a measure of inner friction which works as a resistance to the change of molecule positions in fluid flows when they are under the impact of shear force, or in other words, it is the resistance of fluid particles to shear.

The viscosity is a changeable category and it depends on the change of temperature and pressure. A higher temperature reduces the viscosity and makes a fluid thinner.

Multigrade engine oils among numerous additives always contain also viscosity index improvers. These additives are special types of polymers, which in small concentration significantly improve engine oils rheological properties, especially viscosity and viscosity index.

However, during engine oils utilization, degradation of viscosity index improvers i.e. Break down of polymeric molecules occurs. It results in reduction of their molecular weight what leads to viscosity loss and oil film thickness decrease, which causes undesirable phenomena of friction and wear.

Reasons for the increase of viscosity lubricants are as follows: oxidation of lubricants, cavitations due to foaming lubricants, dissolution of lubricants with water, pouring and charging system viscosity fat greater than recommended and contamination of solid particles and products wear lubricants.

The reasons for the reduction of lubricants viscosity are: lubricants contamination of fuel (for motor oil), shearing additive for reclamation viscosity, drop point of flash, grinding molecules, lubricants contamination without solubility with water, pouring and charging system viscosity less fat than recommended, and the impact of liquid cooling. Also, the causes may be high temperature, load, uncontrolled long interval use, insufficient amount of oil in the oil system, inefficient cooling systems and the like.

As expected, kinematic viscosity usually decreases in time due to fuel penetration, or - in well maintained engines, there occurs a slight increase as a result of the increase of the oil insoluble, without fuel penetration.

Fig. 2 shows the changes viscosity at 40 °C engine oils during exploitation.

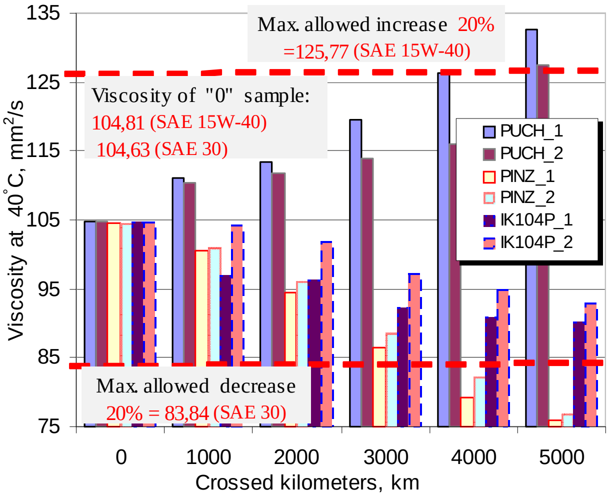

Fig. 2. The change of viscosity at 40 °C [6].

The increase viscosity at 40 °C engine oil is evident for PUCH-1 and PUCH-2 vehicles, exceeding the limit of 20 %. The decrease viscosity at 40 °C engine oil is evident for PINZ (exceeding the limit of 20 %) and IK104P vehicles.

Figure 3 shows the changes viscosity at 100 °C engine oils.

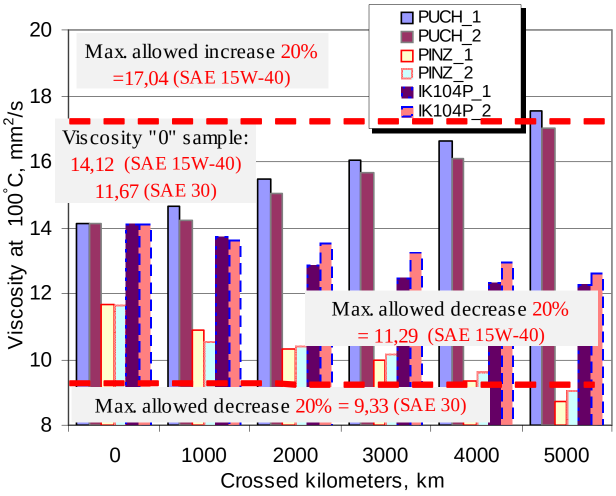

Fig. 3. The change of viscosity at 100°C [6].

TBN is a neutralization number intended for measuring all basic (alkaline) materials in the lube (acid-neutralizing components in the lubricant additive package). The TBN is generally accepted as an indicator of the ability of the oil to neutralize harmful acidic byproducts of engine combustion. The TBN is highest when oil is new and decreases with its use. Low TBN normally indicates that the oil has reached the end of its useful life. TBN is a measure of the lubricant's alkaline reserve, and mostly applies to motor lubricants. If a lube contains no alkaline additives, there is little use to determine a TBN, as there will likely be none. Combustion acids attack TBN, e.g., sulfuric acid, decreasing as it consumes.

