RESEARCH OF BIODEGRADABLE FLUID DURING OPERATING TEST

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Abstract: This paper deals with effect of the biodegradable hydraulic and transmission fluid (Universal Tractor Transmission Oil (UTTO) on operating of the tractor hydraulic and transmission system. This fluid was used in the hydraulic and transmission circuit of a tractor Zetor Proxima 6321. Fluid samples were taken from a Zetor Proxima 6321 tractor at intervals of 250 engine hours. These samples were subjected to an IR spectroscopy analysis and differential scanning calorimetry (DSC). The biodegradable fluid meets the requirements for the operation of agricultural tractors in terms of a low impact on the wear of hydraulic components.

Key Words: biodegradable fluid, IR spectroscopy analysis, pour point

INTRODUCTION

Hydraulic equipment is widely used in powerful mechanisms of agricultural and forest machines as well as in many other areas. The development of modern hydraulic components is aimed at increasing the transmitted power, reducing the energy intensity (smaller reservoirs of hydraulic fluid), minimizing the environmental pollution and increasing the technical life and machine reliability (Tkáč et al. 2017, Hoffmann et al. 2013). Hydraulic and transmission fluid requires monitoring of quality parameters (concentration of metal elements content and concentration of chemical elements representing the additives). Fluid cleanliness is one of the most important features (Majdan et al. 2013, Máchal et al. 2013). Often, the cleanliness and technical condition of the fluid are frequent causes of failures of the transmission and mainly hydraulic system of the tractor. A contaminated fluid creates a risk to the machine in terms of wear and failure (Tkáč et al. 2014, Tulik et al. 2013). Pollution (concentration of metal elements content) is dangerous because it accelerates the degradation and oxidation processes in the fluid. If the fluid is contaminated with dirt above the permitted level, it must be replaced (Angelovič et al. 2013, Majdan et al. 2014). Universal Tractor Transmission Oils (UTTO) are designed for hydraulic and transmission systems in agricultural tractors. These fluids provide lubrication functions for the gear box and the transmission of energy in the tractor's hydraulic system (Hujo et al. 2013). The friction points in the hydraulic and transmission circuit are made from several metals (mostly iron, aluminium, and copper components) (Kumbár et al. 2014). For this reason, there is a need to check for other metals, such as aluminium, copper, chromium, lead, tin, nickel, silver, etc. (Kumbár and Dostál 2013). The aim of this paper is application biodegradable fluid in tractor gear and hydraulic circuit. A biodegradable fluid was used in the gear and hydraulic circuit of a Zetor Proxima 6321 tractor (Zetor Tractors, Czech Republic). The fluid was assessed in terms of the lubrication properties and their effect on the wear during application. Experimental results bring important information from the point of view of oil degradation. The majority of tractors are subjected to the conditions which can cause undesirable phase transition of oil in hydraulic systems. It is necessary to develop the flow of oil due to correct operation of hydraulic equipment (Kosiba et al. 2013).

MATERIALS AND METHODS

An operational test of a biodegradable hydraulic and transmission fluid was set at 500 engine hours (EH). Subsequently, fluid samples were collected for analysis and detection of contamination. As regards biodegradable hydraulic and transmission fluid, the most important is to know the running properties of the fluid, i.e. to know the effect of the fluid on the technical condition of hydraulic and transmission system parts. Table 1 shows the basic technical parameters of biodegradable fluid type UTTO.

Table 1 Technical parameters of biodegradable synthetic fluid (www.shell.com)

PROPERTIES	UNIT	AMOUNT
KINEMATIC VISCOSITY AT 40°C	mm^2/s	67.52
DENSITY AT 15°C	kg/m^3	931
FLASH POINT	°C	212
POUR POINT	°C	-48

Determining the chemical composition of hydraulic and transmission fluid has been measured using Spectroil Q100 (Spectro Scientific, USA), which is a completely solid state spectrometer. With this spectrometer it can be measured trace levels of elements dissolved or deposited as fine particles in mineral or synthetic oil-based fluids using long established and reliable technique with rotating disk electrode. This spectrometer meets the requirements of ASTM D6595 standard method for the determination of wear metals and contaminants in used lubricating oils and hydraulic mixtures (Kosiba et al. 2016, Kumbár et al. 2014). 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)
- pour point by method of differential scanning calorimetry.

