Effect of ecological energy carriers on flow characteristics of tractor hydraulic pump

Vplyv ekologických nositeľov energie na prietokové charakteristiky traktorového hydrogenerátora

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Abstract

This paper deals with the effect of ecological energy carrier on flow characteristics of a hydraulic pump. A hydraulic oil MOL Farm UTTO Synt was used as an ecological energy carrier. After completing 900 engine hours, the flow efficiency of the hydraulic pump decreased by $\Delta\eta_{pr}$ = 1.197 %. Oil samples were taken from the agricultural tractor Zetor Forterra 114 41. These samples were subjected to an IR spectroscopy analysis in an accredited laboratory WearCheck, Hungary. The following oil properties were examined: kinematic viscosity at 40 °C, viscosity index, silicium and ferrum content.

Keywords: flow rate characteristics, hydraulic circuit, tractor

Abstrakt

Predložený príspevok sa zaoberá vplyvom ekologického nositeľa energie na prietokové charakteristiky hydrogenerátora. Ako ekologický nositeľ energie bol použitý hydraulický olej MOL Farm UTTO Synt. Pokles prietokovej účinnosti hydrogenerátora po odpracovaní 900 motohodín bol na úrovni $\Delta\eta_{pr}$ = 1,197 %. Z poľnohospodárskeho traktora Zetor Forterra 114 41 boli odoberané vzorky oleja, ktoré boli podrobené rozboru pomocou IR spektroskopie v akreditovanom laboratóriu WearCheck. Boli sledované nasledovné vlastnosti oleja: kinematická viskozita pri 40 °C, viskozitný index, obsah kremíka a obsah železa.

Kľúčové slová: hydraulický obvod, prietokové charakteristiky, traktor

Introduction

Due to advantages in renewability and environmental acceptability, bio-sourced and biodegradable hydraulic fluids are increasingly used in fluid power applications (Shick, 2008). In this time, the difference between a conventionally produced fluid and ecological fluid is two or three times of the price. Therefore, it is necessary to look for new solutions how to extend the technical life, which could have an effect on

their increased use (Tkáč et al., 2012; Kučera et al., 2008). The consumption of ecological fluids in the EU is 0.12 Mt per year from total world production of 35 Mt per year (Mosolygó et al., 2008). Almost 50 % of all the sold oils in the world finish at present times as forfeits during the operation in nature (Jakob, 2006).

This paper presents a research of the effect of ecological energy carrier on flow rate characteristics of the tractor hydraulic pump. The biodegradable synthetic oil MOL Farm UTTO (universal tractor transmission oil) Synt was used as an ecological energy carrier. The synthetic oil MOL Farm UTTO Synt is currently under development. The performance test was performed on one of the most used tractors in Slovak farms, the tractor Zetor Forterra 114 41. The hydraulic pump was removed from the tractor at specified time intervals. The pump was mounted on an experimental laboratory device for measuring the flow characteristics at the Department of Transport and Handling, Faculty of Engineering, Slovak University of Agriculture in Nitra.

Subsequently, oil samples were collected for analysis and detection of infrared spectra of iron and copper contamination. As regards hydraulic fluid utilisation in a machine, 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 system's parts (Jobbágy et al., 2003; Jablonický et al., 2007; Majdan et al., 2008; Žikla et al., 2006).

Most current lubricants contain petroleum base stocks, which are toxic to the environment and difficult to dispose of after use. Environmental pollution continues to increase due to excessive use of lubricants and various leakages, especially total losses.

Over 60 % of lubricants used in the world are lost in the environment. Vegetable oils are capable to contribute to the goal of energy independence and security since they are a renewable resource (Campanella et al., 2010; Kučera et al., 2011; Čuchran et al., 2011). The amount of biodegradable oils in the market is quite low. There is a catch-up to make a stronger pressure for using biodegradable oils as fillings of hydraulic circuits and gearboxes. It is the fact that the application of biodegradable rapeseed-based oils is doubtful. If operating parameters of recent hydraulic circuits are compared with older ones, we observe a significant increase in pressure and operating temperatures. A limited range of operating temperatures (40–70 °C) gives limits for the area of their use (Kučera et al., 2008, 2012).