Figure 4 shows the changes of total base number (TBN) engine oils.

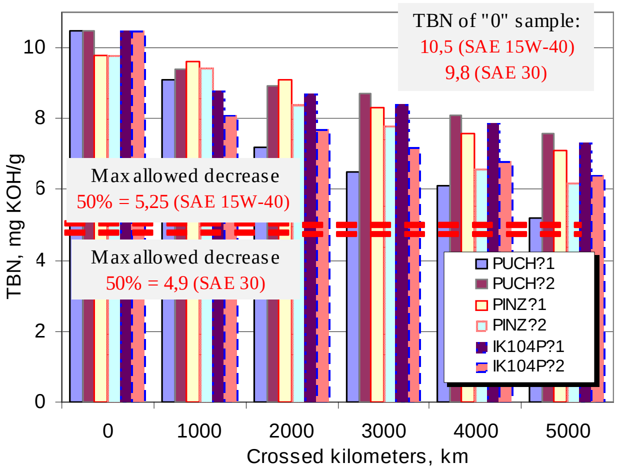

Fig. 4. The change of TBN [6]

The decrease TBN engine oil is evident for all vehicles. Until 5.000 km TBN value does not exceed the allowed limit, except for PUCH-1 vehicle.

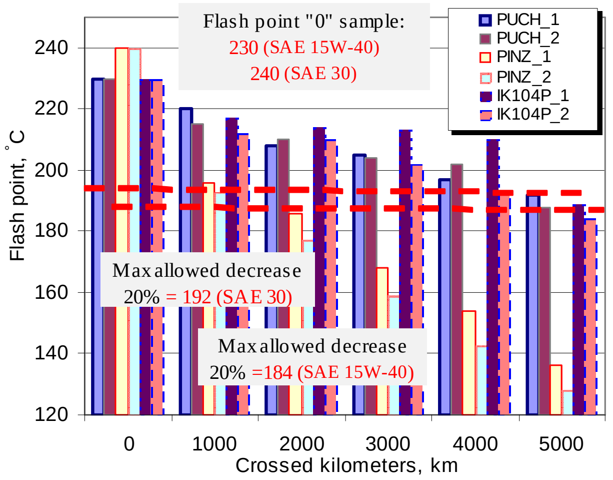

Fig. 5. The change of flash point [6]

Flash point represents data that shows what temperature leads to open fire ignition by the steam created by oil heating. In engine oil analysis the flash point determines the presence of fuel oil, which is a consequence of poor motor (bad work injectors). The reduction of flash point is due to the penetration of fuel.

Figure 5 shows the change of flash point for engine oils. The decrease in the flash point is noticeable, and by the end of exploitation testing exceeds the allowed limits (20 %, Table 5) for PINZ vehicles.

Analysis of the contents of different metals that are in the lubricant is very important. Metal particles are abrasive, and act as catalysts in the oxidation of oils. In motor oils, the origin of the elements may be from the additives, the wear, the fuel, air and liquid for cooling.

Metals from the additives can be Zn, Ca, Ba, or Mg and that indicates the change of additives. Metals originating from wear are: Fe, Pb, Cu, Cr, Al, Mn, Ag, Sn, and they point to the increased wear in these systems. Elements originating from the liquid for cooling are Na and B, and their increased content indicates the penetration of cooling liquid in the lubricant. Increased content of Si or Ca, which originate from the air, points to a malfunction of the air filter.

Iron and copper content (Figs. 6 and 7), as a product of wear, in the oil charge to the end of exploitation testing have a growing trend.

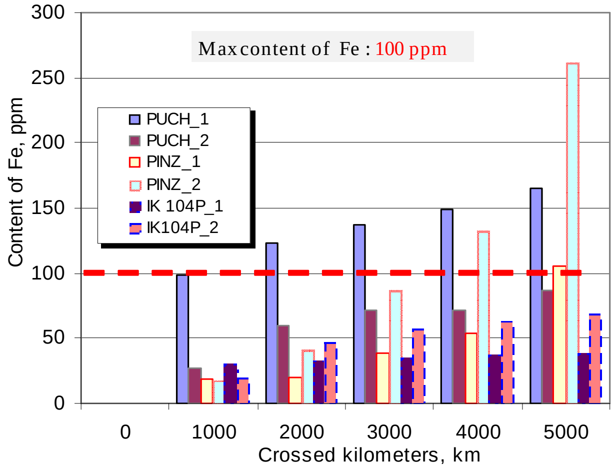

Fig. 6. The change of content Fe [6]

