EFFECT OF ECOLOGICAL HYDRAULIC FLUID ON OPERATION OF TRACTOR HYDRAULIC CIRCUIT

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Abstract
This paper deals with the effect of biodegradable synthetic fluid on operation of tractor hydraulic circuit. Biodegradable synthetic fluid was applied in the hydraulic circuits of the tractor Zetor Proxima 6321. Operation test of this fluid was set at 500 engine hours. The flow efficiency of hydraulic pump was determined with the start of the test and after completing 500 engine hours and fluid samples were taken from the tractor hydraulic circuit. In terms of a decrease in hydraulic pump flow efficiency, operation tests of this fluid did not show negative effects of its application. These samples were subject to a measuring of kinematic viscosity at 40 °C and total acid number.

Key words: flow efficiency, kinematic viscosity at 40 °C, total acid number, density at 15 °C.

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, minimizing the environmental pollution and increasing the technical life and machine reliability (TKÁČ ET AL., 2008; HOFFMANN ET AL., 2013). Universal tractor transmission oils (UTTO) are designed for hydraulic and transmission systems of agricultural tractors. These fluids provide lubrication functions in the gear box and transmission of energy in the hydraulic system of the tractor (HUJO ET AL., 2013; KUČERA ET AL., 2013).

Environmental protection is an actual topic already for several years, and it becomes a preferred problem in the established trend of economic development (TÓTH ET AL., 2014). Agricultural technology has a negative impact on all elements of the environment (KUČERA ET AL., 2008). It was reported that over 60% of all lubricants end up in soil and water. Hydraulic line breaks are extremely common. If not attended to, these releases can cause contamination of the soil, ground and surface water (MAJDAN ET AL., 2014). The ecological fluids market is expanding, and ecological oils which can be used in hydraulic and transmission systems are one of the provided products (KUČERA ET AL., 2014A; KOSIBA ET AL., 2013). This paper presents the results of a long-term operational test of the biodegradable synthetic fluid. The operational test was performed on the tractor Zetor Proxima 6321 (ZETOR TRACTORS A. S., BRNO, CZECH REPUBLIC).

The aim of this work is application biodegradable synthetic fluid in tractor gear and hydraulic circuit. A biodegradable fluid was used in the gear and hydraulic circuit of a tractor Zetor Proxima 6321. The fluid was assessed in terms of the lubrication properties and their effect on the wear of a tractor hydraulic pump during application. The basic indicator of hydraulic pump lifetime is flow characteristics. During operating of a tractor were evaluated the major characteristics of the biodegradable fluids; kinematic viscosity at 40 ºC, total acid number (TAN) and density at 15 ºC. 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. The rate of oil flow is important to the life of the hydraulic system.

MATERIALS AND METHODS

Operational test of biodegradable synthetic fluid type universal tractor transmission oil (UTTO) was set at 500 engine hours (EH). Tab. 1 shows the basic technical parameters of biodegradable synthetic fluid type UTTO. Fluid samples were taken from the tractor hydraulic circuit at the start of the test and after completing 500 EH. Subsequently, fluid samples were collected for laboratory analysis. The following parameters were evaluated:

- kinematic viscosity at 40 °C,
- total acid number (TAN),
- density at 15 °C.

Tab. 1. – Technical parameters of biodegradable synthetic fluid

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

To establish a methodology for the flow of hydraulic characteristics of hydraulic pumps measuring, it is needed to set up the components that would be used to achieve the intended results. The most important components include a flow sensor, pressure sensor, temperature sensor, recording unit, load member and joint flange. By the draft of the measurement chain, it is required to follow the certain measurement conditions. The most important condition by measuring of the flow characteristics of hydraulic pumps is the oil temperature. The temperature must be maintained at constant value, because the viscosity of the oil depends on it. At the same time, by measuring of the flow characteristics, the oil temperature must be on operating value. Another extremely important parameter is speed of hydraulic pump. The speed of hydraulic pump will be monitored based on the combustion engine speed among which is transference (TKÁČET, 2014). The speed of the hydraulic pump will be monitored based on speed of the combustion engine, whereas the internal combustion engine and the hydraulic pump axle ratio i = 1.467 reducing. Tab. 1 shows the speed of hydraulic pump type UD 20 (Jihostroj Aero Technology and Hydraulics, Velesin, Czech Republic) during measuring of flow rate. Fig. 1 shows of kinematic scheme of hydraulic pump flow rate measuring.

