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OILS DEGRADATION IN AGRICULTURAL MACHINERY

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Abstract:

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Evaluating of oils condition in agricultural machinery is very important. With monitoring and evaluating we can prevent technical and economic losses. In this paper there were monitored the liquid lubricants taken from mobile thresher New Holland CX 860. Chemical and viscosity degradation of the lubricants were evaluated. Temperature dependence dynamic viscosity was observed in the range of temperature from −10 °C to 80 °C (for all oils). Considerable temperature dependence dynamic viscosity was found and demonstrated in case of all samples, which is in accordance with theoretical assumptions and literature data. Mathematical models were developed and tested. Temperature dependence dynamic viscosity was modeled using a polynomial 6th degree. The proposed models can be used for prediction of flow behavior of oils.

oils, chemical degradation, viscosity degradation, modeling

It should be noted that the motor oil is to be understood as one of the structural elements of the engine, transmission oil that must be understood as one of the components of the transmission and hydraulic oil is to be understood as one of the components of hydraulic system. The development of the new systems requires changes in the properties of lubricants. This change is necessary to increase performance and extend the lifetime of lubricants. Extending the lifetime of lubricants is an attractive customer advantage, which contributes to a reduction in vehicle operating costs. And it saves time of service.

For large transport companies can be advantages know the lubricants level. Attention is focused mainly on the metal content and the lubricant viscosity and its stability. Many other operators makes analyzes only in cases of suspected abnormal operation. Sometimes it can be too late.

In publication (Kumbár *et al.*, 2011) is stated that the most of the friction surface is made of certain metals. It is a refined iron addition of other metals. There are the aluminum and copper parts. Or the parts with a surface layer of another metal. It aims to increase the surface hardness, improve sliding characteristics, and improve corrosion protection. We are therefore also interested in other metals than an iron. For example, aluminum, copper, chromium, lead, tin, nickel, silver.

Other chemical elements in lubricant are oil additives. There are the detergents, friction modifiers, viscosity modifiers, anti-corrosive additives and antioxidants, substances that affect the freezing point, anti-abrasion additives, lubrication additives and some others with chemical elements: molybdenum, phosphorus, boron, calcium, zinc, magnesium (Meng and Huang, 2011).

MATERIAL AND METHODS

The mobile thresher

The mobile energy resource from which the used oils were removed and analyzed was the modern mobile thresher New Holland CX 860. The manufacturer of this thresher features many improvements, especially the new drive concept exploits the threshing drum speed changes with the high speed of the CVT with lower transmission power and propulsion system is not so much stress.

The threshing system concept is based on a proven four-drum arrangement. Increased threshing drum diameter (750 mm) and increased Concave wrap guarantees a higher separation effect. The threshing basket of 1.18 m^2 in dimension, form the basis of a large threshing and separating area. Transporting material from here eight-bladed beater, whose speed is synchronized with the speed of the threshing drum. The next stage is the separation of grain separator "Rotary Separator", transportation and drum "Straw Flow" which transports the material to the front of the straw walkers. Those are six in the type CX 860. The thresher New Holland CX 860 can be fitted with a cutter bar width from 5.18 to 9.15 m. To reduce the torque on the drive shaft universal joint bar was raised to 576 rpm. Total engine power is 265 kW.

The analyzed liquid lubricants

Four samples of used oils were removed from the thresher. There were motor oil, hypoid gear oil and universal (tractor) oil. Universal oil was used as the gear oil in the engine gearbox, and as the hydraulic oil in the hydraulic circuit. A detailed description of the samples of operating oils is shown in Tab. I.

The hypoid gear oil was used in running gear, where the sample (No. 1) was removed after 200 hours of operation.

The engine oil (No. 2) was removed from the fill of engine after 200 hours of operation.

The universal (tractor) oil was used as the gear oil in the engine gearbox (No. 3), and as the hydraulic oil in the hydraulic circuit. Both samples were removed after 1000 hours of operation.

