DYNAMIC VISCOSITY AND POUR POINT OF HYDRAULIC OILS

V. Vozárová, A. Petrović, J. Csillag, M. Božiková, Ľ. Híreš, M. Valach

Department of Physics, Faculty of Engineering, Slovak University of Agriculture in Nitra, Slovak Republic

Abstract
This article presents the experimental results of dynamic viscosity and pour point of three hydraulic oil OSO S 46 AGIP samples – new oil and two used oils. Measurements were made under laboratory conditions with laboratory viscometer DV2T fy Brookfield. Examination of the dynamic viscosity in the temperature interval from 25°C to 90°C was made. The exponential dependency of viscosity on the temperature for the each sample was obtained in accordance with Arrhenius equation. Monitoring of pour point was provided by differential scanning calorimetry (DSC) this method gives information on thermal effects in the sample subjected to the temperature programme was realised in the temperature range from 20°C to the temperature of -45°C by using differential scanning calorimeter DSC 1 Mettler Toledo. It was determined that temperature of freezing (pour point) of used oil samples is lower than new oil sample.

Key words: hydraulic oil, dynamic viscosity, pour point.

INTRODUCTION

At the present time, hydrostatic systems are widely dispersed in the industry. It provides the various types of motions. The power transmission is realized by hydraulic fluid. Hydraulic fluid needs service and observation of operating parameters (HUJO ET AL., 2012). Today time offers us various kinds of industrial fluids. Hydraulics, which is used in transport and handling equipment, for its operation need the working medium - liquid in its hydrostatic systems (KOSIBA ET AL., 2013). The testing of hydraulic systems is important for the design of new types of devices, the research of biodegradable fluid properties and their impact on the technical condition of hydraulic components (HUJO ET AL., 2015). Hydraulic systems are widely used in the executive mechanisms, road and construction machinery, agricultural and forestry equipment, as well as in many other areas. Development of existing hydraulic components is focused at increasing the transmitted power, reduction of energy consumption, minimize environmental pollution and increase technical lifetime and reliability (JABLONICKÝ ET AL., 2012). Hydraulic fluid in the hydraulic system have multiple functions, in addition to energy transfer, universal oils must lubricate, dissipate heat and be compatible with the seal material and metal materials of the system components (MAJDAN, 2014; TKÁČ ET AL., 2010). The transmission of hydrostatic pressure and the use of hydrodynamic principle requires perfect medium. Each liquid has its own characteristics, which have different impact on the various elements of the hydraulic system of working equipment. Fluid must meet all the conditions, which are occur during the operation of hydraulic systems.

Physical properties such as viscosity and temperature interval of thermal stability are very important factors of bio-lubricants or bio-fuels which influence the possibilities of their use in agricultural machinery. Physical properties of bio-oil, bio-diesel and bio-ethanol were investigated by several authors, e.g. VALACH ET AL., 2015; VOZÁROVÁ ET AL., 2015; HLAVÁČ ET AL., 2014; HLAVÁČ AND BOŽIKOVÁ, 2014 and others.

This work is part of analysis of the physico-chemical properties of sampled hydraulic fluids with evaluation of changes in hydraulic fluids, which are used in hydraulic presses at lines number 46 and 47 of DS Smith Worldwide ™ Dispenser manufacturing plant.

MATERIALS AND METHODS

Temperature dependence of viscosity – viscosity as one of the most important rheological parameters is defined as the resistance of a fluid to flow. Viscosity of most of the liquids decreases with increasing temperature according to Arrhenius equation (FIGURA AND TEIXEIRA, 2007):

$$\eta = \eta_0 e^{\frac{E_A}{RT}}, \qquad (1)$$

where η is, dynamic viscosity (Pa.s), η_0 is reference value of dynamic viscosity (Pa.s), E_A is activation energy (J/mol), R is gas constant (J/K.mol) and T is absolute temperature (K). Present data have been obtained from measurements performed on laboratory viscometer DV2T fy Brookfield. The experiments have been performed with use of ULA (0) spindle.

Monitoring of pour point by differential scanning calorimetry (DSC) - differential scanning calorimetry or DSC is a thermo-analytical technique which monitors heat effects associated with phase transitions and chemical reactions as a function of temperature, at pre-defined speed of heating (cooling), with assuming that both materials – sample and reference are under the same conditions (HAINES, 1995).

