

# The operation of agricultural tractor with universal ecological oil

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## Abstract

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This contribution presents the results of the research into the characteristics of ecological oil labelled MOL Farm UTTO Synt in the tractor operating conditions. Biodegradable fluid was applied in the gear and hydraulic circuits of the tractor Zetor Forterra 114 41. The fluid was assessed for contamination and lubrication properties by its effect on the wear of tractor hydraulic pump during the application. The hydraulic pump was removed from the tractor at specified time intervals because of its technical condition relating to the flow efficiency. The measurements were calculated as flow efficiency with minimum environmental impact of oil on the hydraulic pump wear.

**Keywords:** synthetic oil; hydraulic pump; flow characteristic

At the present time, hydrostatic systems are widely spread in the industry. They provide various types of motion. The power transmission is realised by hydraulic fluid. Hydraulic fluid needs servicing and requires the control of operating parameters (MAJ-DAN et al. 2008; BELOVIČ, Majdan 2011). Almost 50% of all the oils sold in the world finish at the present time as forfeits during the operation in nature (JAKOB, THEISSEN 2006). Therefore, it is extremely important to replace mineral oils with vegetable oils or plant-based synthetic oils (TKÁČ et al. 2010).

Agricultural technology has a negative impact on all elements of the environment. As to air, it is affected by the exhaust emissions, and the soil respectively water by oil and for fuel components (JABLONICKÝ et al. 2007; KUČERA, PRŠAN 2008; KUČERA, RÉDL 2008). This paper presents the results of a long-term operational test of the biodegradable synthetic oil

MOL Farm UTTO Synt (Slovnaft a.s., Bratislava, Slovak Republic), which is currently under development. The operational test was performed on one of the most used tractors, the tractor Zetor Forterra 114 41 (Zetor Tractors a.s., Brno, Czech Republic) in the conditions of Slovak farms. The hydraulic pump was removed from the tractor in the time intervals; the pump was mounted onto the experimental laboratory device for measuring the flow characteristics at the Department of Transport and Handling, Faculty of Engineering, University of Agriculture in Nitra, Nitra, Slovak Republic.

Subsequently, the oil samples were collected for the analysis and detection of iron and copper contamination by means of infrared spectra. In view of the utilization of hydraulic fluid in a machine, it is the most important to know the running properties of the fluid, i.e. to know the influence of the fluid

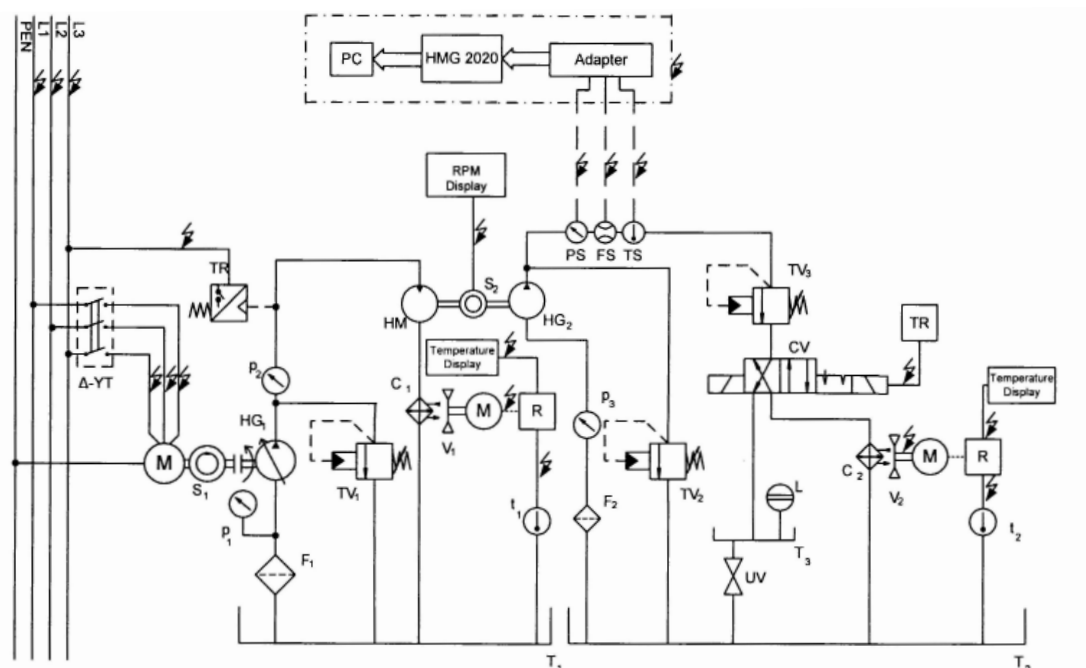


Fig. 1. Experimental device for measuring the flow characteristics of the hydrostatic pump