For the evaluation chemical and viscosity degradation were used oils compared with the new oils with same signification. Like as done authors in publications (Kumbár *et al.*, 2013) and (Severa *et al.*, 2010).

Spectrometry

In the new and used oils were searched primarily metals and elements involved in oils as additives. Determining the chemical composition of the oils was performed on the device Spectroil Q100. The measuring device Spectroil Q100 is a completely semiconductor spectrometer, specifically designed for oil analysis. The apparatus is intended for detection of trace metal contents in mineral and/or synthetic oils. The well verified measuring technique of rotational disc electrode is used. The device meets the requirements for standardized methods ASTM D6595 for detection of abrasive metals and contaminants in lubricating oils and/or hydraulic fluids.

Temperature dependent of dynamic viscosity

The temperature measurements of the dynamic viscosity were determined in the temperature range from −10 °C to 80 °C. The samples were cooled and then slowly heated.

Measuring of temperature dependence of dynamic viscosity of given oils were performed using rotational viscometer Anton Paar DV–3P. This experimental device measures the torque of rotating spindle placed into the sample. The viscometer detects the resistance against rotation of cylinder or disc surrounded by measured fluid. The rotating cylinder or disc is connected with electric motor shaft via defined springs. The shaft is rotating by set speed (expressed in rotations per minute). The angle of swing is electronically monitored and offers the precise information on shaft (spindle) position. The measured data are used for calculation of dynamic viscosity expressed in *mPa.s*. In case of fluids with constant viscosity is the resistance against movement increased with spindle size. The range of measuring and rheological properties determination can be customized according to specific measuring and experimental conditions by selection of spindle and its rotation velocity. Relevant evaluation of the results is conditioned by detailed knowledge of tested material. It is necessary to classify the material in a correct way (Kumbár and Polcar, 2012).

The sample oil was measured with use of standard spindle of R3 type, which is the most suitable spindle for this kind of test specification. The spindle speed (*rpm*) was selected to 6–50 rpm.

The temperature dependence was modeled using polynomial of 6^{th} degree.