RESULTS AND DISCUSSION

Measuring of three samples dynamic viscosity of hydraulic oil OSO S 46 Agip 46, as a function of temperature, has been considered. First sample was new (Fig. 1). The others were used oils in two different press lines: press line No. 46 – sample 1, and press line No. 47 – sample 2 (Figs. 2 and 3). The procedure of sample preparation for viscosity measurements corresponded to a typical sampling procedure. The adequate volume (20 ml) of oil was put into the apparatus cuvette. The viscosity data were obtained in temperature range from 25°C to 90°C. Temperature of the sample was adjusted by the device automatically. The measured values of dynamic viscosity were saved in a table form. Based on these values, dynamic viscosity – temperature charts were plotted.

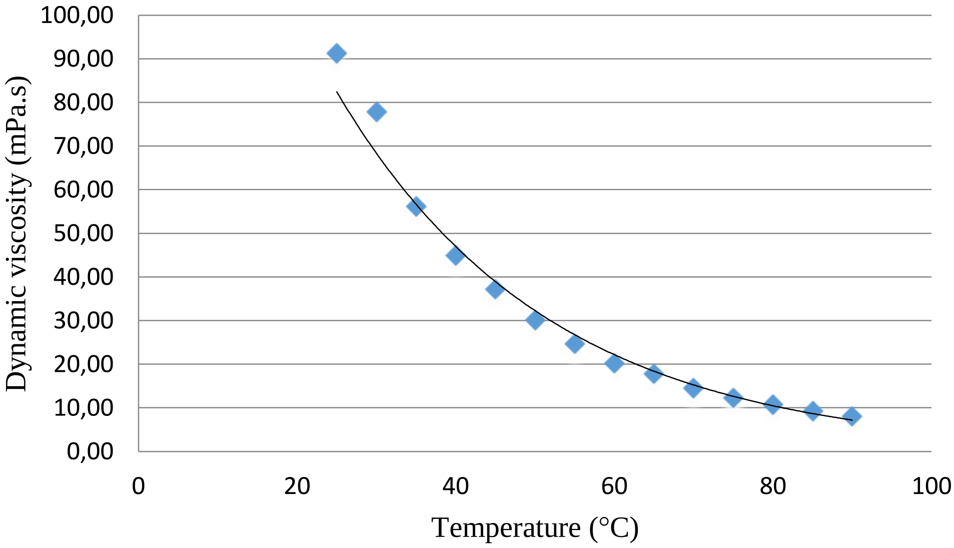

Fig. 1. – Temperature dependent viscosity of OSO S 46 AGIP hydraulic oil – new oil sample

The operating temperature in press lines, from which the samples of the oil were taken, is 50°C, so the most attention has been paid what happens with the viscosity at that temperature. It is possible to observe from Figs. 1-3 that dynamic viscosity of hydraulic oils is decreasing exponentially with increasing of temperature, what was expected and corresponds with conclusions reported in literature (VALACH ET AL., 2015; VOZÁROVÁ ET AL., 2015; HLAVÁČ ET AL., 2014; HLAVÁČ AND BOŽIKOVÁ, 2014; TRÁVNÍČEK ET AL., 2013; SEVERA ET AL., 2012). Regression equations and determination coefficients for individual samples are in the Tab. 1. As it can be seen from the dependencies for all samples, the development is characterized by the curve very well. The determination coefficients for all the samples are very high, which also confirms strong exponentially decreasing dependence.