Specification of Zetor Forterra 114 41 hydraulic circuit

The agricultural tractor Zetor Forterra 114 41 is manufactured by Zetor Tractors Brno, the Czech Republic. Engine power is 81 kW. The basic technical parameters of the tractor hydraulic circuit are shown in Table 1.

Table 1: Basic technical parameters of the tractor hydraulic circuit

	Units	Parameter
Hydraulics		
Type		Electro-hydraulic ZMS 23LS
Control		electronic
Operating pressure	MPa	18
Internal circuit		6+1 couplers
Hydraulic pump		
Type		UD 25
Nominal speed		1,500
Max. speed	rpm	3,000
Min. speed		500
Max. pressure at input		0.05
Min. pressure at input	MPa	0.03
Nominal speed at output		20
Max. pressure at output		23
Geometric volume	cm^3	25

The ecological oil is made from synthetic fluid, and it is marked as MOL Farm UTTO Synt. This oil is for common gear-hydraulic circuits of agricultural tractors.

Materials and Methods

Before the operating test of MOL Farm UTTO Synt, the tractor was equipped with a new hydraulic pump UD 25. At the same time, the tractor hydraulic circuit was cleaned, and new oil filters were used. At the intervals of 450 engine hours, the hydraulic pump was removed from the tractor. The hydraulic pump was mounted on the laboratory device for measuring the flow characteristics at the Department of Transport and Handling, Faculty of Engineering, Slovak University of Agriculture in Nitra. The test stand for measuring the hydraulic pump flow characteristics is shown in Figure 1.
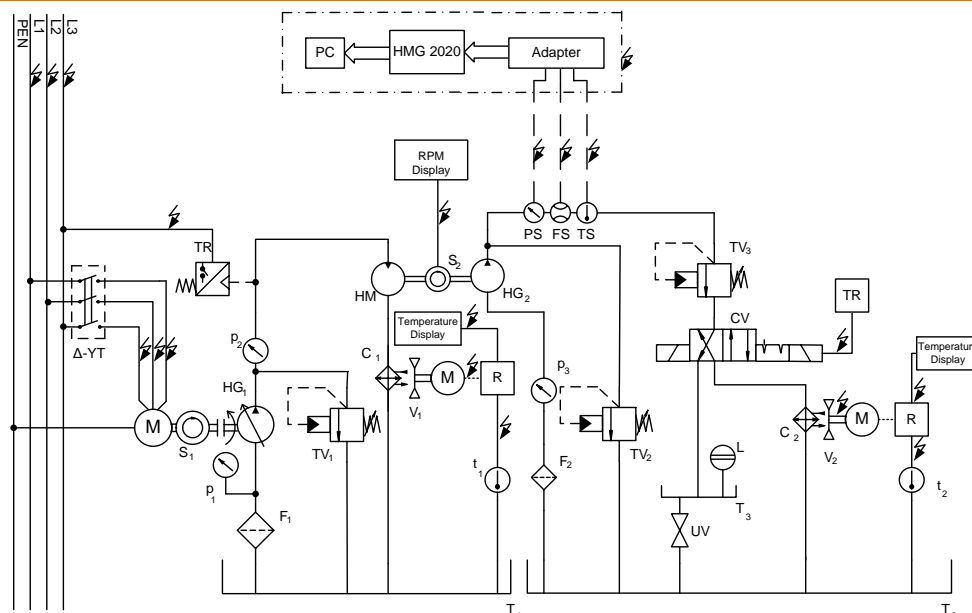
Figure 1: Device for measuring the hydraulic pump flow characteristics

