The comparison of biodegradable hydraulic fluid with mineral oil on the basis of selected parameters

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Abstract

Majdan R., Kosiba J., Tulík J., Kročková D., Šinský V., 2011. **The comparison of biodegradable hydraulic fluid with mineral oil on the basis of selected parameters.** Res. Agr. Eng., *57 (Special Issue)*: S43–S49.

The paper presents a comparison of two fluids quality. The first one was mineral oil type UTTO which is commonly used in the transmission and hydraulic systems of agricultural tractors. The second one tested was biodegradable hydraulic fluid type ERTTO which could replace the toxic mineral oil. Both fluids were tested under the same test conditions using a special test device. The selected parameters of the hydrostatic pump were evaluated. The tests were evaluated according to the parameters describing the technical state of the hydrostatic pump as follows: flow efficiency, decrease of flow efficiency and cleanliness level of the fluid tested. This additional measurement verifies the test results. On the basis of the results achieved, we can state that the biodegradable hydraulic fluid exerts no harmful influence on the technical state of the hydrostatic pump. Therefore, the biodegradable fluid tested can be applied to the agricultural tractor. Has been demonstrated that the selected parameters are suitable for the evaluation of hydraulic fluid during its working performance. Therefore, these parameters will be used in the next examination of the fluid under operational conditions of an agricultural tractor.

Keywords: cleanliness level; hydrostatic pump; flow efficiency; agricultural tractor

The durability and reliability of hydraulic systems depend among others on the hydraulic fluid used. Hydraulic fluids are used for the transmission of energy and control the hydraulic components. Another significant role is the lubrication in the operational system. In practice, it is often needed to integrate new and often contradictory properties of hydraulic fluids resulting from the increasing use of hydraulic systems in more and more extreme conditions, e.g. temperature, pressure, military engineering, space research etc. (Jobbágy et al. 2003; Petranský et al. 2003; Tkáč et al. 2005).

This article presents a comparison between biodegradable hydraulic fluid and mineral oil. The tests were realised in the laboratory of the Department of Transport and Handling of the Faculty of Engineering, Slovak University of Agriculture in Nitra.

MATERIAL AND METHODS

The tests were carried out as follows:

– test was realised on a special test device according to the standard STN 11 9287 (1983) and the work published by Radhakrishanan (2003),
– hydraulic pump was loaded with cyclically changing pressure from 0.1 MPa to the nominal pressure of the hydraulic pump 20 MPa during the test,

Supported by the Scientific Grant Agency VEGA of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences, Grant No. 1/0462/09.