PEN – neutral;  $L_1$  – phase 1;  $L_2$  – phase 2;  $L_3$  – phase 3;  $\Delta$ -YT – delta-ye transformer; M – electric motor;  $HG_1$  – regulating hydrostatic pump;  $TV_1$ ,  $TV_2$  – insured valve;  $S_1$ ,  $S_2$  – coupler; HM – hydrostatic 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 – flowmeter;  $p_1$ ,  $p_2$ ,  $p_3$  – pressure sensors;  $t_1$  – 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)

on the technical state of the hydraulic system parts (ŽIKLA, JABLONICKÝ 2006; JABLONICKÝ et al. 2007; Tkáč et al. 2008).

## MATERIAL AND METHODS

The experimental device for measuring the flow characteristics is shown in Fig. 1. It was designed at the Department of Transport and Handling, Technical Faculty of Slovak University of Agriculture in Nitra, Nitra, Slovak Republic.

This device allows to measure the following characteristics:

$Q = f(p)_n$  dependence of the flow rate on the pressure at constant speeds and  $Q = f(n)_p$  dependence of the flow rate on the speed at constant pressure.

The test stand consists of two hydraulic circuits. The left hydraulic circuit is used to drive the hydraulic pump  $HG_2$  in the 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). To set the speed of the measured hydraulic pump  $HG_2$ , the flow change is used made by the hydraulic pump  $HG_1$ . The pressure valves  $TV_1$

and  $TV_2$  have the function of the safety valve. The pressure valve  $TV_3$  is designed to set the values of pressure (from zero to the nominal value). We measure 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 at the nominal value (measured by the hydraulic pump  $HG_2$ ) by changing the flow hydraulic pump ( $HG_1$ ). In the measurement of the characteristics, a gradual increase in pressure is created by the pressure valve  $TV_3$  (to the nominal value of the pressure measured by hydraulic pump

Table 1. Specifications of oil MOL Farm UTTO Synt

Property	Unit	Amount
Density at 15°C	g/cm <sup>3</sup>	0.8681
Kinetic viscosity at 40°C	mm <sup>2</sup> /s	58.14
Kinetic viscosity at 100°C	mm <sup>2</sup> /s	10.22
Viscosity index		165
Pour point	°C	–42
Flash point	°C	232
Calcium	%	0.318

HG<sub>2</sub>). Based on these data, we can determine the flow characteristics of the hydraulic pump (DRABANT et al. 2010; MAJDAN 2010; TKÁČ et al. 2010).

During the operation of the tractor, the following physico-chemical properties of the ecologic oils were monitored:

- contamination of liquid admixtures, by IR spectroscopy,
- iron content,
- copper content important factors for obtaining high quality representative samples are: the correct choice of the delivery points; mixing and heating the fluid at the operating temperature. The analysis of the pollution samples of iron and copper was performed in the accredited laboratory WearCheck, Hungary.

**Ecological oil.** Ecological oil is made from the synthetic fluid and is marked as MOL Farm UTTO Synt. It belongs to the type of oil UTTO (Universal Tractor Transmission Oil). This oil is destined for the common gear-hydraulic circuits of agricultural tractors. Table 1 shows the basic technical parameters of the synthetic oil tested.

Before operating, the test tractor was equipped with a new hydraulic pump type UD 25 (Jihostroj a.s., Velešín, Czech Republic). At the same time, the gear-hydraulic circuit of the tractor was mounted and also a new oil filter was installed. At the start of the operational testing of the synthetic oil MOL Farm UTTO Synt the temperature regimes were tested of the tractor working with a gear-hydraulic circuit. The measurements were performed by placing the temperature sensor using a coupling flange on the output line of hydraulic pump.

Operations, and types of auxiliary equipment for measuring the thermal regime:

- disc cultivator LBD 4.5,
- plow Kverneland LD 100,
- drill SE 1073 M.

## RESULTS AND DISCUSSION

The measuring system consisted of the digital recording unit HMG 2020 (Hydac GmbH, Sulzbach/Saar, Germany) and temperature sensor (ETS 4144-A-000; Hydac GmbH). The digital recording unit HMG 2020 recorded temperatures at one second intervals. The measurement of the thermal regime lasted 50 minutes. The temperature modes of the tractor gear-hydraulic circuit operation during the work operations are shown in Fig. 2. The highest temperature was reached in the tractor with seeder SE 1073 M (Agroplus s.r.o., Hlohovec, Slovak Republic). The oil temperature was stabilised at approximately the same time with all measurements (KOSIBA et al. 2011a, b).