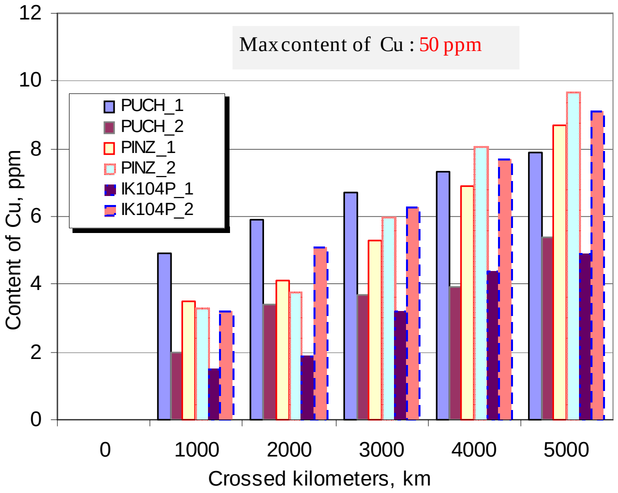

Figure 7. The change of content Cu [6]

Content of iron is significantly above the allowable limits (100 ppm, Table 5) for PUCH-1 and PINZ-2 vehicles.

Content of cooper is significantly below the allowable limits (50 ppm, Table 5) for all vehicles.

5. CONCLUSION

The interpretation of used oils analysis is very complex, because the individual analyses are interdependent. That is the reason why it is necessary to know the entire oil analysis, and not bring conclusions based on individual analysis results. It is also necessary to establish both normal and critical quality levels for specific oils in given engines and under specific application conditions.

The lubricant, being an inevitable factor in the tribomechanical system of engine has – apart from the usual lubricating role, also an important role in detecting the engine operation efficiency and condition. This is achieved through a systematic monitoring of oil in application and a permanent contact between the motor oil manufacturer and user.

Analyses from used oil sample should always be compared with previous samples and final conclusions should be based on "trend analysis" and has two closely related objectives: to obtain information on the lubricant drain intervals and preventive maintenance of the machine.

Investigations it was realized that there is a change of physical-chemical characteristics of oil for lubrication in the engines vehicle. These changes are in direct dependence on the state of all elements tribomechanical engines system, and depending on their functional characteristics.

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REFERENCES

[1] J. Denis: *Lubricant properties analyses and testing*, Editions Tehniq, Paris, 1997.

[2] D. Grgić: *On-line monitoring of oil quality and conditioning in hydraulics and lubrications systems,* in: *Proceedings of 10th SERBIATRIB '07,* Kragujevac, Serbia, pp. 305-309.

[3] R. I. Taylor and R. C. Coy: *Improved fuel efficiency by lubricant design*, 2001.

[4] M. Piest and C. M. Taylor: *Automobile engine tribology,* 2000.

[5] R. Pešić, S. Veinović, R. Pavlović: *Diagnostics of complex technical systems applied on motor vehicles*, Traktori i pogonske mašine, Vol. 6, No. 3, pp. 79-87, 2001.

[6] S. Perić: *The development of a method of diagnosis the condition from the aspect of physical-chemical and tribological characteristics of lubricating oils of vehicles*, PhD thesis, Military Academy, Belgrade, Belgrade, 2009.

[7] S. Perić, B. Nedić: *Monitoring oil for lubrication of tribomechanical engine assemblies*, Journal of the Balkan tribological association, Vol. 16, No. 2, pp. 242-257, 2010.

[8] B. Nedić, S. Perić, M. Vuruna: *Monitoring Physical and Chemical Characteristics Oil for Lubrication*, Tribology in Industry, Vol. 31, No. 3&4, pp. 59-66, 2009.

[9] I. Mačužić, P. Todorović, A. Brković, U. Proso, M. Đapan, B. Jeremić: *Development Of Mobile Device For Oil Analysis*, Tribology in Industry, Vol. 32, No. 3, pp. 26-32, 2010.

[10] V. Macia´n, B. Tormos, P. Olmeda, L. Montoro: *Analytical approach to wear rate determination for internal combustion engine condition monitoring based on oil analysis*, Tribology International, Vol. 36, No. 10, pp. 771–776, 2003.

[11] L. Guan, X. L. Feng, G. Xiong, J. A. Xie: *Application of dielectric spectroscopy for engine lubricating oil degradation monitoring*, Sensors and Actuators A: Physical, Vol. 168, No. 1, pp. 22–29, 2011.

[12] V. Macian, R. Payri, B. Tormos, L. Montoro: *Applying analytical ferrography as a technique to detect failures in diesel engine fuel injection systems*, Wear, Vol. 260, No. 4-5, pp. 562–566, 2006.