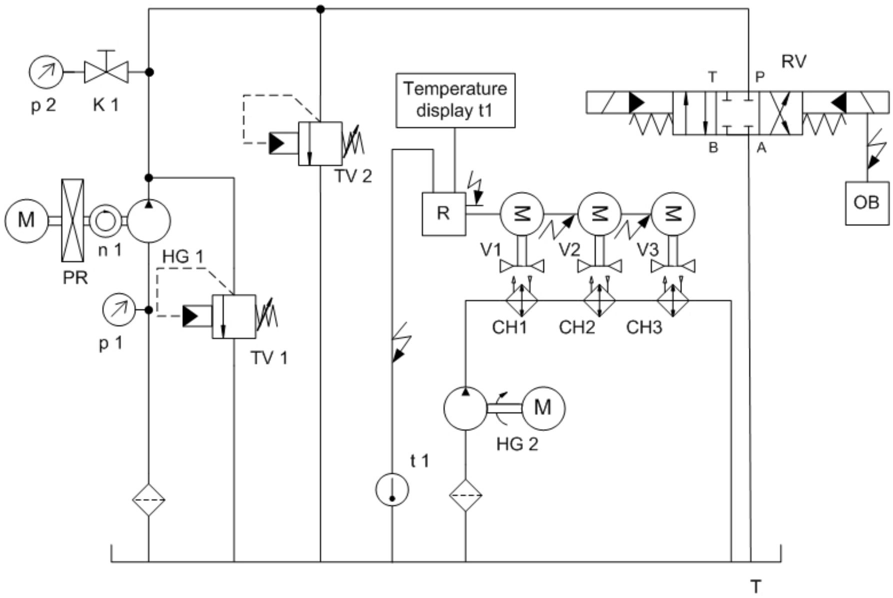

Fig. 1. Test device for realisation of laboratory durability test of hydrostatic pumps (Tkáč et al. 2008)
M – electric motor, n 1 – rpm sensor, HG 1 – tested hydrostatic pump, TV 1 – two stage pressure relief valve, TV 2 – two stage sequence valve for adjusting nominal pressure in the hydrostatic pump outlet, p 1 – pressure gauge of pressure in the inlet, p 2 – pressure gauge of pressure in the outlet, K 1 – spherical plug valve, PR – gear box, OB – control block, T – tank, RV – tree-positions, four-port slide valve with closed center which is operated electro-hydraulically, CH 1, CH 2, CH 3 – coolers, V 1, V 2, V 3 – fans, HG 2 – hydrostatic pump for cooler, t 1 – temperature sensor for tank, R – thermostatic regulator which controls switching on of cooling fans

– the criteria of quality of the tested fluids comprised the flow efficiency, decrease of flow efficiency and fluids contamination (Sloboda, Sloboda 2002; Mihalčová, Al Hakin 2008, 2009),
– fow efficiency was calculated from the flow characteristics measured,
– flow characteristics and the selected parameters were determined every 250,000 cycles until ending the test after 10^6 pressure load cycles.

Mineral oil MOL Traktol NH Ultra

MOL Traktol NH Ultra is a UTTO-type (Universal Tractor Transmission Oil) lubricant which can also be used in the gears and hydraulic systems of the tractors fulfilling the requirements generated by heavy loads in a wide range of the operating temperature. The fluid was made by the company Slovnaft, Ltd. (Bratislava, Slovak Republic). The product is suitable for use in wet brakes as well a long drain lubricant for cog-wheel gears, equalising gears, Power-Shift transmissions, wet break- and hydraulic control systems of agricultural and forest off-road machines and tractors. This oil belongs to the group of universal tractor oils UTTO. The technical parameters are listed in Table 1.

Table 1. Technical parameters of mineral oil MOL Traktol NH Ultra

Parameter	Value
Kinematic viscosity under 100°C (mm^2/s)	10.7
Kinematic viscosity under 40°C (mm^2/s)	60
Specific weight under 15°C (g/cm^3)	0.888
Viscosity class	SAE 80W
Performance level	API GL-4

Biodegradable hydraulic fluid MOL Traktol ERTTO

The hydraulic fluid is of an ERTTO-type (Environmentally Responsible Tractor Transmission

Table 2. Technical parameters of biodegradable fluid MOL Traktol ERTTO

Parameter	Value
Kinematic viscosity under 100°C (mm^2/s)	10.38
Kinematic viscosity under 40°C (mm^2/s)	47.89
Viscosity index VI (–)	213
Congealing point (°C)	–39

Table 3. The evaluation of mineral oil test

Cycle count	Rotation speed (n = 1,500 rpm)			
	flow Q (dm^3/min)	flow efficiency η (%)		decrease of flow efficiency Δ η (%)
0	35.98	0.959	95.9	0
250,000	36.46	0.972	97.2	–1.33
500,000	36.85	0.983	98.2	–2.42
750,000	36.91	0.984	98.4	–2.58
1,000,000	36.05	0.961	96.13	–0.19

Oil) and is biodegradable tractor oil. The fluid was made by the company Slovnaft, Ltd. The oil is made from vegetable natural oil and special additives. The oil is destined for use in the gearbox and hydraulic circuit of agricultural and construction machines. Primary biodegradation per CECL-33-A-93 is 90% within 28 days and test method OECD 301 B is 65%. The technical parameters are listed in Table 2.