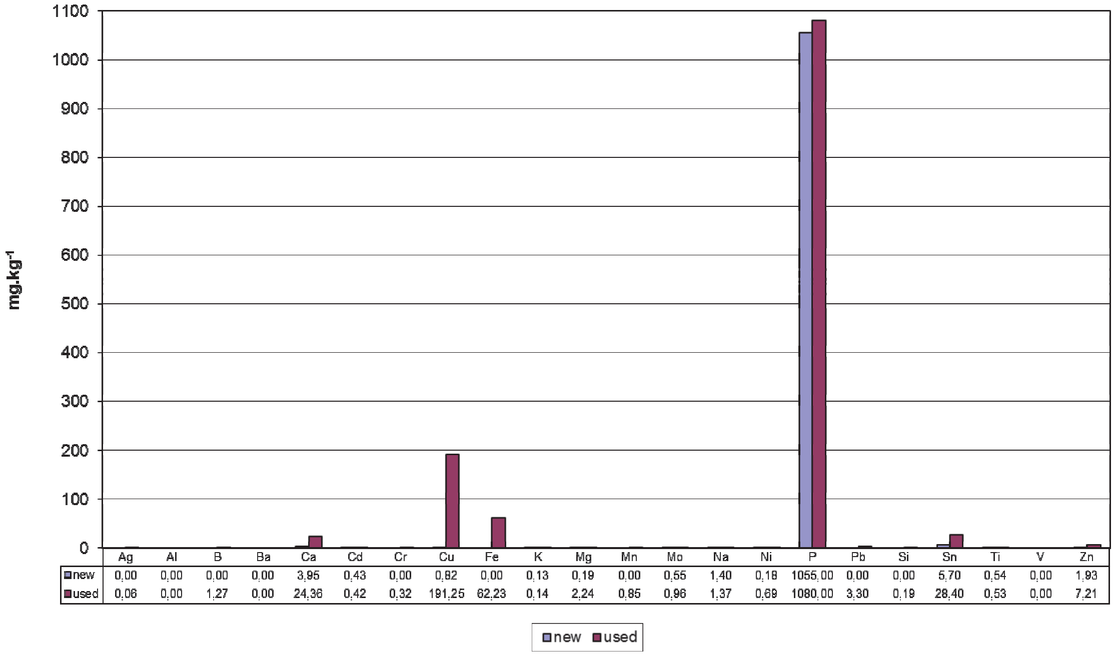
RESULTS AND DISCUSSION

Spectrometry

For four samples of used oils have been determined the chemical compositions. These oils

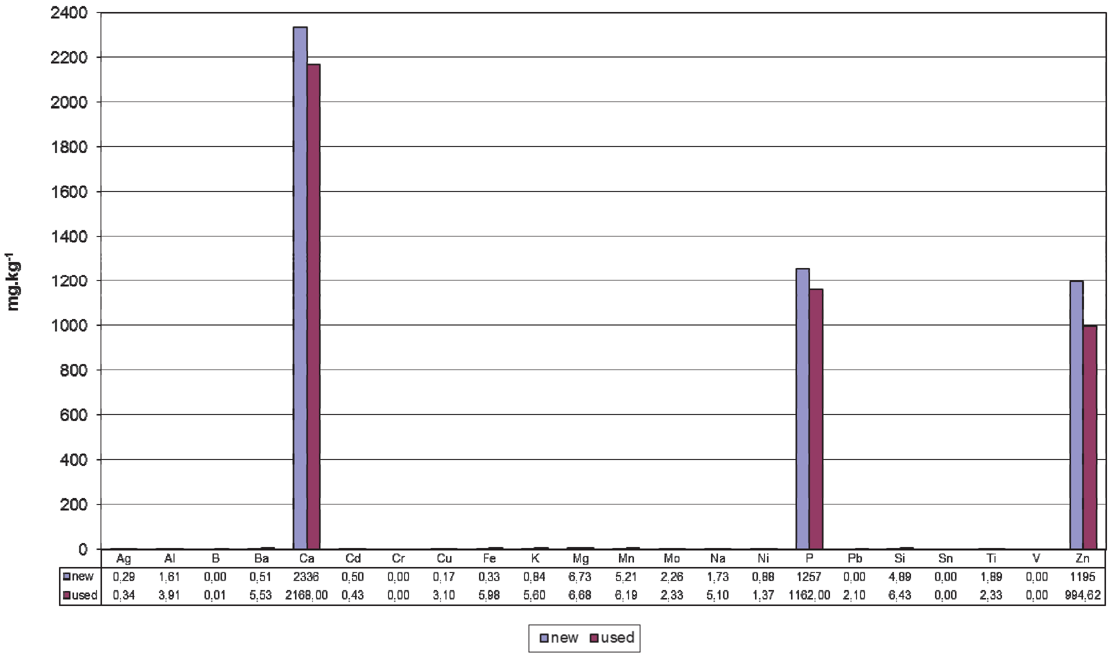
I: *Description of samples of oils*

Number of sample	Type of oil	Signification	Viscosity class	Performance class	Use	Hours of operation
1	Hypoid gear oil	Castrol EPX90	90W	GL-5	Gear oil	200
2	Engine oil	Castrol Agri Power	15W40	API CH-4/SH, ACEA E3/E5/B3/A4	Engine oil	200
3	Universal (tractor) oil	Castrol Agri Trans Plus	10W30, 80W	GL-4	Gear oil	1,000
4	Universal (tractor) oil	Castrol Agri Trans Plus	10W30, 80W	GL-4	Hydraulic oil	1,000



	Ag	Al	B	Ba	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	Si	Sn	Ti	V	Zn
new	0,00	0,00	0,00	0,00	3,95	0,43	0,00	0,82	0,00	0,13	0,19	0,00	0,55	1,40	0,18	1055,00	0,00	0,00	5,70	0,54	0,00	1,93
used	0,06	0,00	1,27	0,00	24,36	0,42	0,32	191,25	62,23	0,14	2,24	0,85	0,96	1,37	0,69	1080,00	3,30	0,19	28,40	0,53	0,00	7,21