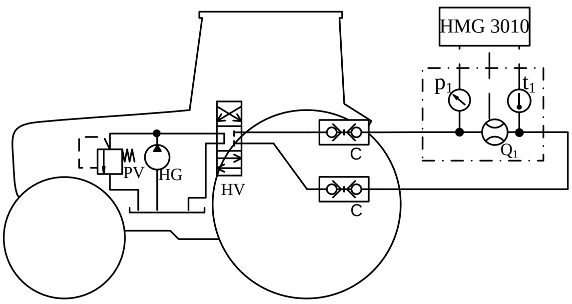


Fig. 1. – Scheme of hydraulic pump flow rate measuring
(PV – pressure relief valve, HG – hydraulic pump, HV – hydraulic valve, C – quick couplings, p1 – pressure sensor HDA 3774-A-600-000, Q1 – flow rate sensor EVS 3100, temperature sensor ETS 4144-A-000, HMG 3010 – portable data recorder).

Tab. 2. – Speed of combustion engine and hydraulic pump

Combustion engine speed (rpm)	Hydraulic pump speed (rpm)
1600	1090
2200	1500
2300	1570

The flow, temperature and pressure sensors were placed on the joint flange Hydac (Fig. 2). On the both ends of the joint flange Hydac, there were placed glad-hands. On the inlet side of the joint flange Hydac (oil inflow from the tractor distributor), there was placed plug-in "male" glad-hand and on the output side (oil run-off from the joint flange), there was placed plug "female" glad-hand. The measuring device was placed between the exit glad-hand from the tractor and loading equipment Owattona.

The measurement of the flow characteristics is used to determine the impact of the biodegradable synthetic oil on the hydraulic pump life. The flow hydraulic pump efficiency was calculated from the measured flow characteristics:

$$\eta_{pr} = \frac{Q}{VG \cdot n} \cdot 100 \qquad (1)$$

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).

Fig. 2. – Placing of the flow, temperature and pressure sensor on the joint flange HYDAC (Hydac GmbH, Sulzbach/Saar, Germany)

Statistical analysis

Standard deviation σ is defined as a positive square root of variance. Standard deviation is calculated if we have a complete set of possible states of the process (system). In probability theory and in statistics, standard deviation or mean square deviation is a measure of statistical dispersion. Simply said, it refers to how widely are the values distributed in a set (HILL AND LEWICKY, 2006).

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2} \qquad (2)$$

where:

n – population size,

x_i – individual values of population,

$\bar{x}$ – arithmetic average of population.

We say that a continuous random variable x has normal (Gaussian) distribution with parameters $\bar{x}$, σ^2 if density is:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} . e^{-\frac{(\bar{x}-\alpha)^2}{2\sigma^2}} \text{ for } x \in R_1, \alpha \in (-\infty, \infty), \sigma > 0 \qquad (3)$$

where:

e – base of natural logarithm,

σ – standard deviation,

$\bar{x}$ – arithmetic average of population.

If a variable x has normal distribution with parameters $\bar{x}$, σ^2, then, after transformation:

$$Z_i = \frac{x_i - \bar{x}}{\sigma} \qquad (4)$$

where:

σ – standard deviation,

x_i – individual values of population,

$\bar{x}$ – arithmetic average of population,

z_i – variable with normal distribution,

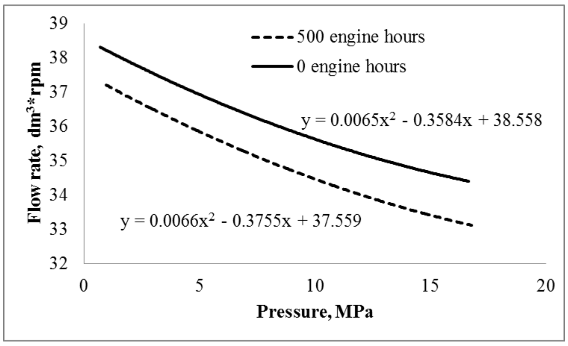
the variable has normal distribution with mean value 0 and variation 1 (then standard deviation is also 1). This distribution is called as standardized normal distribution (HILL AND LEWICKY, 2006).

- When selecting a value from the range –1σ, +1σ, the probability of standard normal distribution is 68.27 %;
- When selecting a value from the range –2σ, +2σ, the probability of standard normal distribution is 95.46 %;
- When selecting a value from the range –3 σ, +3σ, the probability of standard normal distribution is 99.73 %.