M – electric motor, HG_1 – regulating hydrostatic pump, TV_1, TV_2 – safety valve, S_1, S_2 – coupler, HM – hydraulic motor, HG_2 – tested hydrostatic pump, TV_3 – valve for adjusting pressure, PS – pressure sensor, FS – flow sensor, TS – temperature sensor, CV – control valve, TR – trigger, T – oil temperature controllers, L – flow meter, p_1, p_2, p_3 – pressure sensors, t1 – temperature sensor for tank T_1, t_2 – temperature sensor for tank T_2, T_1, T_2, T_3 – tank, F_1, F_2 – filter, V_1, V_2 – ventilator, C_1, C_2 – cooler, UV – spherical plug valve (Tkáč et al., 2008)

The test stand consists of two hydraulic circuits. The left hydraulic circuit is used to drive the hydraulic pump HG_2 for measurement. The output line of the hydraulic pump HG_1 is directly connected to the hydraulic motor output HM (HG_1 is a regulatory axial piston pump). A change in the flow of the hydraulic pump HG_1 is used to set the speed of the measured hydraulic pump HG_2. The pressure valves TV_1 and TV_2 are functioning as safety valves. The pressure valve TV_3 is designed to set the values of pressure (from zero to the nominal value). We measured the flow $Q = f(p)_n$ at the set pressure value, or the pressure to measure $Q = f(n)_p$. Before measuring the flow characteristics of the hydraulic pump, we set the speed to the nominal value (measured hydraulic pump HG_2) by changing the flow of the hydraulic pump (HG_1). The measurement of characteristics is performed by gradually increasing the pressure by the pressure valve TV_3 (up to the nominal pressure value of the measured hydraulic pump HG_2). Based on these data, it is possible to determine the flow characteristics of the hydraulic pump (Tkáč et al., 2010; Majdan, 2010; Drabant et al., 2010).

A flow sensor EVS 3100 was used for recording the flow characteristics. This sensor is specifically designed for use in hydraulic systems. The sensor connection diagram is shown in Figure 2.

Basically, the sensor works on the principle of a turbine, that means the speed of the turbine is taken from the impeller, which rotates in a liquid stream. The number of revolutions is measured and then converted to analogue signal from 4 to 20 mA with

inductive sensor. The impeller is typically made from stainless steel and suitable for use in applications of pulse and dynamic flow.
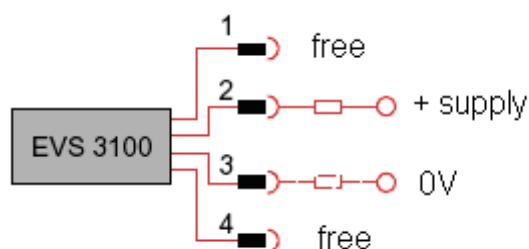

Figure 2: Sensor connection diagram

From the measured data of hydraulic pump flow characteristics, there was obtained a sample of values to determine the mean value of flows at a pressure of 20 MPa. Flow efficiency was calculated from this mean value and is given by the following equation (Cvíčela et al., 2008):

$$\eta_{pr} = \frac{Q_m}{V_G \cdot n} \cdot 100 \tag{1}$$

Where:

Q   – output flow rate (dm^3*rpm)

V_G – geometrical volume of hydraulic pump (dm^3)

n   – nominal rotation speed of hydraulic pump (rpm)

At the same time, oil samples were taken from the tractor at specified time intervals. These samples were subjected to the IR spectroscopy analysis in the accredited laboratory WearCheck, Hungary. The following oil properties were analyzed in oil samples:

> ➢ kinematic viscosity at 40 °C,

> ➢ viscosity index,

> ➢ silicium content,

> ➢ ferrum content.

