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RESEARCH OF BIODEGRADABLE FLUID IMPACTS ON OPERATION OF TRACTOR HYDRAULIC SYSTEM

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This paper is focused on the impacts of the biodegradable hydraulic and transmission fluid (Universal Tractor Transmission Oil) on operation of tractor hydraulic and transmission systems. The fluid was used in the hydraulic and transmission systems of a Zetor Proxima 6321 tractor. Fluid samples were taken from the Zetor Proxima 6321 tractor at intervals of 250 engine hours. These samples were subjected to an infrared spectroscopy analysis in order to measure the total acid number and perform the ferrography analysis. This paper proves minimal impacts of the biodegradable hydraulic fluid on operation of the Zetor Proxima 6321 tractor. The biodegradable fluid meets the requirements for the operation of agricultural tractors in terms of low impacts on the wear of hydraulic components.

Keywords: LaserNet Fines (LNF) tests; infrared spectroscopy analysis; ferrography analysis

Hydraulic equipment is widely used in powerful mechanisms that are part of agricultural and forest machinery, as well as in many other fields. The development of modern hydraulic components is aimed at increasing of the transmitted power, reducing energy intensity, minimising the environmental pollution, and increasing of the both technical life and machine reliability (Hoffmann et al., 2013). Hydraulic and transmission fluid requires monitoring of quality parameters. Fluid purity is one of the most important features in the entire process (Majdan et al., 2013). Very often, the questionable purity and general technical condition of hydraulic and transmission fluid cause frequent failures in transmission or hydraulic systems in tractors. Contaminated fluid creates a risk to the machine in terms of wear and failure (Tulík et al., 2013). Contamination is dangerous because it accelerates the degradation and oxidation processes in the fluid. If the fluid is contaminated by dirt above the permitted level, it must be replaced (Majdan et al., 2014; Hlaváč et al., 2016). Universal Tractor Transmission Oils (UTTO) are designed for hydraulic and transmission systems in agricultural tractors. These fluids provide lubrication for the gear box and transmit the energy in the tractor's hydraulic system (Hujo et al., 2013). The friction points in the hydraulic and transmission circuit are made of several metallic materials (mostly iron, aluminium, and copper) (Kumbár et al., 2014). Due to this reason, there is a need to determine the content of other metals, such as aluminium, copper, chromium, lead, tin, nickel, silver, etc. (Kumbár and Dostál, 2013). The aim of this paper is to test the application of biodegradable fluid in the tractor gear and hydraulic circuit. Biodegradable fluid was applied to the gear and hydraulic circuit of the Zetor Proxima 6321 tractor. The fluid was assessed in terms of lubrication properties and their impacts on wear during application. Experimental results bring important information considering the oil degradation. The majority of tractors are subjected to the conditions that might cause the undesirable phase transition of oil in the hydraulic system. It is necessary to develop the flow of oil in order to establish the correct operation of hydraulic equipment.

Material and methods

An operational test of a biodegradable hydraulic and transmission fluid was set to 500 engine hours (EH). Oil samples were taken after completing 0, 250, and 500 engine hours. Subsequently, the fluid samples were collected for analysis and detection of any contamination. Table 1 shows the basic technical parameters of biodegradable fluid of UTTO type.

Table 1 Technical parameters of biodegradable synthetic fluid

Properties	Unit	Amount
Kinematic viscosity at 40 °C	$mm^2 \cdot s^{-1}$	67.52
Density at 15 °C	$kg \cdot m^{-3}$	931
Flash point	°C	212
Pour point	°C	- 48

The chemical composition of hydraulic and transmission fluid was determined by means of Spectroil Q100, which is a completely solid state spectrometer. Using this

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spectrometer, even the trace levels of elements, which have been dissolved or deposited as fine particles in mineral or synthetic oil-based fluids, can be detected thanks to a long-established and reliable technique involving a rotating disk electrode. Considering the determination of the wear rate of metals and the levels of contaminants in lubricating oils and hydraulic mixtures that are being used (Kumbár et al., 2014), this spectrometer meets the requirements of the ASTM D6595 standard.