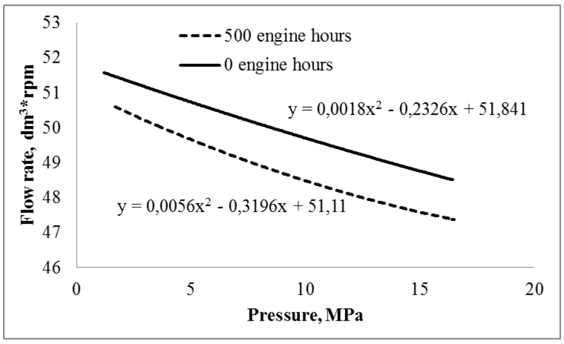
We have chosen to evaluate the data of -1σ and +1 σ so that we obtain the values as close as possible to the nominal pressure of the hydraulic pump (p = 16 MPa). When choosing the range of -1σ and +1 σ, the credibility of results is 68.27 %. The flow efficiency of the hydraulic pump was calculated from this sample of values.

RESULTS AND DISCUSSION

The flow characteristics were measurement at 0 EH and after completing 500 EH. The measurement of the flow characteristics was performed at speeds of hydraulic pump n = 1,090 rpm, n = 1,500 rpm and n = 1,570 rpm. Fig. 3 a, b and c shows the flow characteristics of the hydraulic pump UD 20 at different speeds.



a



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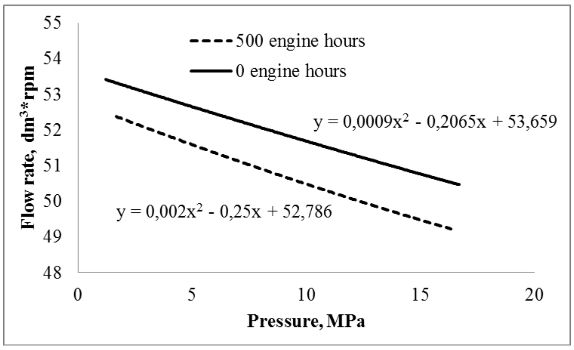

c

Fig. 3. – Flow characteristics of hydraulic pump (a - flow characteristics at n = 1,090 rpm, b - flow characteristics at n = 1,500 rpm, c - flow characteristics at n = 1.570 rpm)

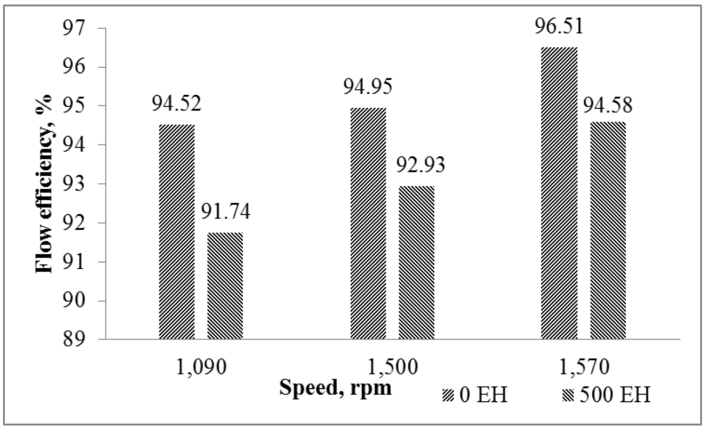

Fig. 4. – Flow efficiency of the hydraulic pump

Fig. 4 shows the hydraulic pump flow efficiency at particular speeds and engine hours.

The greatest decrease in the hydraulic pump flow efficiency was detected at a speed n = 1,090 rpm. The flow efficiency of the hydraulic pump dropped from η_0 = 94.52% to η_{500} = 91.74%. Under the nominal speed of the hydraulic pump n = 1,500 rpm, the flow efficiency of the hydraulic pump declined from η_0 = 96.51% to η_{500} = 94.58%.

When applying the oil EKOUNIVERZÁL, the tractor type ZTS 8011 with the hydraulic pump PZ 2 – 18 KS was used in operation from 0 EH to 2,242 EH. For p = 16 Mpa pressure at hydraulic pump output and n = 2,200 rpm nominal speed, flow rate measured at

0 Eh was Q = 22.80 dm^3*rpm. After 2,242 EH, the measured flow rate was Q = 19.05 dm3*rpm. The lifetime of hydraulic pump type 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 Q = 19 dm^3*rpm (TKÁČ ET AL., 2002, 2003). In case of the hydraulic pump type PZ 2 – 19 KS with the oil EKOUNIVERZÁL, ŠKULEC ET AL. (2001) found at speeds n = 1,500 rpm and pressure p = 16 MPa a decrease in flow rate by Δη = 1.25 % after 300 EH. Škulec used a new hydraulic pump type PZ 2 – 19 KS in test. For this reason, there was two times higher decrease in flow rate with the hydraulic pump UD 20 than with the hydraulic pump PZ 2 – 19 KS.