1: *Chemical degradation of transmission oil*



	Ag	Al	B	Ba	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	Si	Sn	Ti	V	Zn
new	0,29	1,61	0,00	0,51	2336	0,50	0,00	0,17	0,33	0,84	6,73	5,21	2,26	1,73	0,88	1257	0,00	4,89	0,00	1,89	0,00	1195
used	0,34	3,91	0,01	5,53	2168,00	0,43	0,00	3,10	5,98	5,60	6,68	6,19	2,33	5,10	1,37	1162,00	2,10	6,43	0,00	2,33	0,00	994,62

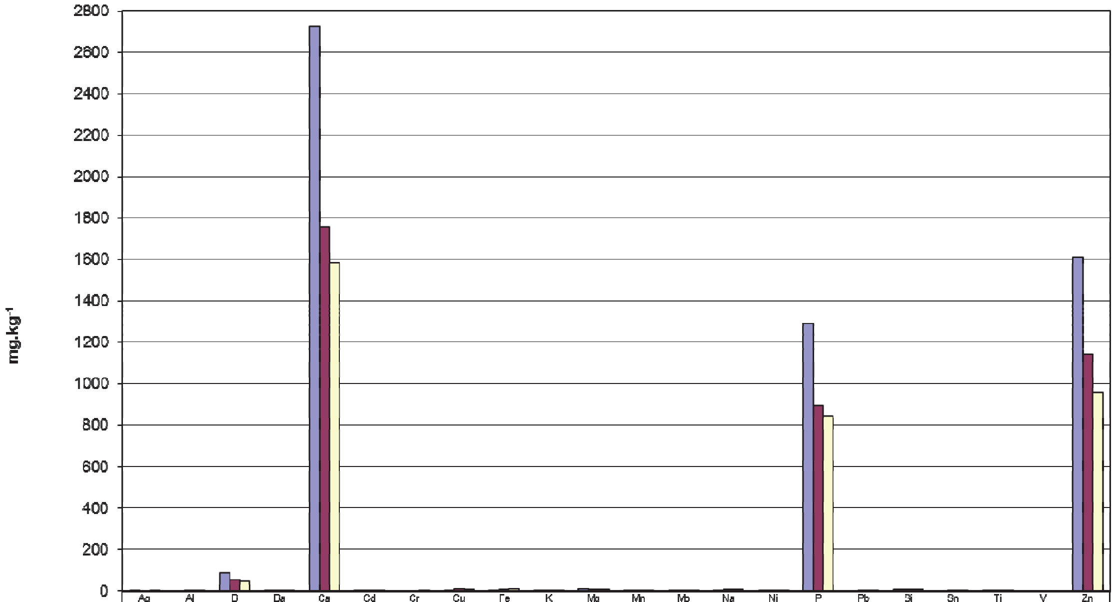
2: *Chemical degradation of engine oil*

have always been compared with the new (unused) oils of the same specification. In order to assess how individual operating oil degraded.

Fig. 1 shows a graph and table of contents of individual chemical elements in the sample No. 1 (hypoid gear oil). The content of individual chemical elements is given in $mg.kg^{-1}$, respectively in *ppm*.

The graph in Figure 1 shows the increase of copper (Cu) and iron (Fe). These two elements are commonly used as part of construction material of running gear. The increase of copper from less than 1 $mg.kg^{-1}$ up to 191 $mg.kg^{-1}$ and iron from 0 to the 62 $mg.kg^{-1}$ is alarming. There are very high values. Hypoid gear oil should be immediately replaced. It is also necessary to continue to monitor the condition of the oil in suitably chosen (rather shorter) intervals to avoid any mechanical accident. It would also be appropriate to shorten the interval exchange hypoid gear oil.