The test device designed to tests of hydrostatic fluids

The designed test device (Fig. 1 shows the schema) enables to test the hydraulic fluids on the ground of the evaluation of the technical state of the hydrostatic pump which is tested with the fluid. In this case, the load of the hydrostatic pump and fluid is realised by cyclic pressure loading under pressure changing from p = 0.1 MPa to the nominal pressure p = 20 MPa, frequency f = 1.1 Hz, and velocity of pressure increasing v = 340 MPa/s. Radhakrishanan (2003) also presented this type of fluid test. The cyclic pressure loading is technically realised by the cyclic change of the slide valve position RV. This valve changes its state from the central position to the left position. The nominal pressure on the pump outlet is limited by the sequence pressure valve TV 2. The test device was designed according to the works published by Tkáč et al. (2001, 2003, 2006), Horka et al. (2005).

The calculation of flow efficiency decrease

The standard STN 11 9287 (1983) determines the way of the test evaluation. The fluid must be evaluated by flow efficiency decrease of the hydrostatic pump as follows:

$$\Delta\eta_{pr} = \frac{\eta_{pr0} - \eta_{prm}}{\eta_{pr0}} \times 100 \quad \% \qquad (1)$$

where:
$\Delta\eta_{pr}$ – the flow efficiency decrease (%)
η_{pr0} – the flow efficiency at 0 cycles (start of the fluid test)
η_{prm} – the flow efficiency after 10^6 cycles (end of the fluid test)

Then, the flow efficiency is expressed by the Eq.:

$$\eta_{pr} = \frac{Q_2}{V_G \times n} \times 100 \quad \% \qquad (2)$$

where:
Q_2 – flow of hydrostatic pump (dm^3/min)
V_G – geometrical volume of hydrostatic pump (dm^3)
n – nominal rotation speed of hydrostatic pump (1/min)

Table 4. The evaluation of biodegradable fluid test

Cycles count	Rotation speed (n = 1,500 rpm)			
	flow Q (dm^3/min)	flow efficiency η (%)		decrease of flow efficiency Δ η (%)
0	36.549	0.975	97.5	0
250,000	37.035	0.988	98.8	–14
500,000	36.634	0.977	97.7	–0.2
750,000	35.337	0.942	94.2	3.2
1,000,000	33.958	0.906	90.4	7.3

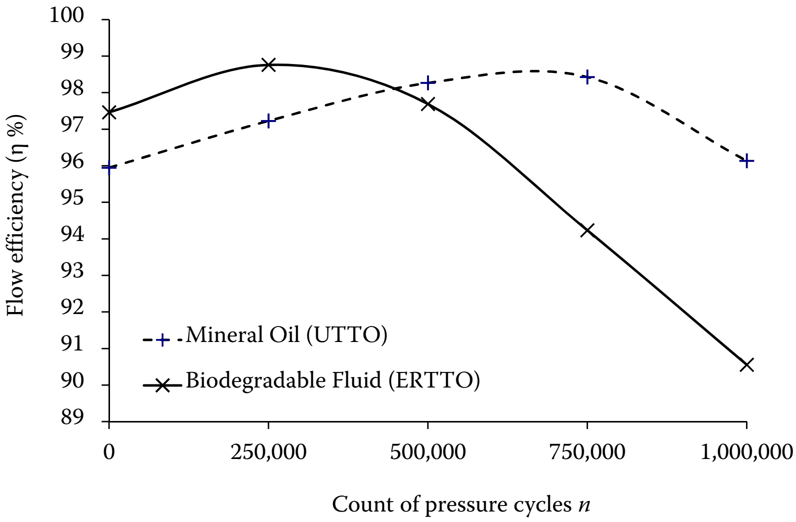

Fig. 2. The comparison between the biodegradable fluid (ERTTO) and the mineral oil (UTTO) on the basis of flow efficiency

RESULTS AND DISCUSSION

Test of mineral oil MOL Traktol NH Ultra

Table 3 shows the calculated flow rate, flow efficiency, and decrease of flow efficiency coming from mineral oil test at the rated speed $n = 1{,}500$ rpm. All values have been calculated from the measurements of the flow rate characteristics of the hydraulic pump UD 25 (Jihostroj Ltd., Velesin, Czech Republic). The flow rate characteristics were measured every 250,000 cycles during the fluid test.