The work operations conducted during the synthetic oil performance test are shown in Table 2.

The oil temperature is the most important parameter for the use of biodegradable oils in the gear-hydraulic circuits of tractors. The measured values of the oil temperature can not reduce an operating test of MOL Farm UTTO synthetic oil. The oil is applied into the gear-hydraulic circuit Zetor Forterra 114 41 tractor. The hydraulic pump type UD 25 was removed from the tractor at intervals of 450 engine hours and 900 engine hours. Then an experimental laboratory device was installed for measuring the flow characteristics. The measurement of the flow characteristics is used to determine the impact of the synthetic oil on the hydraulic pump life. The flow hydraulic pump efficiency was calculated from the measured flow characteristics (CVÍČELA et al. 2008):

$$\eta_{pr} = \frac{Q}{V_G \times n} \times 100 \quad (1)$$

where:

$Q$  – output flow rate (dm<sup>3</sup>.rpm)

$V_G$  – geometrical volume of hydrostatic pump (dm<sup>3</sup>)

$n$  – nominal rotation speed of hydrostatic pump (rpm)

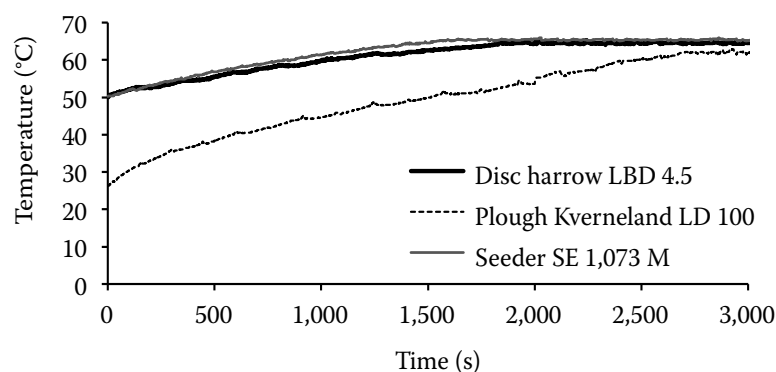


Fig. 2. Temperature modes of Zetor Forterra 114 41 tractor

Table 2. Working operations performed with Zetor Forterra 114 41 tractor during operating test

Work	Machinery type (producer)	Engine hours	
		0–450	450–900
Stubble cultivation	LBD 4,5 (Chervona Zirka, Kirovograd, Ukraine)	86	95
Transport	BSS-9 (Brandýrské strojírný, Senice na Hané, Czech Republic)	46	70
Ploughing	Kverneland LD 100 (Kverneland Group, Kverneland, Norway)	105	149
Seeding	1 073 M (Pneusej – Accord, Hlahovec, Slovak Republic)	191	118
Plant protection	Forrás 2006/18 (Interat ZRT., Bicske, Hungary)	20	19
Summary		448	451

The flow efficiency was determined with a new hydraulic pump, after completing 450 engine hours and after completing 900 engine hours. The measurement of the flow characteristics was performed at speeds  $n = 800$  rpm,  $n = 1200$  rpm, and  $n = 1,500$  rpm. Figs 3, 4, and 5 show the flow efficiency of the hydraulic pump UD 25 at different speeds.

The greatest decrease in the hydraulic pump flow efficiency was detected at a speed  $n = 800$  rpm and a pressure of 20 MPa. The flow efficiency of the hydraulic pump type UD 25 dropped from  $\eta_0 = 89.8\%$  to  $\eta_{900} = 87.75\%$ . Under the nominal speed of the hydraulic pump  $n = 1500$  rpm and a pressure of 20 MPa, the flow efficiency of the hydraulic pump declined from  $\eta_0 = 96.89\%$  to  $95.73\% = \eta_{900}$ .

### Basic parameters of descriptive statistics

Table 3 presents the basic descriptive statistics indicators, which were determined by statistical data analysis module in a MS Excel 2007 (Microsoft Corp., Redmond, USA). The graphic processing of the results was performed using software Statistica 7 (Statsoft, Inc., Tulsa, USA).

$$V = \frac{1}{N} \times \sum_{i=1}^N (x_i - \bar{x})^2 \quad (2)$$

where:

$N$  – statistical file size

$x_i - \bar{x}$  – values of the units

$\bar{x}$  – average

Standard deviation:

$$SD = \sqrt{V} \quad (3)$$

The differences in the range between the min. and max. values are relatively small. The outliers and

