FLOW CHARACTERISTICS OF THE TRACTOR HYDRAULIC CIRCUIT BY APPLICATION OF THE BIODEGRADABLE SYNTHETIC FLUID

Ján KOSIBA[1], Juraj JABLONICKÝ[1], Rastislav BERNÁT[2], Zoltán ZÁLEŽÁK[2]

[1]Department of Transport and Handling, Faculty of Engineering, Slovak University of Agriculture in Nitra, Slovakia
[2]Department of Quality and Engineering Technologies, Faculty of Engineering, Slovak University of Agriculture in Nitra, Slovakia

Abstract
This paper deals with lifetime test of biodegradable synthetic fluid. This fluid was used in the hydraulic and transmission circuit of a tractor type Zetor Proxima 6321. The test of the biodegradable synthetic fluid was set 500 engine hours (EH). During operating test was monitored the influence of the biodegradable synthetic fluid on flow characteristics and decrease of flow efficiency of the tractor hydraulic pump. The decrease of the flow efficiency of the hydraulic pump by nominal speed after completing 500 EH was $\Delta\eta pr$ *= 1.701%. The measurements were founded the minimal influence of the fluid on the hydraulic pump wear.*

Key words: *engine speed; flow efficiency; hydraulic pump.*

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 (*Haas et al, 2016*). 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*, *Majdan et al, 2018*). Agricultural technology has a negative impact on all elements of the environment (*Kučera et al, 2016*). It was reported that over 60% of all lubricants end up in soil and water (*Majdan et al, 2013*). Hydraulic line breaks are extremely common. If not attended to, these releases can cause contamination of the soil, ground and surface water. The ecological fluids market is expanding, and ecological oils which can be used in hydraulic and transmission systems are one of the provided products *(Hnilicová et al, 2016*). Biodegradability has become one of the most important design parameters both in the selection of base fluids and in the overall formulation of the finished lubricant (*Mendoza et al, 2011*).

This paper presents the results of a long-term operational test of the biodegradable synthetic fluid (type HEES – Hydraulic Environmental Ester oil Synthetic). The biodegradable synthetic fluid was applied in the transmission and hydraulic circuit of the tractor type Zetor Proxima 6321. During operating test was monitored the influence of the biodegradable synthetic fluid on flow characteristics of the tractor hydraulic pump. Flow characteristics of the tractor hydraulic pump is a basic indicator its lifetime. The test of the biodegradable synthetic fluid was set 500 engine hours (EH). The majority of tractors are subjected to conditions (especially during the winter) which can cause an undesirable phase transition of fluid in hydraulic systems. It is necessary to further develop and improve fluid flow by means of the correct operation of hydraulic equipment. The flow characteristics are important to the life of the hydraulic system.

MATERIALS AND METHODS

To choose the agricultural tractor for testing, it was taken into account analysis of the sale of agricultural tractors and the utilization of tractors on farms in Slovakia. By these criteria, it was selected Zetor Proxima 6321 tractor. Before application of biodegradable synthetic fluid, there was removed fluid from the transmission and hydraulic circuit and it was purified. At the same time, the new oil filter was fitted to the tractor. To the transmission and hydraulic circuit of the tractor there was applied selected biodegradable synthetic fluid.

Operational test of the biodegradable synthetic fluid was set at 500 engine hours (EH) (the tractor had over 2,450 EH). Measurements of flow characteristics are made after completing 0, 250 and 500 engine hours. 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 fluid depends on it. At the same time, by measuring of the flow characteristics, the fluid temperature must be on operating value. Another extremely important parameter is revolution of hydraulic pump. The hydraulic pump revolution will be monitored based on the combustion engine revolution among which is transference. The temperature of oil during measuring of flow characteristics was t = 40°C. Table 1 shows the basic technical parameters of biodegradable synthetic fluid.