Test of biodegradable hydraulic fluid

In Table 4 are the calculated values of flow rate, flow efficiency, and flow efficiency decrease of biodegradable fluid at the rated speed of the hydraulic pump $n = 1{,}500$ rpm. All values have been calculated from the measurements of the flow rate characteristics of the hydraulic pump type UD 25. The flow rate characteristics were measured every 250,000 cycles during the fluid test.

The comparison of biodegradable fluid with mineral oil

In Fig. 2 can be seen the comparison between the biodegradable fluid and mineral oil based on the tests performed with the test device (Fig. 1). The value of the flow efficiency of the biodegradable oil was decreased after the test as compared to the value measured before the test, while with the mineral oil no decrease was recorded.

In the case of the mineral oil test, the flow efficiency at the end of the test ($\eta = 96.1\%$) was higher than at the beginning ($\eta = 95.9\%$). Fig. 2 shows that no decrease of the flow efficiency occurred (dashed

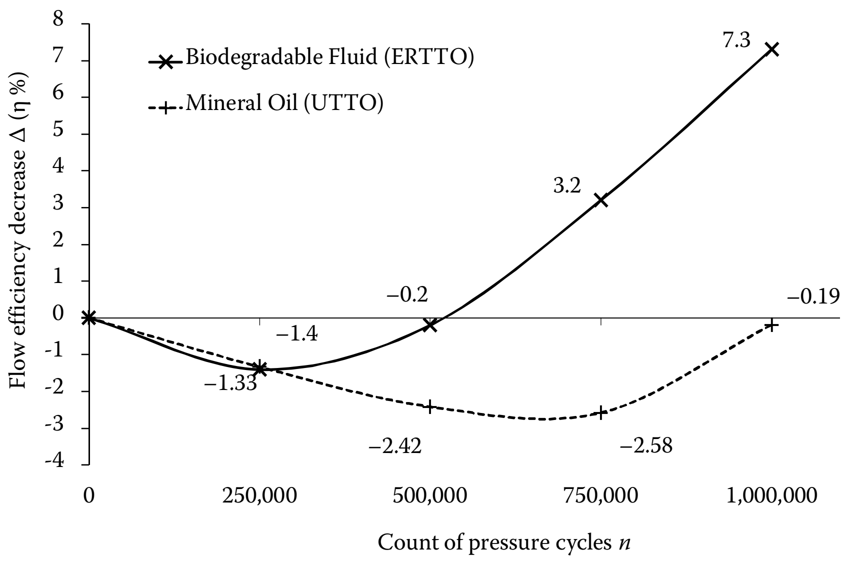

Fig. 3. The Comparison between the biodegradable fluid (ERTTO) and the mineral oil (UTTO) on the basis of flow efficiency decrease