A small increase in silicon (Sn) suggests that the thresher is operated in dusty environments. But this is not dangerous yet. High proportion of



	Ag	Al	B	Ba	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	Si	Sn	Ti	V	Zn
new	0.01	0.00	87.50	0.07	2726.00	0.49	0.00	0.17	0.37	1.74	12.20	0.87	2.32	2.87	0.27	1290.00	0.00	7.89	0.00	0.78	0.00	1608.00
used_transmission	0.00	2.62	55.67	0.65	1759.00	0.78	0.00	10.33	5.74	2.34	5.97	1.50	1.78	6.75	0.31	894.35	0.83	6.22	0.74	0.59	0.00	1143.00
used_hydraulics	0.03	1.86	47.55	0.13	1582.00	0.67	0.29	5.40	11.54	3.22	6.87	1.29	2.25	5.58	0.43	844.55	3.70	6.16	0.52	0.51	0.00	957.44

3: *Chemical degradation of universal oil*

phosphorus (P) is due to the fact that this element is at the core of additives.

The Fig. 2 shows a graph and table of contents of individual chemical elements in the sample No. 2 (engine oil).

In the graph in Figure 2 can be seen only a small decrease in the elements calcium (Ca), phosphorus and zinc (Zn), which are the elements contained in motor oil additives. Other changes in the chemical composition of motor oil are almost negligible.

The Fig. 3 shows the graph and table of contents of individual chemical elements in the sample No. 3 and No. 4 sample (universal tractor oil). Sample No. 3 was launched from the gear motor. Sample No. 4 was launched from a common hydraulic and hydrostatic circuit.

The graph in Fig. 3 is a slight decrease in additives, like as in motor oil. For the used universal (tractor) oil was a decrease in the elements boron (B), calcium, magnesium (Mg), phosphorus and zinc. It is also possible to see that dropped more additives in the oil that was used as a hydraulic.

The biggest change in the content of metal in the gear oil was the rise of the copper content from 0 to the 10 mg.kg^{-1}. The hydraulic oil was up to the 5 mg.kg^{-1}. However, this was contained in the iron, where the gear oil was a rise from 0 to the 5 mg.kg^{-1}. The hydraulic oil was up to the 10 mg.kg^{-1}. These values are very low, but there is no reason to deal with them more.

Temperature dependence dynamic viscosity

The viscosity degradation of liquid lubricant was monitored by measuring and comparing the temperature dependence dynamic viscosity. As expected of authors and in accordance with the publication (Mang and Dresel, 2001) significantly decreased dynamic viscosity with increasing temperature.

The graph in Fig. 4 shows a decrease of dynamic viscosity of hypoid transmission oil with increasing temperature.

The graph in Fig. 5 shows the decrease of dynamic viscosity motor oil with increasing temperature.

For the temperature dependence of dynamic viscosity of the new (unused) and used engine oils were developed mathematical models using polynomial 6th degree, according to the general form:

$$y(f) = a_6 \cdot x^6 + a_5 \cdot x^5 + a_4 \cdot x^4 + a_3 \cdot x^3 + a_2 \cdot x^2 + a_1 \cdot x + a_0. \quad (1)$$

For the calculation of dynamic viscosity apply:

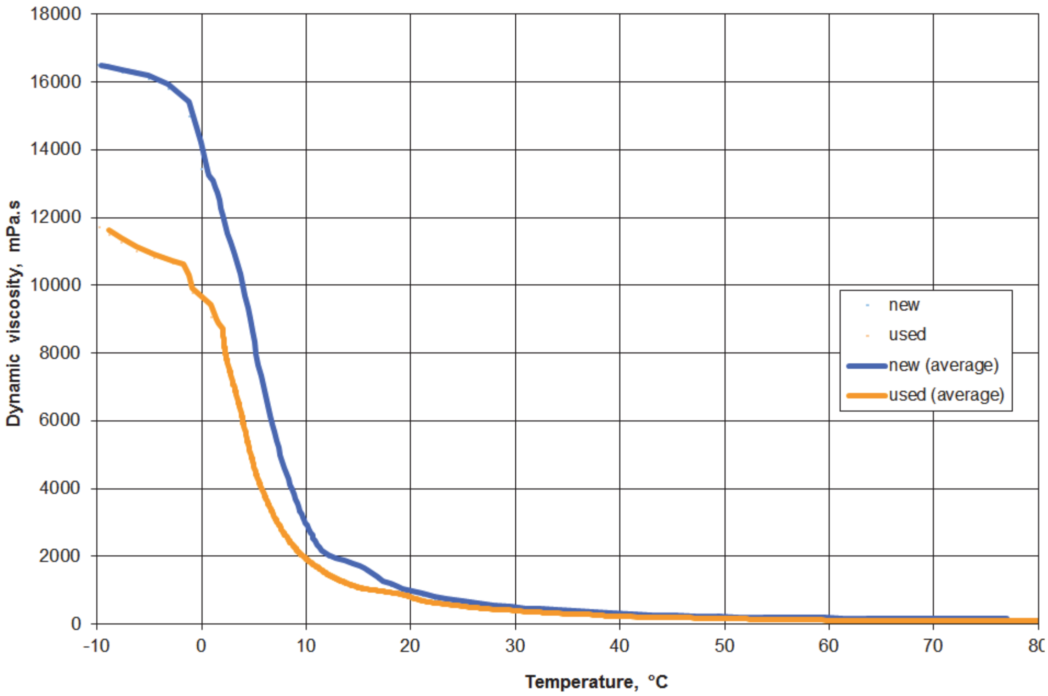
$$\eta(t) = a_6 \cdot t^6 + a_5 \cdot t^5 + a_4 \cdot t^4 + a_3 \cdot t^3 + a_2 \cdot t^2 + a_1 \cdot t + a_0, \quad (2)$$

where η is dynamic viscosity, t is temperature and a_1 are constants.

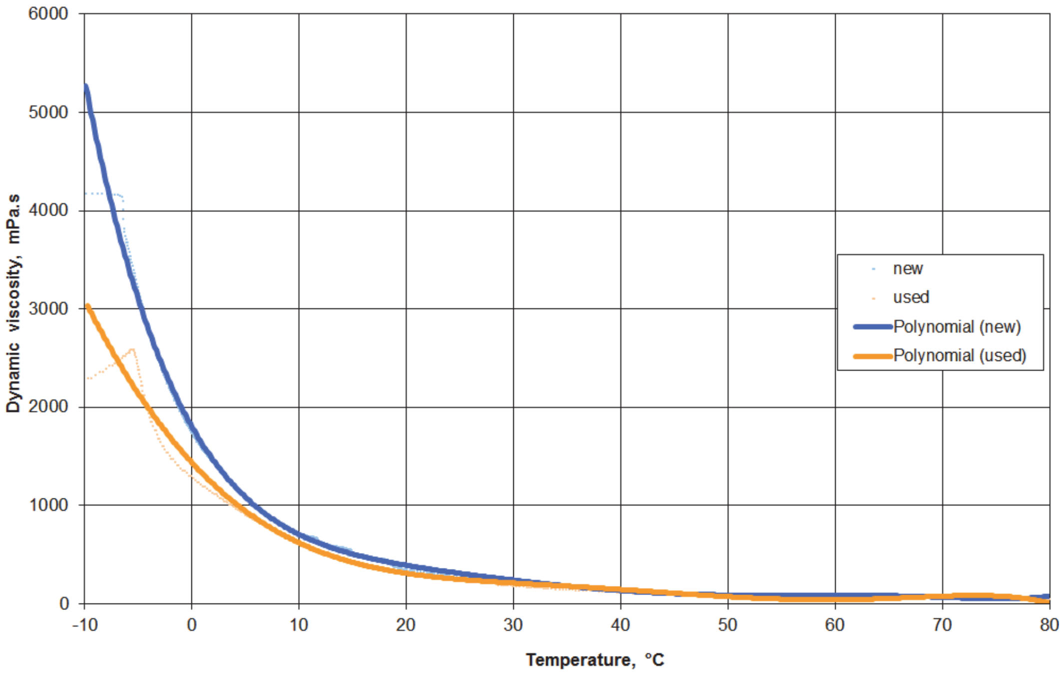
For an accurate calculation of dynamic viscosity (in the temperature range −10 °C to 80 °C) of engine oil, the values of constants given in Tab. II.