Tab. 1 Technical parameters of biodegradable synthetic fluid

Properties	Unit	Amount
Kinematic viscosity at 40°C	$mm^2 s^{-1}$	67.52
Density at 15°C	$kg m^{-3}$	931
Flash point	°C	212
Pour point	°C	- 48

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. Table 2 shows the speed of the hydraulic pump during measuring of flow characteristics.

Tab. 2 Speed of combustion engine and hydraulic pump

Combustion engine speed (rpm)	Hydraulic pump speed (rpm)
1,600	1,090
2,200	1,500
2,300	1,570

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 (*Tkáč et al, 2014*).

RESULTS AND DISCUSSION

The flow characteristics were measurement at 0 EH, after completing 250 EH and after completing 500 EH. Fig. 1 – 3 shows the flow characteristics of the hydraulic pump type UD 20 at the different speeds and Fig. 4 flow efficiency of the hydraulic pump after statistical processing. The polynomial regression function of 2 orders at analysis of measurement was used.
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 & Lewicky, 2006*).

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

where: n – population size, x_i – individual values of population, $\bar{x}$ – arithmetic average of population.

When selecting a value from the range –2σ, +2σ, the probability of standard normal distribution is 95.46%. The flow efficiency of the hydraulic pump was calculated from this sample of values.

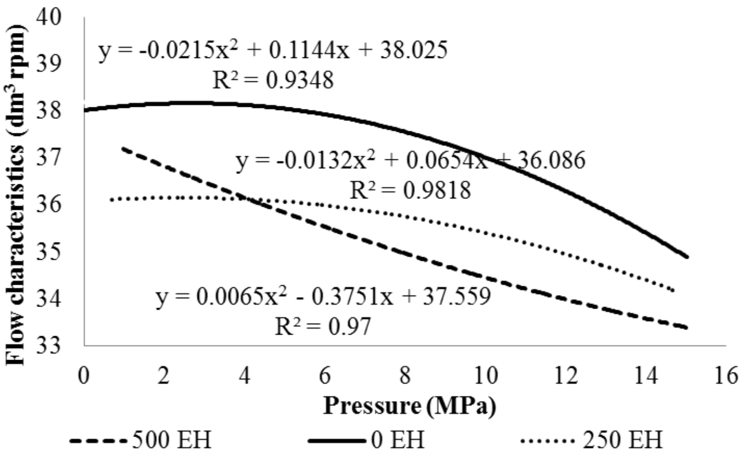

Fig. 1 Flow characteristics of hydraulic pump at n = 1,090 rpm

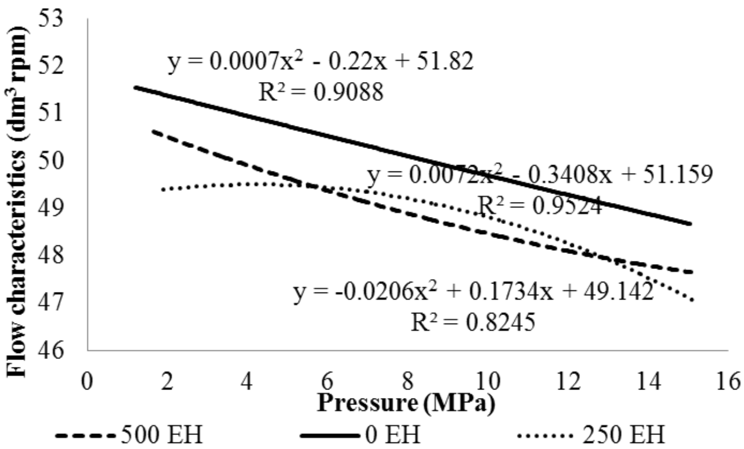

Fig. 2 Flow characteristics of hydraulic pump at n = 1,500 rpm (nominal speed)