Results and Discussion

After completing 450 and 900 engine hours, the hydraulic pump was removed from the tractor. After that, it was mounted to the laboratory device to measure the flow characteristics. Flow characteristics were measured at a speed of 1,500 rpm (nominal speed of hydraulic pump). Figure 3 shows the flow characteristics of the UD 25 hydraulic pump.
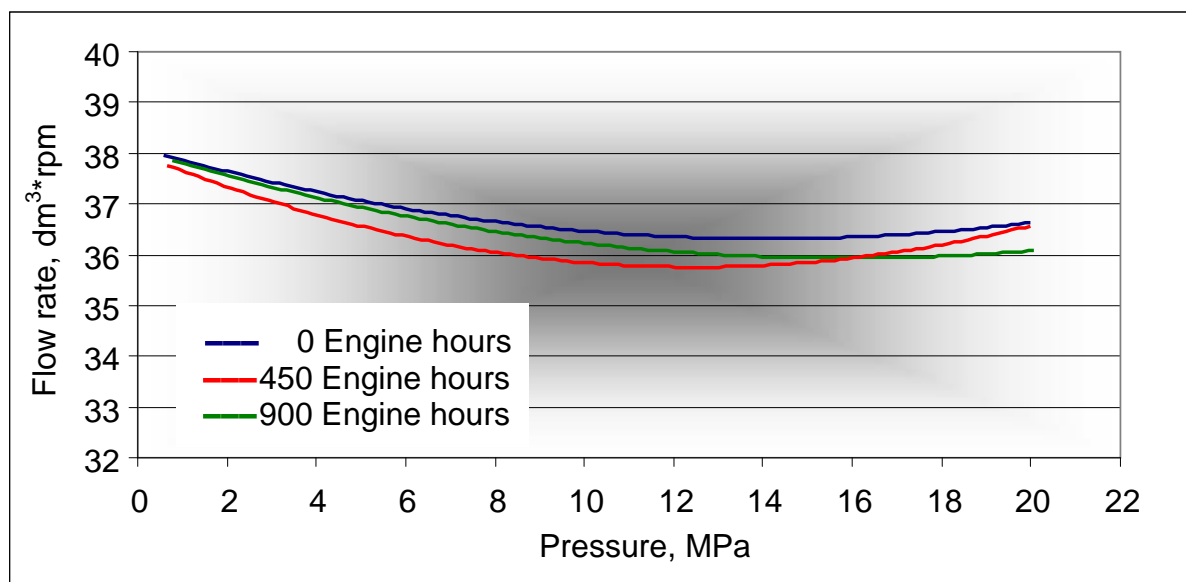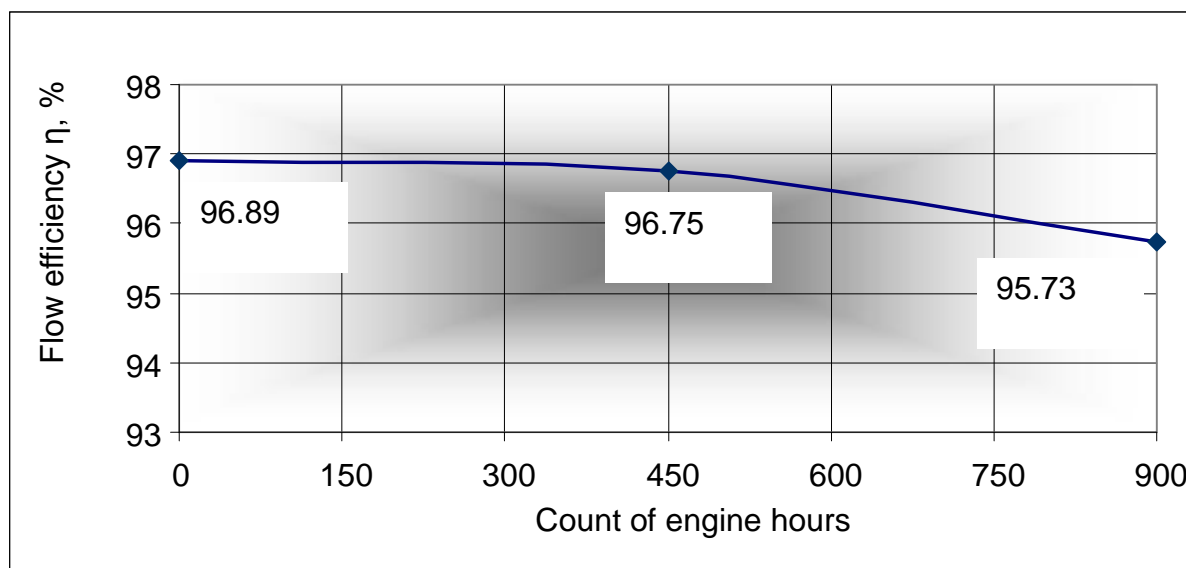
Figure 3: Flow characteristics of the hydraulic pump at n = 1,500 rpm