Tab. 3 shows the following parameters of biodegradable synthetic fluid (kinematic viscosity at 40 °C, total acid number and density at 15 °C).

Tab. 3. – Following parameters of biodegradable hydraulic fluid

Count of engine hours	Kinematic viscosity at 40 °C, mm*s^{-2}	Total acid number, mgKOH*g^{-1}	Density at 15 °C, kg*m^{-3}
0 engine hours	68.41	0.75	910.40
500 engine hours	71.08	0.80	909.20

The increase of kinematic viscosity at 40 °C was V = 2.67 mm*s^{-2} (ΔV = 3.9%), based on the value of new oil v_0 = 68.41 mm^2*s^{-1} and value of used oil v_{500} = 71.08 mm^2*s^{-1}. ALIAS ET AL, (2009) evaluated the kinematic viscosity at 40 °C of palm oil-based TMP ester (TMPE) and found the increase of kinematic viscosity after completing 400 hours ΔV = 1.72%. The increase of total acid number was TAN = 0.05 mgKOH*g^{-1} (ΔTAN = 6.6%). The decrease of density at 15 °C was D = 1.20 kg*m^{-3} (ΔD = 0.13%), based on the value of new oil D_0 = 910.40 mm^2*s^{-1} and value of used oil D_{500} = 909.20 mm^2*s^{-1}. According to ASSAF ET AL. (2014), the total acid number (TAN) is of interest because it indicates the degree of fluid oxidation. ASSAF ET AL. (2014) evaluated the total acid number (TAN) of biodegradable hydraulic fluid of TAN = 0.95 mgKOH*g^{-1}. Concerning the acid content, this value is acceptable in the vegetable-based formulations in comparison with the reference oil. Concentration of the acid content of the biodegradable synthetic fluid druring the test is acceptable and in accord by authors ASSAF ET AL. (2014) and KUČERA ET AL. (2013B).

CONCLUSIONS

Agricultural technology has a negative impact on all elements of the environment. This paper presents the results of a long-term operational test of the biodegradable synthetic fluid. The operational test was performed on one of the most used tractors, the tractor Zetor Proxima 6321 in the conditions of Slovak farms. Based on the results obtained, it is possible to state that the biodegradable synthetic fluid is a full-value hydraulic oil for the tractor Zetor Proxima 6321. Operational test of this fluid was set at 500 engine hours. During the performance test, there were measured changes in the most important qualitative indicator (flow efficiency) corresponding to engine hours for the ecological oil. The measured values of flow efficiency correspond to standard and they do not influence the technical and exploitation properties of the tractor hydraulic circuit. The decrease in the flow efficiency of the UD 20 hydraulic pump at nominal speed (n = 1,500 rpm) during the test was Δηpr = 2.127 %. This decrease showed a negative impact of the biodegradable synthetic fluid on hydraulic pump flow efficiency.

Kinematic viscosity is one of the most important properties for the characterization of lubricants and their transport properties, and it is a measure of internal friction in a fluid (ALIAS ET AL, 2009). The increase of kinematic viscosity at 40 °C during operating test was V = 2.67 mm*s^{-2}. For this reason we need remember the difference of kinematic viscosity during of the operating test. The evaluation of fluid's TAN (Total acid number) is important because of an increasing amount of acids in the fluid, which is characteristic for the ageing process and directly determines the degree of fluid degradation (MIHALČOVÁ, 2016). The measured values of TAN had a slightly increasing trend up to 500 engine hours. Testing of biodegradable synthetic fluid were researched by authors KUSAK ET AL., (2012), RIDDERIKHOFF ET AL., (2005) and MICHAEL ET AL., (2009).

ACKNOWLEDGEMENT

Supported by the Ministry of Education of the Slovak Republic, Project VEGA 1/0337/15 "Research aimed at influence of agricultural, forest and transport machinery on environment and its elimination on the basis of ecological measures application".

The research leading to these results has received funding from the European Community under project no 26220220180: Building Research Centre „AgroBioTech".

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