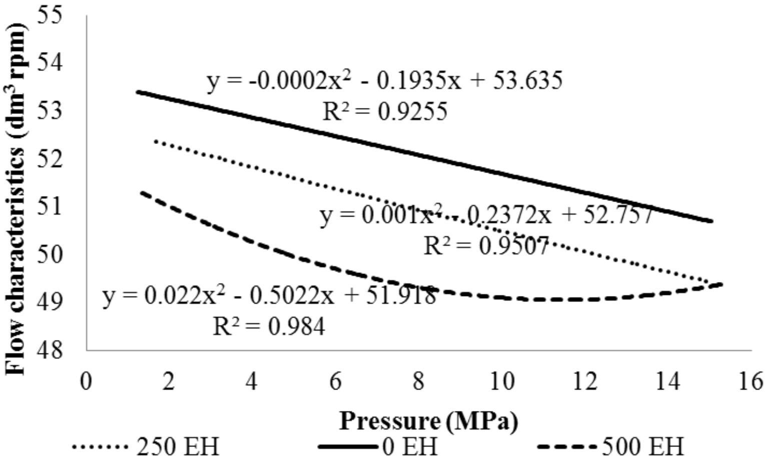

Fig. 3 Flow characteristics of hydraulic pump at n = 1,570 rpm

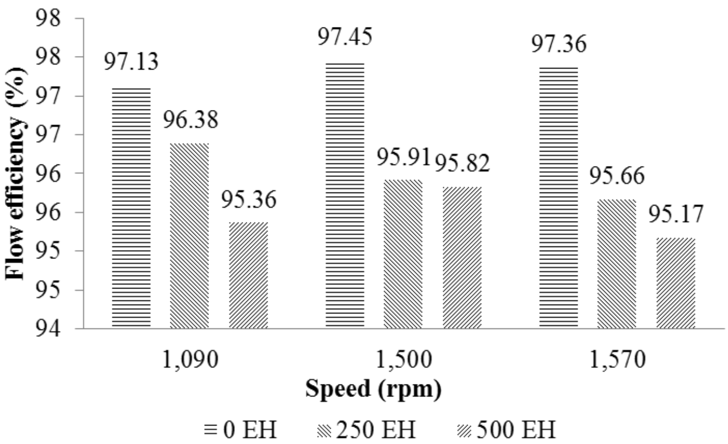

Fig. 4 Flow efficiency of the hydraulic pump

Hydraulic pump-operating conditions affect significantly the pump efficiencies, it is very important to understand how the pump efficiencies depend on the hydraulic pump-operating conditions (*Inaguma & Yoshida, 2013*). At the beginning of the performance test of biodegradable synthetic fluid, the level of flow efficiency by nominal speed of hydraulic pump was at η_{pr0} = 97.45%; at the end of the performance test, it was at η_{pr500} = 95.82%. This means that the decrease of the hydraulic pump flow efficiency after completing 500 EH was $\Delta\eta_{pr}$ = 1.701%. This decrease indicates a minimal impact of biodegradable synthetic fluid on the lifetime of the hydraulic pump of tractor type Zetor Proxima 6321. *Dobrota et al*, (2010) evaluated the flow efficiency of the hydraulic pump at the nominal speed η = 95.73% depending on the pressure p = 20 MPa and *Michael et al*, (2012) evaluated the flow efficiency at the nominal speed η = 95.00%. These values corresponded with our results.
Kinematic viscosity at 40 °C (Fig. 5) is evaluated based on the positive or negative tolerance of the measured values in comparison with the value of new oil (0 engine hours). The decrease of kinematic viscosity at 40 °C does not exceed the limit of 20% which is prescribed for the ISO 15380:2011 standard. The deviation of kinematic viscosity at 40°C is calculated by using the formula:

$$\Delta V = \frac{V_0 - V_{500}}{V_0} . 100 \qquad (2)$$

where: ΔV – deviation of kinematic viscosity at 40 °C, V_0 – kinematic viscosity at 40 °C at 0 engine hours, V_{500} – kinematic viscosity at 40 °C at 500 engine hours