Figure 4: Flow efficiency of the hydraulic pump

At the beginning of the performance test, the level of flow efficiency was at $\eta_{pr0} =$ 96.89 %; at the end of the performance test, it was at $\eta_{pr900} = 95.73$ %. This means that the decrease in flow efficiency of the UD 25 hydraulic pump after completing 900 Eh was $\Delta\eta_{pr} = 1.197$ %. This decrease indicates a minimal impact of synthetic oil MOL Farm UTTO Synt on the lifetime of the hydraulic pump.

Basic parameters of descriptive statistics

Table 3 shows the basic descriptive statistics determined by a statistical data analysis module in MS Excel 2007.

Average:

$$\overline{x} = \frac{1}{N} \cdot \sum_{i=1}^{N} x_i \tag{2}$$

x_i – x_i value of units

N – sample size

Median:

For an odd number of values:

$$Me = x_{\frac{n+1}{2}} \tag{3}$$

Variance:

$$V = \frac{1}{N} \cdot \sum_{i=1}^{N} (x_i - x)^2 \tag{4}$$

N – sample size

x – average

Standard deviation:

$$SD = \sqrt{V^2} \tag{5}$$

Table 2: Basic parameters of descriptive statistics at p = 20 MPa

	Unit	Average	Median	Variance	Standard deviation
		x	Me	V	SD
Flow rate - 0 engine hours	(dm^3*rpm)	36.335	36.321	0.057	0.239
Flow rate - 450 engine hours	(dm^3*rpm)	36.282	36.368	0.243	0.493
Flow rate - 900 engine hours	(dm^3*rpm)	35.902	35.903	0.112	0.334

Results of monitored oil properties and degree of pollution

The evaluation of monitored oil properties and the degree of pollution was prepared in the accredited laboratory WearCheck in Almásfüzitő, Hungary. It was performed from samples taken after completing 450 and 900 engine hours. The values of kinematic viscosity and viscosity index did not exceed the limit values for the use of synthetic oil. The degree of pollution of the synthetic oil MOL Farm UTTO Synt was determined using the ICP spectrometry.
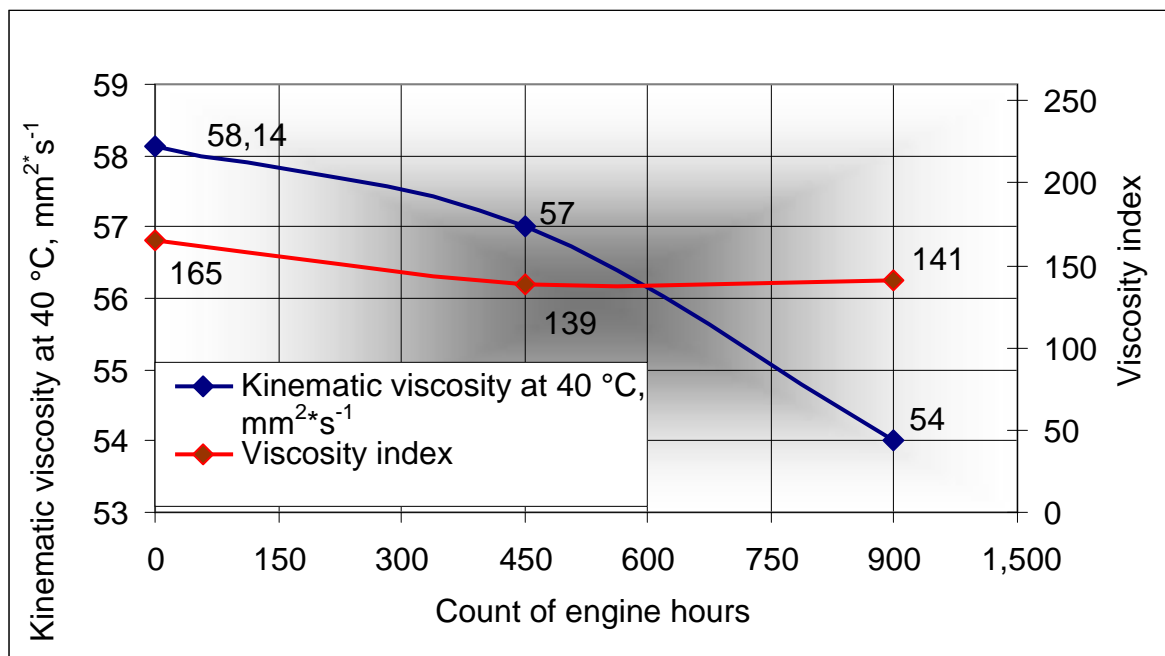