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):

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

ΔED – decrease in concentration of chemical elements

ED_0 – concentration of chemical elements 0 EH

ED_{500} – concentration of chemical elements 500 EH

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

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

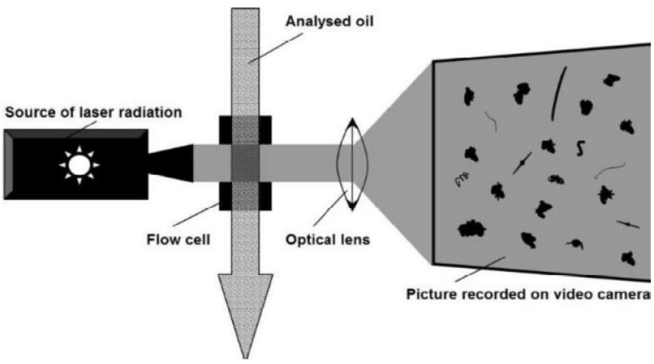
ΔEI – increases in concentration of chemical elements

EI_{500} –concentration of chemical elements 500 EH

EI_0 – concentration of chemical elements 0 EH

LNF is an automated optical oil debris device, which combines the functions of a highly accurate particle counter as well as a particle shape classifier. The basic operating principle of the LNF is illustrated in Fig. 1 (Kučera et al. 2016).

Figure 1 The basic principle of the measuring device LNF (Kučera et al. 2016)



Differential scanning calorimetry (DSC) is a technique in which difference in heat flow (power) to a sample and to a reference is monitored against time or temperature while the temperature of the sample, in a specified atmosphere, is programmed (Haines 1995). Differential method compares thermal behaviour of reference material with sample. This method provides information on thermal effects which are characterized by an enthalpy change and by temperature range, such as phase transitions (melting, crystallization etc.) (Tulík et al. 2013, Kosiba et al. 2016).

Differential scanning calorimetry (DSC) was performed on a Mettler Toledo DSC (Mettler Toledo, United Kingdom) unit. Samples with weight (8–3) mg were hermetically sealed in aluminium crucibles and thermally treated at a speed of heating 2 K/min in the temperature range from 20 °C to the temperature of -60 °C. The measurement was carried out in an air atmosphere. As a result, we got a DSC thermogram, which was evaluated in STAR^e software (Mettler Toledo, United Kingdom).

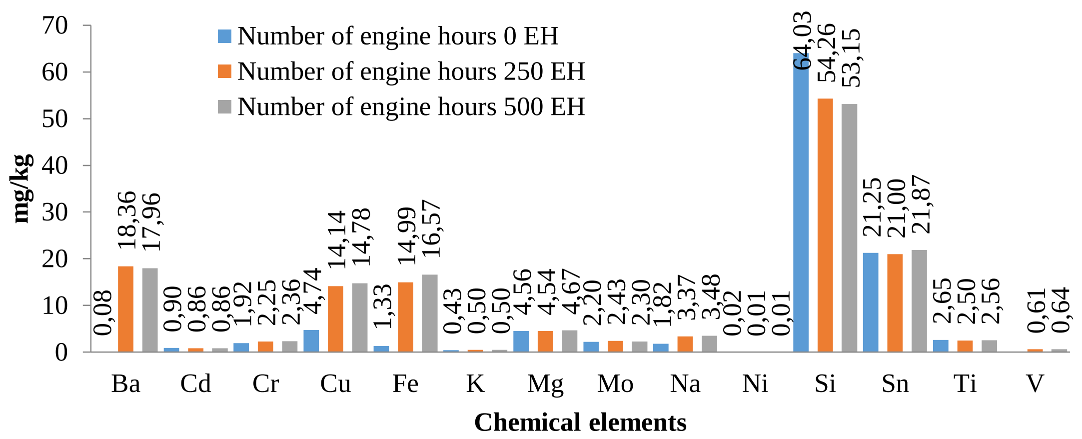
RESULTS AND DISCUSSION

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

Table 2 Concentration of chemical elements (%)