The following parameters were evaluated:

- concentration of metallic elements (Ag, Al, Cu, Cr, Fe, Mg, Mo, Mn, Ni, Ti, Si);
- concentration of chemical elements representing the additives (B, Ca, Zn);
- ferrography analysis.

A decrease in the content of these chemical elements (concentration of chemical elements representing the additives) is calculated by using the following formula (Kosiba et al., 2016):

$$\Delta ED = \frac{ED_0 - ED_{500}}{ED_0} \cdot 100 \quad (\%) \qquad (1)$$

and an increase in the content of metallic elements is calculated by using the following formula:

$$\Delta EI = \frac{EI_{500} - EI_0}{EI_0} \cdot 100 \quad (\%) \qquad (2)$$

Results and discussion

Table 2 shows an increase in the concentration of chemical elements in hydraulic and transmission fluid during tractor operation.

The highest increase of deposited metals in the oil was observed in relation to barium (Ba), iron (Fe), and copper (Cu). Iron (Fe) and barium (Ba) are used as construction material in the transmission system, and copper (Cu) is used as construction material in the oil cooling system. Any observed concentration of Ba, Fe, and Si is considered standard value of content in accordance with the publications by authors Tarasov et al. (2002) and Assaff et al. (2014). Other changes in the chemical content of hydraulic and transmission oil are almost negligible.

Table 3 shows the basic elements that characterise the set of additive packages. The chemical properties of the hydraulic fluid, being used as the quality evaluation parameters, were monitored in publications by authors Kučera and Rousek (2008), and Phillips and Staniewski (2016).

The highest decrease was observed for boron (B) at 86.61%. Zinc (Zn) is used either as an anti-wear agent, or as an antioxidant. Too high content of zinc additive in hydraulic and transmission oils leads to the corrosion of metals as it chemically deteriorates the metallic surfaces (Nicholls et al., 2005).

There are several methods for assessing the technical condition of biodegradable fluid. Kučera et al. (2016) performed the LaserNet Fines (LNF) tests in order to determine the aging (the long-term stability) of biodegradable fluid. Table 4 shows the LNF tests of biodegradable fluid.

Table 2 Concentration (mg·kg^{-1}) of chemical elements

Chemical content	Number of engine hours			ΔEI (%), ΔED (%)
	0 EH	250 EH	500 EH	
Ag	0	0	0	0
Al	0	0	0	0
Ba	0.08	18.36	17.96	22350
Cd	0.90	0.86	0.86	4.44 (ΔED)
Cr	1.92	2.25	2.36	22.92
Cu	4.74	14.14	14.78	211.81
Fe	1.33	14.99	16.57	1145.86
K	0.43	0.50	0.50	16.28
Mg	4.56	4.54	4.67	2.41
Mn	0	0	0	0
Mo	2.20	2.43	2.30	4.55
Na	1.82	3.37	3.48	91.21
Ni	0.02	0.01	0.01	50.00 (ΔED)
Pb	0	0	0	0
Si	64.03	54.26	53.15	16.99 (ΔED)
Sn	21.25	21.00	21.87	2.92
Ti	2.65	2.55	2.56	3.40 (ΔED)
V	0.44	0.61	0.64	45.45

Table 3 Concentration (mg·kg^{-1}) of chemical elements representing the additives

Chemical content	Number of EH			ΔED (%)
	0 EH	250 EH	500 EH	
B	4.63	0.70	0.62	86.61
Ca	86.82	23.90	17.59	79.74
Zn	20.57	7.90	6.32	69.28

The results of LNF tests of biodegradable fluid correspond with the data obtained by authors Stachowiak et al. (2008) and Perić et al. (2013). Important consideration of wear particle contamination of gear oil is also focused on the trend of cleanliness code according to ISO 4406: 1999 (Kučera et al., 2016). Cleanliness code changed from value 19/17/16 to 21/18/15 during the experiment.