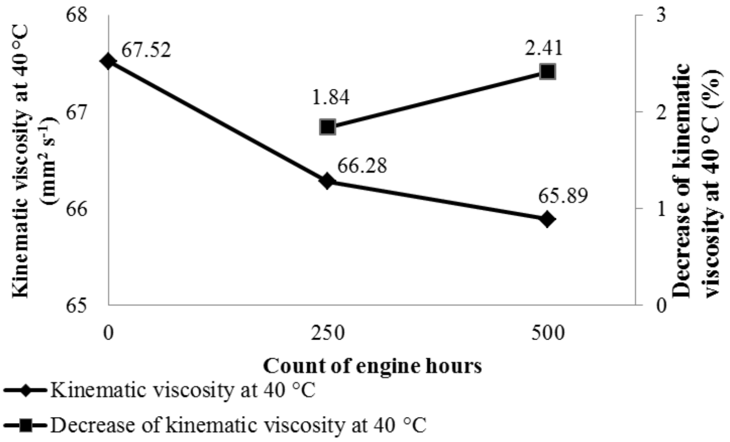

Fig. 5 Kinematic viscosity at 40 °C and decrease of kinematic viscosity at 40 °C

The decrease of kinematic viscosity at 40 °C (after completing 500 engine hours) was calculated ΔV = 2.41% according to Eq. (3), based on the value of new oil v_0 = 67.52 mm^2 s^{-1} and value of used oil v_{500} = 65.89 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%. Decrease of kinematic viscosity of the fluid means too thin oil film and therefore low load capacity. The lower viscosity, the higher wear occurs (*Sejkorová et al, 2017, Majdan et al, 2014*).

CONCLUSIONS

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, Kučera et al, 2017*). The decrease of the hydraulic pump flow efficiency by nominal speed after completing 500 EH was $\Delta\eta_{pr}$ = 1.701%. This decrease indicates a minimal impact of biodegradable synthetic fluid on the lifetime of the hydraulic pump of the tractor type Zetor Proxima 6321. We can say that the biodegradable synthetic fluid does not affect the construction or operation of the tractor type Zetor Proxima 6321.

Biodegradable synthetic fluid has no negative influence on the rubber components in the hydraulic circuit of the tractor type Zetor Proxima 6321. One of the reasons for the high price of environmentally friendly hydraulic fluids is the necessity for the manufacturers of hydraulic pumps to approve the usage of the fluid in the hydraulic system and to verify its compatibility with hydraulic circuit components (*Xuejun et al, 2015, Stojilković & Kolb, 2016).*

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REFERENCES

1. Alias, N.H., Yunus, R., Idris, A., & Omar. R. (2009). Effect of additives on oxidation characteristics of palm oil-based trimethylolpropane ester in hydraulic applications. *European Journal of Lipid Science and Technology 111*(4), 368–375.
2. Haas, P., Kadnár, M., Tóth, F., Rusnák, J., & Nógli, D. (2016). Influence of bellows setting on its spring rate and on temperature adjustment of electromechanical thermostats. *Acta technologica agriculturae*, *19*(2), 43–48.
3. Hill, T. & Lewicky, P. (2006). *Statistics: Methods and applications*. Statsoft Inc., Tulsa USA.
4. Hnilicová, M., Kučera, M., & Pavlu, J. (2016). Analysis of hydraulic oil in handling lines baljer & zembrod using the methods of