Chem. content	Ba	Cd	Cr	Cu	Fe	K	Mg
ΔEI (%)	22350		22.92	211.8	1146	16.28	2.41
ΔED (%)		4.44					
Chem. content	Mo	Na	Ni	Si	Sn	Ti	V
ΔEI (%)	4.55	91.21			2.92		45.54
ΔED (%)			50	16.99		3.40	

Figure 2 Concentration of chemical elements (mg/kg)



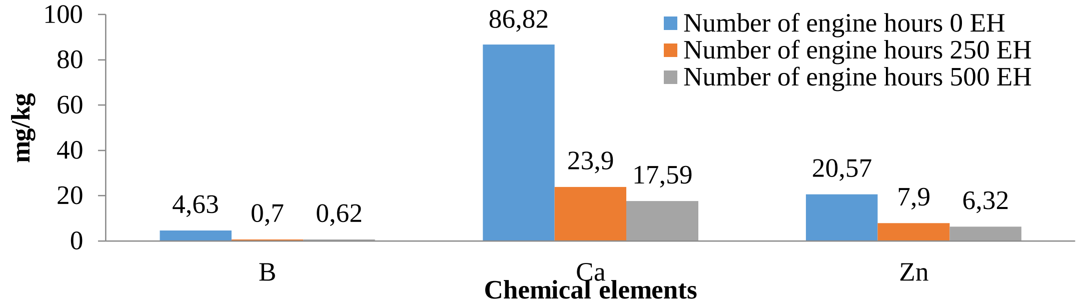
The biggest increase of deposited metals in the oil was observed in relation to barium (Ba), iron (Fe), and copper (Cu). Iron (Fe) and barium (Ba) are used as construction material in the transmission, and copper (Cu) is used as construction material in the oil cooling system. Any concentration of Ba,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

Table 3 and Figure 3 shows the base elements that characterise 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).

Table 3 Concentration of chemical elements representing the additives (%)

Chemical content	B	Ca	Zn
ΔED (%)	86.61	79.74	69.28

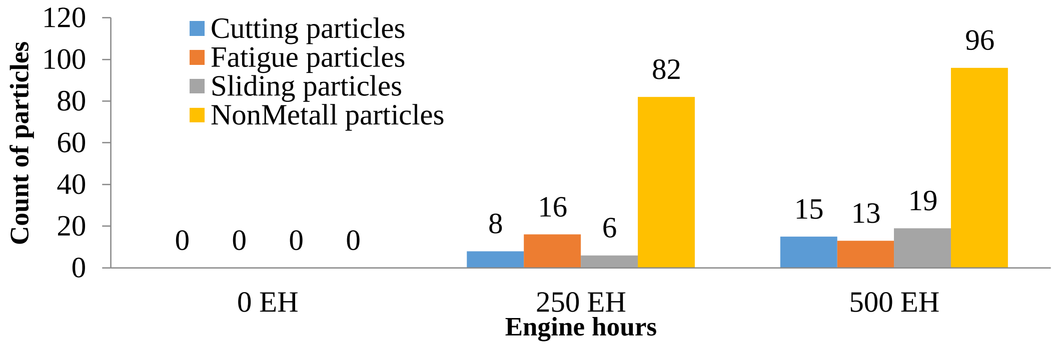
Figure 3 Concentration of chemical elements representing the additives (mg/kg)



The largest decrease was observed in the measuring of boron (B) at 86.61%. Zinc (Zn) is used as an anti-wear agent or as an antioxidant. Hydraulic and transmission oils with zinc additives that are too high have of leading to the corrosion of metals as they chemically attack the metal surfaces (Nicholls et al. 2005).