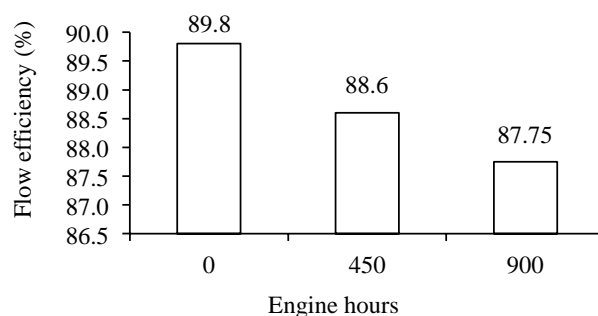


Fig. 3. The flow efficiency of UD 25 hydraulic pump at rotation speed  $n = 800$  rpm

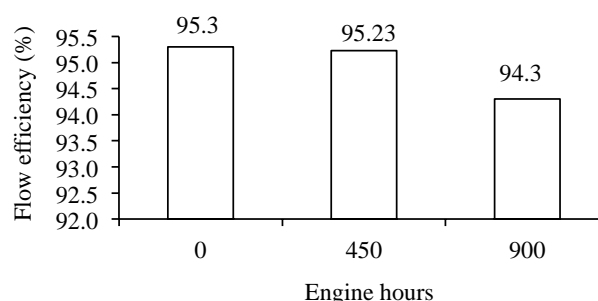


Fig. 4. The flow efficiency of UD 25 hydraulic pump at rotation speed  $n = 1,200$  rpm

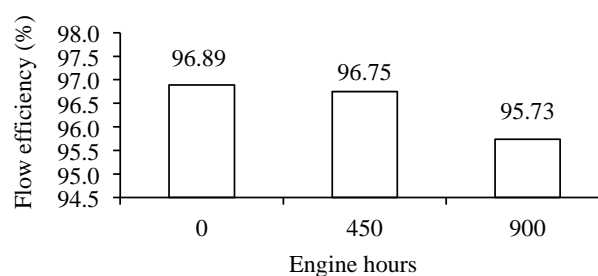


Fig. 5. The flow efficiency of UD 25 hydraulic pump at rotation speed  $n = 1,500$  rpm

Table 3. Basic parameters of descriptive statistics at pressure  $p = 20$  MPa

	Average	Median	Modus	Min.	Max.	Variance	Standard deviation
Output flow rate – 0 engine hours (dm <sup>3</sup> .rpm)	36.335	36.32	36.29	35.741	36.865	0.057	0.239
Output flow rate – 450 engine hours (dm <sup>3</sup> .rpm)	36.282	36.368	36.423	34.516	36.988	0.243	0.493
Output flow rate – 900 engine hours (dm <sup>3</sup> .rpm)	35.902	35.903	35.778	34.91	36.595	0.112	0.334

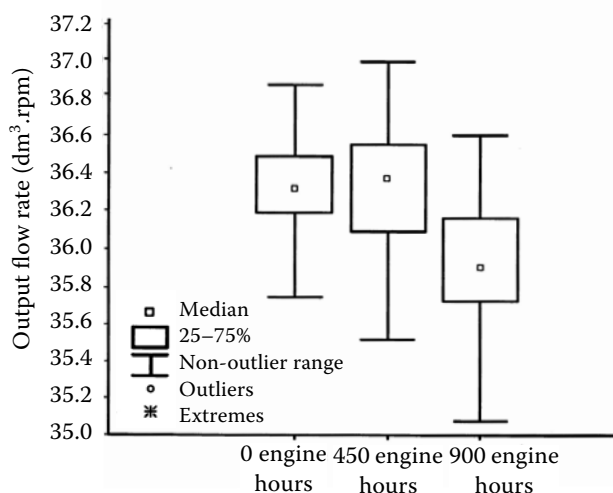


Fig. 6. Box-and-Whisker diagram of the output flow rate

extreme points on the Box-and-Whisker diagram of the output flow rate were not found (Fig. 6).

### Evaluation of oil pollution

The analysis of oil pollution by chemical elements (iron and copper) was performed in the accredited laboratory WearCheck, Hungary. The test was performed by ASTM D 4951-02 (standard test method for the determination of additive elements in lubrication oils by inductively coupled plasma atomic emission spectrometry). New oil was evaluated after completing 450 and 900 engine hours. The

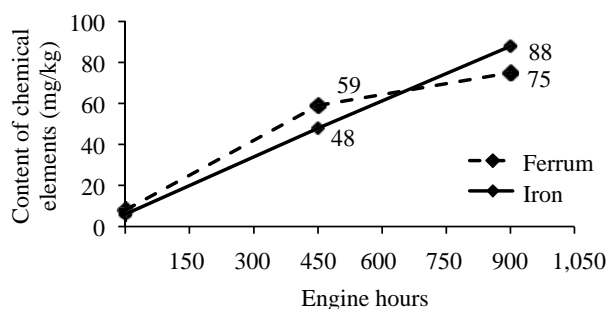


Fig. 7. Contents of chemical elements

course of oil contamination by the chemical elements is shown in Fig. 7.