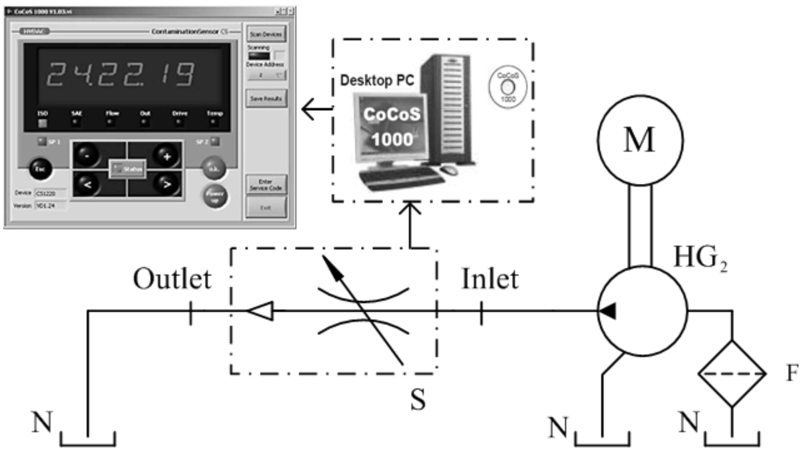

Fig. 4. The device CS 1000 intended for the measurement of fluid cleanliness level in the test device
N – tank of test device, S – contamination sensor, F – filter, HG_2 – pump which transports fluid through contamination sensor, M – electric motor

line). During the mineral oil test, the hydraulic pump was just running-in, which is expressed by the negative values listed in Table 3 and Fig. 3.

In the case of the biodegradable fluid, the flow efficiency at the end of the test (η = 90.4%) was lower than at the beginning (η = 97.464%). Fig. 2 shows this flow efficiency decrease (solid line). During the test of the biodegradable fluid, the hydraulic pump was only running-in to 500,000 cycles, which is expressed by the negative values listed in Table 4 and Fig. 3.

The cleanliness level of biodegradable fluid

The cleanliness level was measured with the help of the device type CS 1000 (Fig. 4; Hydac GmbH, Sulzbach, Germany), which enables to evaluate the fluids according to ISO 4406 (1999).

During the machine operation, all the particles resulting from wear and tear are collected in the fluid. The standard ISO 4406 (1999) evaluates the fluid pollution on the basis of three quantitative classes measurements. The classes are destined by the numbers of particles bigger that 4 µm, 6 µm and 14 µm. The classes are depicted in the form of columns in the graphs (Figs 5 and 6). Biodegradable fluid contamination is shown in Fig. 5.

The cleanliness level of mineral oil

Mineral oil contamination is shown in Fig. 6. In this case, the same test device was used for the evaluation of the cleanliness level by the standard ISO 4406 (1999).

CONCLUSION

This article presents a comparison between a new type of biodegradable hydraulic fluid ERTTO and the conventionally used mineral oil type UTTO. These

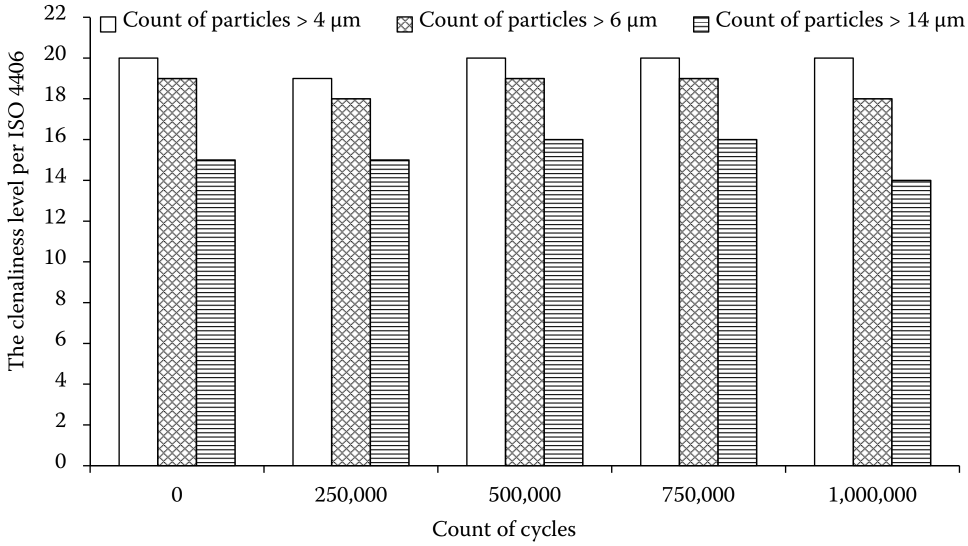

Fig. 5. Cleanliness level of biodegradable fluid evaluated as per ISO 4406 (1999)