Figure 5: Course of monitored properties of the synthetic oil MOL Farm UTTO Synt
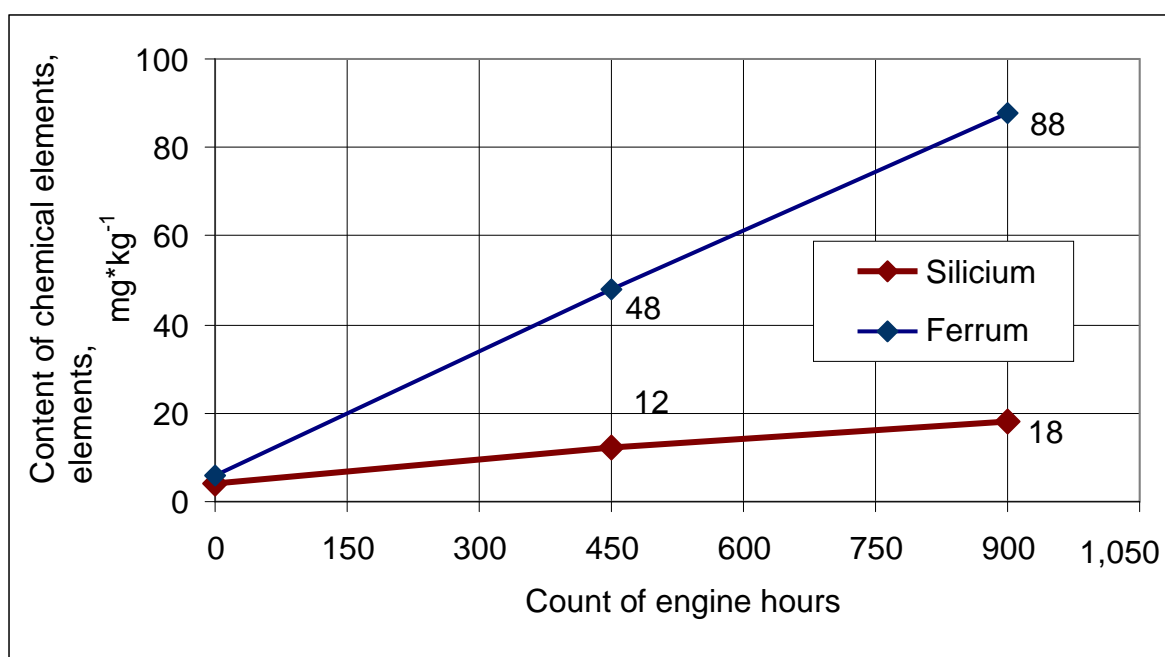

Figure 6: Content of chemical elements

After completing 450 engine hours, values of ferrum and silicium reached a critical level of pollution in the synthetic oil. After completing 900 engine hours, these values of ferrum and silicium reached an unsatisfactory level of pollution. After consultation with the manufacturer of the synthetic oil MOL Farm UTTO Synt, the performance test of the oil in the gear-hydraulic circuit of Zetor Forterra 114 41 was completed.