Prepared mathematical models achieve high accuracy, since the coefficients of determination R^2 ranged from 0.97 to 0.99.

The graph in Figure 6 shows a decrease of dynamic viscosity of universal (tractor) oil with increasing temperature. It can be stated that the universal oil (used as hydraulic oil) more degraded than the universal oil (used as gear oil).



4: *Viscosity degradation of transmission oil*

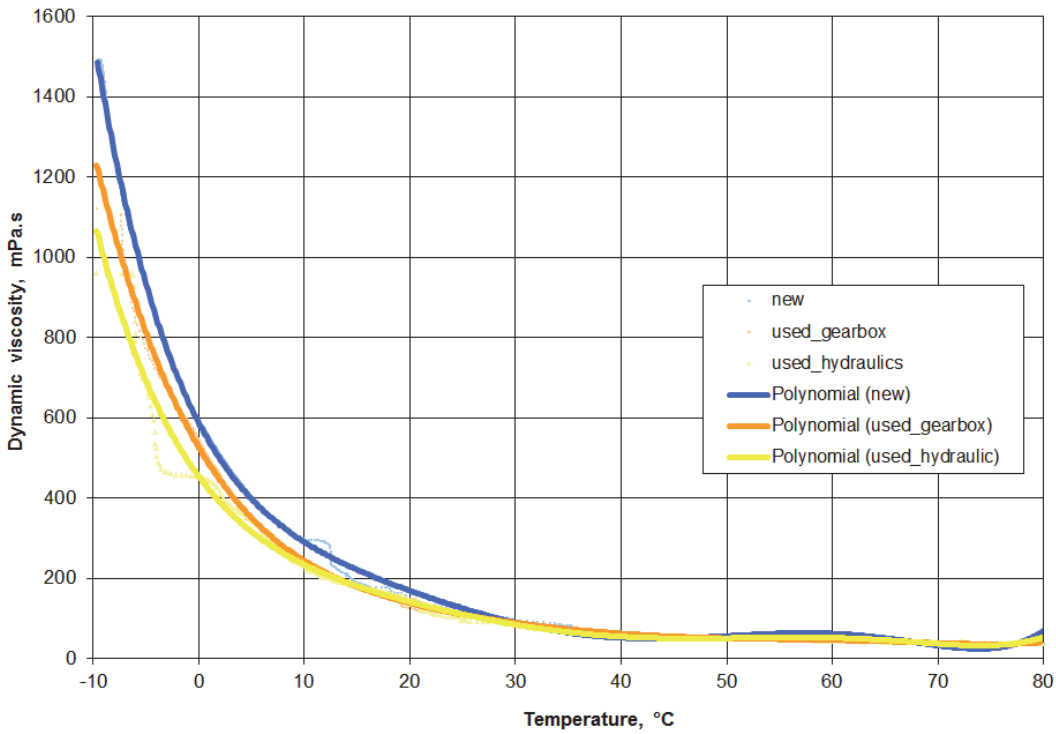


5: *Viscosity degradation of engine oil*

II: *Values of constants (engine oil)*

	a_6	a_5	a_4	a_3	a_2	a_1	a_0
New engine oil	0.00000020	−0.00007	0.0071	−0.3847	11.4010	−191.48	1801.7
Used engine oil	−0.00000009	0.00002	−0.0004	−0.0526	4.2216	−118.31	1437.4