trobotechnical diagnostics. *Key Engineering Materials, 669*, 451–458.
5. Dobrota, D., Lalić, B., & Oršulić, M. (2010). Experimental modelling of volumetric efficiency of high-pressure external gear pump, *Nase More, 57*(5-6), 535–240.
6. Inaguma, Y. & Yoshida, N. (2013) Mathematical analysis of influence of oil temperature in hydraulic pumps for automatic transmissions. *SAE Interantional Jouranl of Passenger Cars – Mechanical Systems, 6*(2) 786–798.
7. Kučera, M., Majdan, R., Abrahám, R., & Haas, P. (2016). Analysis of the effect of loading on tribological system properties. *Acta Universitatis Agriculturae et Silviculture Mendelianae Brunensis, 64*(3), 825–833.
8. Kučera, M., Aleš, Z., Ivandić, Z., & Hujo, Ľ. (2013). Possibility of hydraulic fluids with a low environmental impact application in agriculture and transport machinery. *Journal of Central European Agriculture, 14*(4), 1592–1601.
9. Kučera, M., Aleš, Z., & Pexa, M. (2016). Detection and characterzation of wear particles of universal tractor oil using a particles size analyzer. *Agronomy Research, 14*(4), 1351–1360.
10. Kučera, M. & Aleš, Z. (2017). Morphology analysis of friction particles generated in tractor transmission oils. *Acta Technologica Agriculturae, 20*(3), 57–62.
11. Majdan, R., Tkáč, Z., & Kangalov, P.G. (2013). *Research of ecological oil-based fluids properties and new test methods for lubricating oils : scientific monograph.* 1st ed. Rousse : Angel Kanchev University of Rousse, 98 s.
12. Majdan, R., Tkáč, Z., Abrahám, R., Szabó, M., Halenár, M., Rášo, M., & Ševčík, P. (2016). Proposal for filtration systme for biodegradable lubricants in agricultural tractors. *Agronomy Research, 14*(4), 1395–1405.
13. Majdan, R., Olejár, M., Abrahám, R., Šarea, V., Uhrinová, D., Jánošová, M. & Nosian, J. (2018). Pressure Surce Analysis of a Test Bench for Biodegradable Hydraulic Oils. *Tribology in Industry, 40*(2), 183–194.
14. Majdan, R., Tkáč, Z., Stančík, B., Abrahám, R., Štulajter, I., Ševčík, P., & Rášo, M. (2014). Elimination of ecological fluids contamination in agricultural tractors. *Research in agricultural engineering, 60*(special iss. 1), 9–15.
15. Mendoza, G., Igartua, A., Fermamdez-Diaz, B., Urquiola, F., Vivanco, S., & Arguzoniz, R. (2011). Vegetable oils as hydraulic fluids for agricultural applications. *Grasas y aceites 62*(1), 29–38.
16. Michael, P.W., Khalid H., & Wanke, T. (2012). An Investigation of external gear pump effiecency and stribeck values. *SAE Technical Papers* 8.
17. Sejkorová, M., Hurtová, I., Glos., J., & Pokorný, J. (2017). Definition of a motor oil change interval for high-volume diesel engines based on its current characteristics assessment. *Acta Universitatis Agricultrrae et Silviculturae Mendelianae Brunensis, 65*(2), pp. 481–490.
18. Stojilković, M. & Kolb, M. (2016). Tribological Properties of Biodegradable Universal Tractor Transamission Oil. *Tribology in Industry, 38*(2), 229–234.
19. Tóth, F., Rusnák, J., Kadnár, M., & Váliková, V. (2014). Study of tribological properties of chosen types of environmentally friendly oils in combined friction conditions. *Journal of Central European Agriculture, 15*(1), 185–192.
20. Tkáč, Z., Drabant, Š., Majdan, R., & Cvíčela, P. (2008). Testing stands for laboratory tests of hydrostatic pump of agricultural machinery. *Research in Agricultural Engineering, 54*(1), 183–191.
21. Tkáč, Z., Hujo, Ľ., Tulík, J., Kosiba, J., Uhrinová, & Šinský, V. (2014). Greening of agricultural and forestry tractors. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 62*(5), 1135–1139.
22. Xuejun, H., He, J., & Tenfei, S. (2015) Analysis on design of coiled tubing sliding drilling electronic control tractor with hydraulic-driven in microhole. *Electronic Journal of Geotechical Engineering, 20*(10), 4333–4347.

Corresponding author:
doc. Ing. Ján Kosiba, PhD. Department Transport and Handling, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76, Nitra, Slovakia, phone: +421 37 641 5776, e-mail: jan.kosiba@gmail.com