Fig. 1 shows the ferrography images of biodegradable fluid samples. These images were created by 400 times magnification.

Particles of contamination (Fig. 1a) that can get to fluid during the process of production and distribution were identified in the new fluid. Certain level of contamination particles is always present in hydraulic fluid, even in the new fluid (Casey, 2011). Analyzing the Fig. 1a, 1b and 1c, we can see that the fluid after 500 EH was considerably

Table 4 LNF tests of biodegradable fluid

Number of EH	Cutting particles (20–100 μm)	Fatigue particles (20–100 μm)	Sliding particles (20–100 μm)	Non-metallic particles
0 EH	-	-	-	-
250 EH	8	16	6	82
500 EH	15	13	19	96

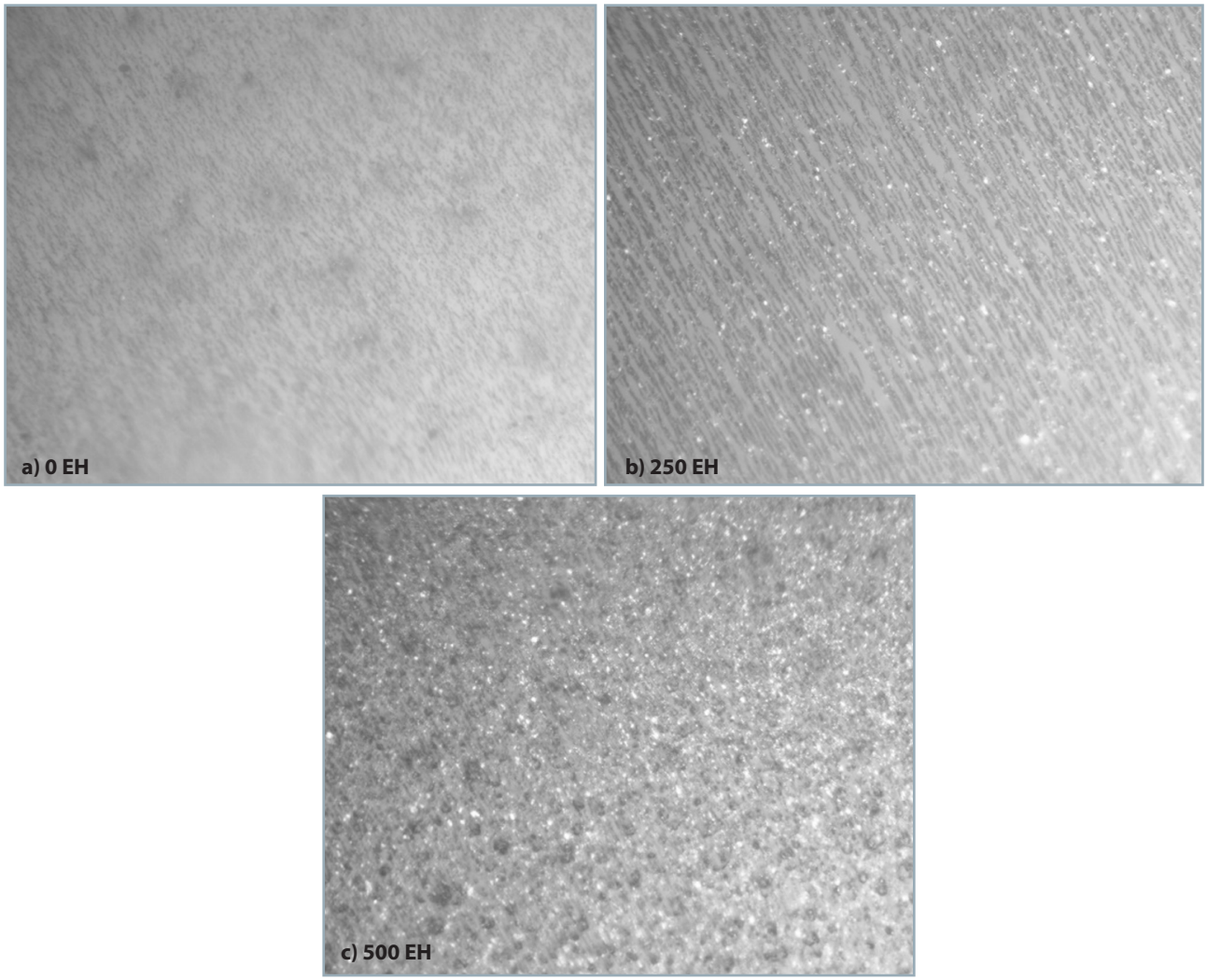

Fig. 1 Wear particles in the oil samples

contaminated with dirt of various origin. This is reflected by the dark colouration of the filter paper. There are mainly resins, which originate from degradation process. Biodegradable hydraulic and transmission fluid had good physico-chemical properties; therefore, the aging products of fluid probably got into the fluid fill through the outer hydraulic circuit from attachments.

Conclusion

Tribotechnical diagnostics use oils as a media that helps to obtain information on processes and changes in the systems they lubricate. If tribodiagnostics is applied properly and thoroughly, it results in significant savings in many areas – they contribute to: an increase of the lifetime of machines and devices; a decrease of energy consumption; limiting of the idle time (Kučera et al., 2013; Haas et al., 2016). The operational test for hydraulic oil was concluded after completion of 500 engine hours. Table 3 provides information on the decreasing trends of oil additives. The largest decrease in oil additives was