When applying the oil EKOUNIVERZÁL, the tractor ZTS 8011 with the hydraulic pump PZ 2 – 18 KS was used in operation from 0 Eh to 2,242 Eh. For 16 MPa pressure at hydraulic pump output and 2,200 rpm nominal speed, flow rate measured at 0 Eh was 22.80 dm^3*rpm. After 2,242 Eh, the measured flow rate was 19.05 dm^3*rpm. The lifetime of PZ 2 – 18 KS is 2,000 Eh. The measurement revealed a necessity to replace the hydraulic pump because the minimally allowed flow rate of the hydraulic pump at nominal speed is 19 dm^3*rpm (Tkáč et al., 2002, 2003).

In case of the hydraulic pump PZ 2 – 19 KS with the oil EKOUNIVERZÁL, Škulec et al. (2001) found at revolutions 1,500 rpm and pressure 16 MPa a decrease in flow rate by 1.25 % after 300 Eh. Škulec used a new hydraulic pump PZ 2 – 19 KS in test. For this reason, there was two times higher decrease in flow rate with the hydraulic pump UD 25 than with the hydraulic pump PZ 2 – 19 KS.

Conclusion

In this paper, there are presented the results of testing the synthetic oil MOL Farm UTTO Synt operating in the gear-hydraulic circuit of Zetor Forterra 114 41, one of the best sold and most used tractors in Slovakia. After completing 900 engine hours, the test had to be completed due to exceeded contamination of the oil sample (silicium and ferrum content). The evaluation of monitored oil properties and the degree of pollution was determined in the accredited laboratory WearCheck in Almásfüzitő, Hungary. Despite this fact, it can be alleged that the developed synthetic oil does not affect the functionality of the tractor gear-hydraulic circuit. The decrease in the flow efficiency of the UD 25 hydraulic pump during the test was $\Delta\eta_{pr} = 1.197$ %. This decrease showed a negative impact of the synthetic oil on hydraulic pump flow efficiency.

Acknowledgements

References

Campanella, A., Rustoy, E., Baldessari, A., Baltanás, Miquel, A., (2010). Lubricants from chemically modified vegetable oils. Bioresource Technology 101, pp. 245 – 254.

Čuchran, J., Kučera, M., Franta, M., (2011). Metódy tribotechnickej diagnostiky pre hodnotenie použitých motorových olejov (Tribotechnical diagnostic methods for evaluation of user motor oils). In: Acta facultatis technicae. Zvolen: TU in Zvolen. No. 2 , pp. 17 – 25

Cvíčela, P., Majdan, R., Abrahám, R., Jablonický, J., (2008) Monitoring the operating loading of a hydrostatic pump UD 25. In: X. International Conference of Young Scientists 2008: Conference Proceedings: CZU Prague.

Drabant, Š., Kosiba, J., Jablonický, J., Tulík, J., (2010) The durability test of tractor hydrostatic pump type UD 25 under operating load. In: Research in Agricultural Engineering. Prague : Institute of Agricultural Economics and Information. Vol. 56, no. 3, pp. 116-121.

Jablonický J., Abrahám R., Majdan R., Cvíčela P., (2007) Skúšky traktora s biologicky odbúrateľným olejom (Tests of the tractor with biodegradable oil). In: Assurance - Quality - Responsibility: 3. International Scientific Conference - Košice: Technical University: 123-127.

Jakob, K., Theissen, H., (2006) Bio-based Oils in Hydraulics – Experience from Five Years of Market Introduction in Germany. Institute for Fluid Power Drives and Controls (IFAS), RWTH Aschen University, Germany.

Jobbágy J., Petranský I., Simoník J., (2003) Tlakové režimy v hydraulike traktorov ZTS v súprave s poľnohospodárskym náradím (Pressure regimes in ZTS tractors hydraulics in a set of agricultural tools). In: International Conference of Young Scientists. Nitra: SUA in Nitre: 94 – 101.