The level of oil MOL Farm UTTO Synt pollution with admixtures (Cu, Fe) has reached a critical level after completing 450 engine hours. The limit values of oil pollution were exceeded in the gear-hydraulic circuit of the tractor Zetor Forterra 114 41 after completing 900 engine hours.

### Analysis of the origin of synthetic oil pollution

The evaluation of the analysis of the origin of synthetic oil pollution by IR spectroscopy is shown in Fig. 8. The change in the synthetic oil MOL Farm UTTO Synt can be seen in the areas of 1,650 cm<sup>-1</sup> and 1,600 cm<sup>-1</sup>. On the  $x$  axis are shown the wavelengths that correspond to the individual chemical compounds. In the case of new oil, the absorbance reflects the chemical compounds concentration in the oil produced. The increase of absorbance after 450 and 900 engine hours reflects the increase of the chemical compounds concentrations. The additives are characterised precisely by the wavelengths from 1,500–1,700/cm. The changes of absorbance at these wavelengths expressing the oil degradation were not identified.

### CONCLUSION

The performance test has shown that the new biodegradable oil MOL Farm UTTO Synt is very beneficial for our lives. We look forward to the possibility of greening the agricultural tractors used in Slovak agriculture. This contribution proves minimal effect of the synthetic oil on the decrease of the flow efficiency during the performance test and hydraulic pump wear. The experimental device was constructed at the Department of Transport and Handling, Faculty of Engineering, Slovak University of

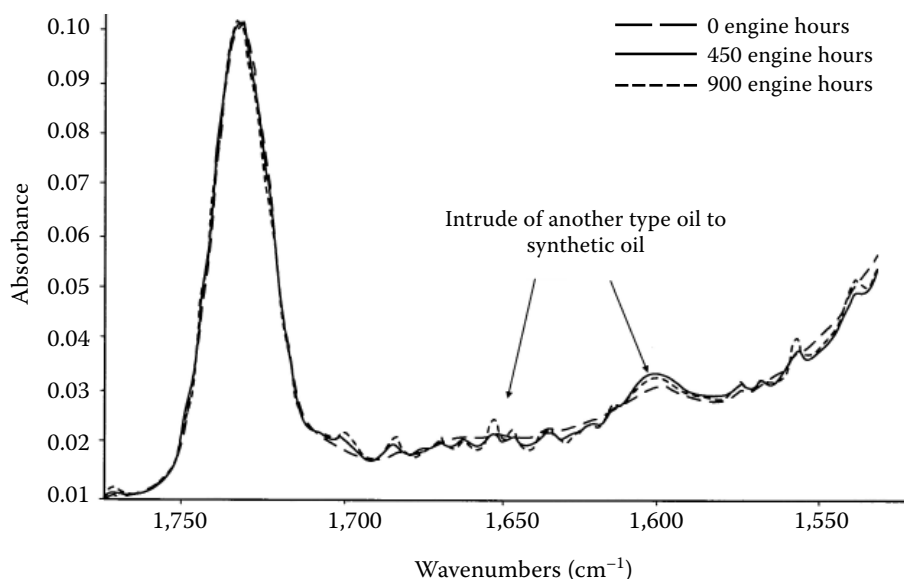


Fig. 8. Evaluation of oil contamination by IR spectroscopy

Agriculture in Nitra. The ecological fluid meets the requirements for the operation of agricultural tractors in terms of a low impact on the wear of hydraulic components. The results show good lubricating properties of the organic oil to ensure a reliable operation of the tractor. The operational test had to be stopped prematurely for increased contents of impurities (chemical elements Fe and Cu), after a consultation with the producer of the synthetic oil. Using IR spectroscopy, it was found that the impurities got into the hydraulic circuit of the tractor Zetor Forterra 114 41. These contaminants get into the hydraulic circuit through external hydraulic outlets admixture of mineral oil. We can say that the new developing biodegradable synthetic oil MOL Farm UTTO Synt does not affect the construction or operation of the tractor Zetor Forterra 114 41. MOL Farm UTTO Synt has no negative influence on the rubber components in the hydraulic circuit of the tractor Zetor Forterra 114 41. The price of the oil is higher than that of standard mineral oils.

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