For the temperature dependence of dynamic viscosity of new and used universal (tractor) oil oils were developed mathematical models using polynomial 6th degree, according to general



6: *Viscosity degradation of universal oil*

III: *Values of constants (universal oil)*

	a_6	a_5	a_4	a_3	a_2	a_1	a_0
New universal oil	0.00000010	−0.00003	0.0027	−0.1231	3.0684	−50.554	587.38
Used universal oil - gearbox	0.00000004	−0.00001	0.0011	−0.0647	2.1828	−44.615	526.20
Used universal oil - hydraulic	0.00000007	−0.00002	0.0016	−0.0735	1.9784	−35.808	453.72

formula (1). For calculate dynamic viscosity shall apply formula (2), but the value of the constants are different. The exact values of constants for calculation dynamic viscosity (in the temperature range −10 °C to 80 °C) of universal (tractor) oil are shown in Tab. III.

Prepared mathematical models achieve high accuracy even here, since the coefficients of determination R^2 ranged from 0.98 to 0.99.

CONCLUSIONS

In this part we can say that the applied methods (spectroscopy and determination of the temperature dependence of dynamic viscosity) are as basic indicators of the state of degradation of liquid lubricants sufficient. All measurements of used lubricants are compared with measurements of the new lubricant. With the results we can state the degree of degradation.

With the evaluation of the state of degradation of liquid lubricants used in modern thresher can be deduced several results:

- With the spectroscopy we determined the chemical composition of liquid lubricants and quantify the individual elements in new and used oils. Hypoid gear oil from the monitored thresher we had identified as a much chemically degraded, which contained high amounts of copper and iron. The engine and universal (tractor) oil showed a low degree of chemical degradation.
- Specifying the temperature dependence of dynamic viscosity, we have determined in all samples, a low degree of viscosity degradation. The decrease of dynamic viscosity can be observed at temperatures lower than about 30 °C. For values of temperature exceeding 30 °C, dynamic viscosity changes between new and used liquid lubricants were small. We can state that the selected liquid lubricants were very well chosen.
- Mathematical models for temperature-dependent behavior of dynamic viscosity of liquid lubricants achieve very high accuracy, which demonstrate a high coefficient of determination R^2 values (0.97–0.99). These models can be used for predicting the viscosity behavior of liquid lubricants (oils) used in agricultural technology.

SUMMARY

The objective of this paper is evaluating of oils condition in agricultural machinery. With monitoring and evaluating oils we can prevent technical and economic losses. In this paper there were monitored the liquid lubricants taken from mobile thresher New Holland CX 860. Chemical and viscosity degradation of the lubricants were evaluated. Considerable temperature dependence of viscosity was found and demonstrated in case of all samples, which is in accordance with theoretical assumptions and literature data. We can state that the applied methods (spectroscopy and determination of the temperature dependence of dynamic viscosity) are as basic indicators of the state of degradation of oils sufficient. All measurements of used oils are compared with measurements of the new oils. With the results we can state the degree of degradation. With the evaluation of the state of degradation of liquid lubricants used in modern thresher can be deduced several results. Spectroscopy is determined the chemical composition of liquid lubricants and quantify the individual elements in new and used oils. Hypoid gear oil from the monitored thresher we had identified as a much chemically degraded, which contained high amounts of copper and iron. The engine and universal (tractor) oil showed a low degree of chemical degradation. Specifying the temperature dependence of dynamic viscosity, we have determined in all samples, a low degree of viscosity degradation. The decrease of dynamic viscosity can be observed at temperatures lower than about 30 °C. For values of temperature exceeding 30 °C, dynamic viscosity changes between new and used liquid lubricants were small. We can state that the selected liquid lubricants were very well chosen. Mathematical models for temperature-dependent behavior of dynamic viscosity of liquid lubricants achieve very high accuracy, which demonstrate a high values of coefficient of determination R^2 values (0.97–0.99). These models can be used for predicting the viscosity behavior of liquid lubricants (oils) used in agricultural technology.

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