Kučera M., Ruesek, M., (2008). Evaluation of thermooxidation stability of biodegradable recycled rapeseed-based oil NAPRO-HO 2003. In: Research in Agricultural Engineering. Praha. Vol. 54, no. 4, pp. 163-169

Kučera M., Ruesek, M. (2011). Determination of the oxidative stability of vegetable oil-based lubricants. In: Acta facultatis technicae. Zvolen: TU in Zvolen. No. 2 , pp. 101-110

Kučera M., Ruesek, M., Hnilicová, M. (2012). Vyšetrovanie kvalitatívnych parametrov recyklovaných hydraulických olejov z nízkym environmentálnym dopadom (Investigation of qualitative parameters of recycled hydraulic oil with low environmental impact). In: Hydraulika a pneumatika. No. 2, Vol. XIV., pp. 31-34.

Kučera M., Rédl J., (2008) Vplyv podmienok experimentu na tribologické vlastnosti vybraných materiálov (Effects of experimental conditions on tribologic properties of selected materials). Acta technologica agriculturae, *1*: 98-104.

Majdan, R., Tkáč, Z., Drabant, Š., Tulik, J., Žigiň, P., Jablonický, J., Abrahám, R., Vozárová, V., (2010) The damping of pressure shock for the hydrostatic circuit of agricultural tractor. In: Traktori i pogonske mašine. Vol. 14, no. 1, pp. 22-26.

Majdan R., Cvíčela P., Bohát M., Ivanišová K., (2008) The observation of hydrostatic pump deterioration during the durability test according to hydraulic fluids contamination. In: X. International Conference of Young Scientists 2008: Czech University of Life Sciences Prague: 147-153.

Majdan R., (2010) Simulácia tlakového rázu v hydraulickom obvode (The simulation of pressure surge in hydraulic circuit) In: XII. International Conference of Young Scientists. Nitra: 119-123.

Mosolygó, E., Jánošík, Š., (2008) Lubricants based on renewable resources. In: Interfaces'08. Sopron : Slovnaft a.s., Member of the MOL Group, 2008, pp. 111-120.

Shick, D., (2008) Compatibility testing of biodegradable hydraulic fluids [online]. Available at: http://www.msoe.edu/academics/research_centers/reu/pdf/2008/ Compatibility% 20Testing%20of%20Biodegradable%20Hydraulic%20Fluids.pdf [Accessed: 03-02-2012]

Škulec, R., Pokorný, K., Tkáč, Z., (2001) The Laboratory Test of Tractor Hydrostatic Pump. In: Agrotech Nitra 2001. pp. 390 -395.

Tkáč, Z., Majdan, R., Drabant, Š., Jablonický, J., Abrahám, R., Cvíčela, P., (2010) The accelerated laboratory test of biodegradable fluid type "ertto". In: Research in Agricultural Engineering. Vol. 56, no. 1, pp. 18-25.

Tkáč, Z., Škulec, R., (2002) Aplikácia bioodbúrateľného oleja v prevodovom a hydraulickom systéme traktora. (Application of bio-degradable oil in the gear and hydraulic system of the tractor). In: Acta Mechanika 2002. TU in Kosice. pp. 297 – 270.

Tkáč, Z., Petranský, I., Varga, D., Hujo, Ľ., Bolla, M., (2003) Hydraulický a prevodový systém traktora ZTS 8011 pri práci s bioolejom. (Hydraulic and transmission system of tractor ZTS 8011 at work with bio oil). In: Hydraulika a pneumatika 2003. pp. 32 – 35.

Tkáč, Z., Majdan, R., Tulík, J., Kosiba, J., (2012) Study of ecological fluid properties under operational conditions of tractors. In: TEAM. Osijek-Baranja : University of Josip Juraj Strossmayer, vol. 4, no. 1, pp. 295-298.

Žikla A., Jablonický J., (2006) Kopírujúca regulácia trojbodového závesu traktorov (Copying control of tractor three-hitch point). Hydraulika a pneumatika, 4: 42-46.