observed in boron (B) and cadmium (Cd). Boron (B) content decreased from 4.63 $mg \cdot kg^{-1}$ to 0.62 $mg \cdot kg^{-1}$, and cadmium (Cd) content decreased from 86.82 $mg \cdot kg^{-1}$ to 17.59 $mg \cdot kg^{-1}$. Boron is used as a corrosion inhibiter, and cadmium is used as a detergent additive.

We can conclude that the biodegradable hydraulic and transmission fluid does not affect the construction or operation of the Zetor Proxima 6321 tractor. Biodegradable fluid has no negative impacts on the rubber components in the hydraulic and transmission systems of the Zetor Proxima 6321 tractor.

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References

ASSAFF, Y. – NEGRILL, V. J. – THEISSE, H. – MURRENHOFF, H. 2014. Analysis of the influence of contaminants on the biodegradability characteristics and ageing of biodegradable hydraulic fluids. In Journal of Mechanical Engineering, vol. 60, no. 6, pp. 417–424.

CASEY, B. 2011. Defining and Maintaining Fluid Cleanliness for Maximum Hydraulic Component Life. Available online at: http://www.plant-maintenance.com/articles/hydraulic_fluid_cleanliness.pdf [Accessed: 11-01-2017]

HAAS, P. – KADNÁR, M. – TÓTH, F. – RUSNÁK, J. – NÓGLI, D. 2016. Influence of bellows setting on its spring rate and on temperature adjustment of electromechanical thermostats. In Acta Technologica Agriculturae, vol. 19, no. 2, pp. 43–48.

HUJO, Ľ. – TKÁČ, Z. – TULÍK, J. – HAJDÁK, V. 2013. Design of laboratory test device for evaluating the lifetime of hydraulic components of tractor three-point hitch. In Advanced Materials Research, vol. 801, special iss., pp. 137–142.

HOFFMANN, D. – HEŘMÁNEK, P. – RYBKA, A. – HONZÍK, I. 2013. Design a drive for interaxle mechanical cutter used in low trellises. In Agronomy Research, vol. 11, no. 1, pp. 39–46.