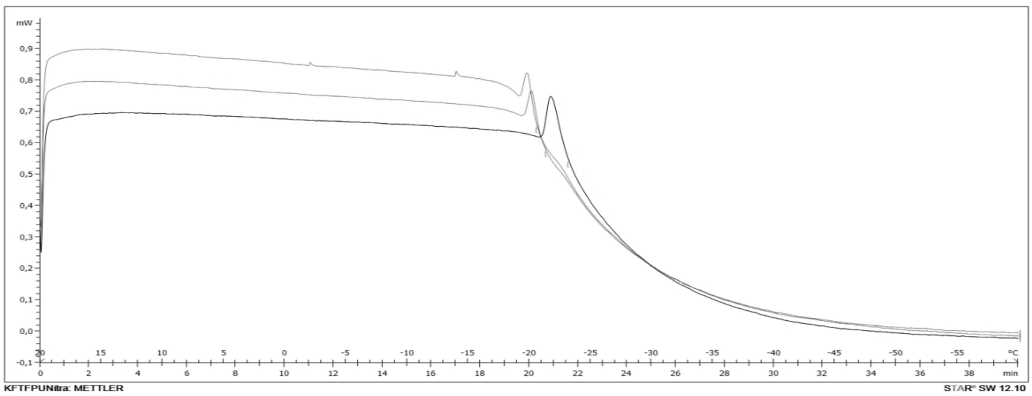
There are several methods how to assess the technical condition of biodegradable fluid. Kučera et al. (2016) used the LaserNet Fines (LNF) tests for the carried out long-term stability of biodegradable fluid. Figure 4 show the LNF tests of biodegradable fluid.

Figure 4 LNF tests of biodegradable fluid



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

Figure 5 Comparison of oil samples by DSC



Legend: SHELL naturelle hf-e46 0MH, 23.06.2017 09:53:06 SHELL naturelle hf-e46 0MH, 12.7700 mg DSC SHELL naturelle hf-e46 250MH, 23.06.2017 10:39:25 DSC SHELL naturelle hf-e46 250MH, 13.2700 mg DSC SHELL naturelle hf-e46 500MH, 23.06.2017 13:31:54 DSC SHELL naturelle hf-e46 500MH, 17.0500 mg

DSC curves which correspond to change of enthalpy due to thermal effects in the samples are on the Figure 5. In the process of oil freezing and in the case of a new oil sample, we observed exothermal peak at the temperature -22.0 °C, which corresponds to the beginning of the change in the crystalline structure of the material. Generally, temperature of phase transition depends on chemical composition and on crystalline structure of material. In the case of oil with 250 engine hours the temperature of peak was -20.35 °C. In the last sample, representing used oil with 500 engine hours, the temperature of exothermal peak was almost the same as previous -19.8 °C.

CONCLUSION

Tribotechnical diagnostics use oils as media that help obtain information about processes and changes in the systems that they lubricate. If tribodiagnostics are applied properly and thoroughly, they result in significant savings in many areas; for example, they contribute to an increase of the lifetime of machines and devices, to a decrease of consumption of energy, to limiting the idle time (Kučera et al. 2013, Haas et al. 2016). After completing 500 engine hours the operating test for hydraulic oil was completed. In Table 3 the decreasing trends for oil additives can be seen. The biggest decrease in oil additives was observed with boron (B) and cadmium (Ca). Boron (B) content decreases from 4.63 mg/kg to 0.62 mg/kg, and cadmium (Ca) content decreases from 86.82 mg/kg to 17.59 mg/kg. Boron is used as corrosion inhibiter and cadmium is used as a detergent additive.

The graph of DSC indicates that peaks corresponding to the pour point for worn out samples are almost identical, so we can infer that the difference between 250 engine hours and 500 engine hours is not very significant. But we can see the difference between new and worn out sample. Pour point (or temperature of freezing) of both worn out biodegradable hydraulic and transmission fluid samples increased more than 2 °C. The pour point introduced in the specifications of the producer is -48 °C, which corresponds to the measured values.

We can say 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 influence on the rubber components in the hydraulic and transmission system of the Zetor Proxima 6321 tractor.

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