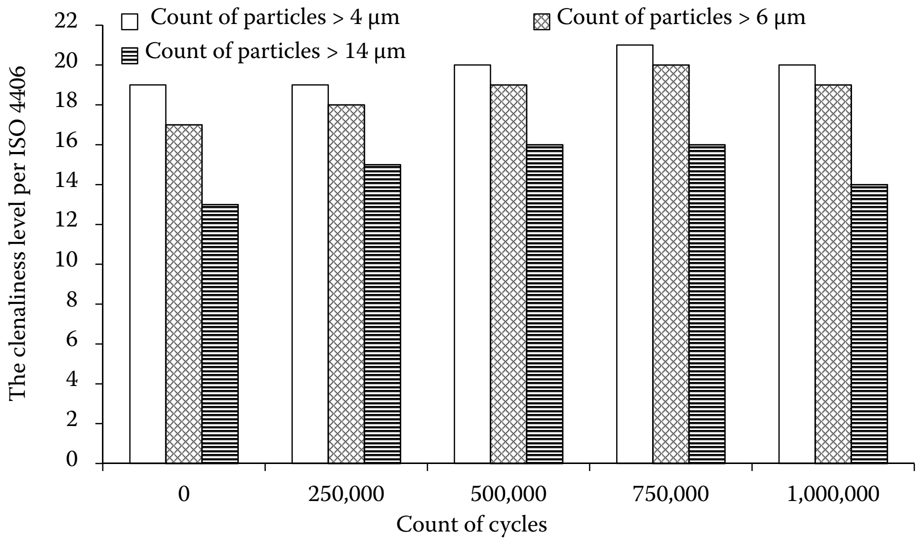

Fig. 6. Cleanliness level of mineral oil evaluated as per ISO 4406 (1999)

fluids have been evaluated on the basis of the technical state of the tractor hydraulic pump type UD 25 used during the test. The evaluation parameters were the flow efficiency and decrease of the flow efficiency; these were calculated based on the measured and statistically processed values of the flow rate. All results were transposed to graphs and tables.

The flow characteristics inform us about the process of deterioration during the tests of both fluids. In the case of the biodegradable fluid test (Figs 2 and 3), it is obvious that the flow on the output of the hydrostatic pump rose to 500,000 cycles. The parameters of the hydrostatic pump were improving. It is possible to explain it by the running-in at the beginning of the test. After 750,000 cycles, the flow started to decline, and at the end of the test the flow declined under the rated one measured within 0 cycles (new hydrostatic pump). The described development of the hydrostatic pump deterioration was confirmed also by the thermo-visual and fluid contamination measurements.

The particles arising from wear and tear are captured in the oil. The oil may also serve as the indicator for the evaluation of the deterioration process. Figs 5 and 6 describe the process of hydrostatic pump deterioration in view of fluid contamination evaluation. The number of particles rose until the end of the running-in. The running-in is characterised by the speeding-up of the deterioration process and a higher production of particles. At the end of the biodegradable fluid test (10^6 cycles), the decline in the particles count was observed only with big particles above 14 μm. In the case of mineral oil test, the decline of the particle count was found with particles above 14 μm and 6 μm.

On the fluids comparison, we can state that the mineral oil has better attributes than the biodegradable oil. While during the mineral oil test the hydraulic pump was just running-in, during the biodegradable oil test we recorded 7.3 per cent decrease of the flow efficiency (Fig. 3). This value is lower than maximum limit 20 per cent given by the standard STN 11 9287 (1983). Therefore, the biodegradable fluid tested can be applied to the agricultural tractor.

As mentioned above, all the parameters selected describe the deterioration process of the hydrostatic pump with which the fluid test was realised. Therefore, these parameters will be used to observe the application of the new biodegradable fluid under conditions of the agricultural tractor operation.

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Received for publication January 18, 2011
Accepted after corrections October 31, 2011

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