HLAVÁČ, P. – BÔŽIKOVÁ, M. – CVIKLOVIČ, V. 2016. Dynamic viscosity and activation energy of wort during fermentation and storing. In Acta Technologica Agriculturae, vol. 19, no. 1, pp. 6–9.

KOSIBA, J. – ČORŇÁK, Š. – GLOS, J. – JABLONICKÝ, J. – VOZÁROVÁ, V. – PETROVIĆ, A. – CSILLAG, J. 2016. Monitoring oil degradation during operating test. In Agronomy Research, vol. 14, no. 5, pp. 1626–1634.

KUČERA M. – ROUSEK M. 2008. Evaluation of thermooxidation stability of biodegradable recycled rapeseed-based oil NAPRO-HO. In Research in Agricultural Engineering, vol. 54, no. 4 pp. 163–169.

KUČERA, M. – ALEŠ, Z. – PEXA, M. 2016. Detection and characterization of wear particles of universal tractor oil using a particles size analyser. In Agronomy Research, vol. 14, no. 4, pp. 1351–1360.

KUČERA, M. – ALEŠ, Z. – IVANDIĆ, Z. – HUJO, Ľ. 2013. Possibility of hydraulic fluids with a low environmental impact application in agriculture and transport machinery. In Journal of Central European Agriculture, vol. 14, no. 4, pp. 1592–1601.

KUMBÁR, V. – GLOS, J. – VOTAVA, J. 2014. Monitoring of chemical elements during liferime of engine oil. In Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, vol. 62, no. 1, pp. 155–159.

KUMBÁR, V. – DOSTÁL, P. 2013. Oils degradation in agricultural machinery. In Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, vol. 61, no. 5, pp. 1297–1303.

MAJDAN, R. – TKÁČ, Z. – STANČÍK, B. – ABARAHÁM, R. – ŠTULAJTER, I. – ŠEVČÍK, P. – RAŠO M. 2014. Elimination of ecological fluids contamination in agricultural tractors. In Research in Agricultural Engineering, vol. 60, no. spec. issue, pp. 9–15.

MAJDAN, R. – TKÁČ, Z. – ABRAHÁM, R. – STANČÍK, B. – KUREKOVÁ, M. – PAULENKA, R. 2013. Effect of ecological oils on the quality of materials of hydraulic pump components. In Advanced Materials Research, vol. 801, pp. 1–6.

NICHOLLS, M. A. – DO, T. – NORTON, P. R. – KASRAI, M. – BANCROFT, G. M. 2005. Review of the lubrication of metallic surfaces by zinc dialkyl-dithiophosphates. In Tribology International, vol. 38, no. 1, pp. 15–39.

PERIĆ, S. – NEDIĆ, B. – TRIFKOVIĆ, D. – VURUNA. 2013. An experimental study of the tribological characteristics of engine and gear transmission oils. In Journal of Mechanical Engineering, vol. 59, no. 7–8, pp. 443–450.

PHILLIPS, W. D. – STANIEWSKI, J. W. G. 2016. The origin, measurement and control of fine particles in non-aqueous hydraulic fluids and their effect on fluid and system performance. In Lubrication Science, vol. 28, no. 1, pp. 43–64.

STACHOWIAK, G. P. – STACHOWIAK, G. W. – PODSIADLO, P. 2008. Automated classification of wear particles based on their surface and shape features. In Tribology International, vol. 41, no. 1, pp. 1135–1139.

TARASOV, S. – KOLUBAEV, A. – BELYAEV, S. – LERNER, M. – TEPPER, F. 2002. Study of friction reduction by nanocopper additives to motor oil. In Wear, vol. 252, no. 1–2, pp. 63–69.

TULÍK, J. – HUJO, Ľ. – STANČÍK, B. – ŠEVČÍK. P. 2013. Research of new ecological oil-based fluid. In Journal of Central European Agriculture, vol. 14, no. 4, pp. 1384–1393.