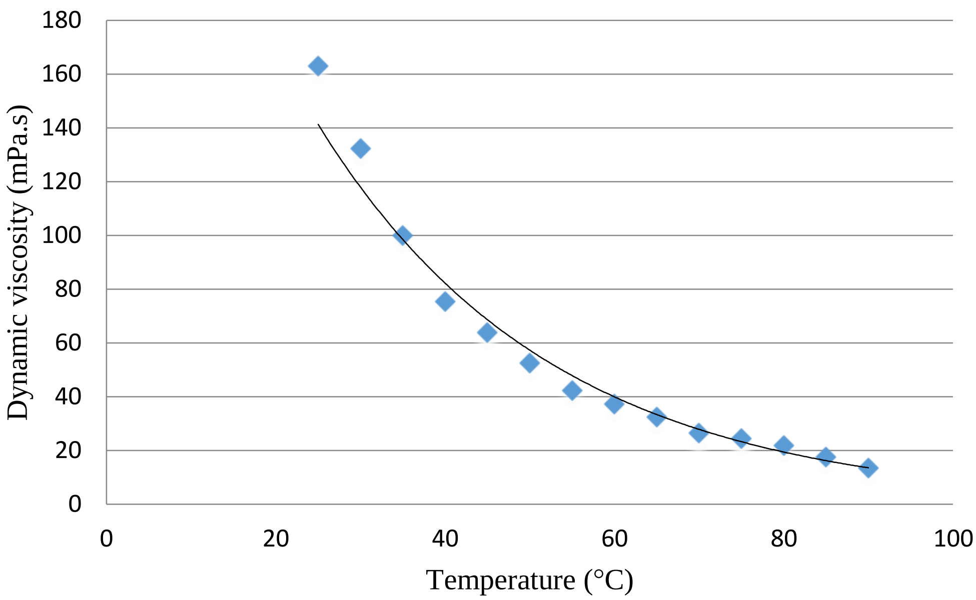

Fig. 2. – Temperature dependent viscosity of OSO S 46 AGIP hydraulic oil – used oil sample 1

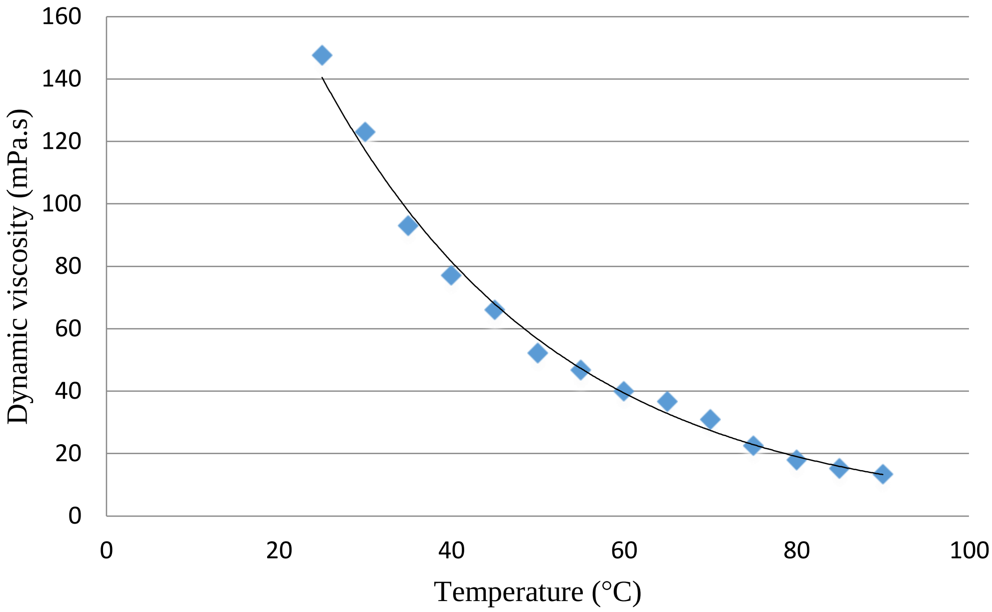

Fig. 3. – Temperature dependent viscosity of OSO S 46 AGIP hydraulic oil – used oil sample 2

Tab. 1. – Determination coefficients and regression equations

Sample	Regression equation	Determination coefficient R^2
New oil	$y = 210.6e^{-0.038x}$	0.9910
OSO S 46 AGIP 46	$y = 348.48e^{-0,036x}$	0.9867
OSO S 46 AGIP 47	$y = 348.34e^{-0,036x}$	0.9933

For monitoring of pour point of oils (phase transition of oil components) by DSC method was used device DSC 1 (Mettler Toledo). Samples of hydraulic oil OSO S 46 Agip with weight (11-13) mg were hermetically sealed in aluminium crucibles and thermally treated at the speed of heating (cooling) 2 K/min in the temperature range from 20°C to the temperature of -45°C. The measurement was carried out in an inert, dynamic atmosphere of N_2. As a result we got a DSC thermogram, which was evaluated in STARe software (Fig. 4).

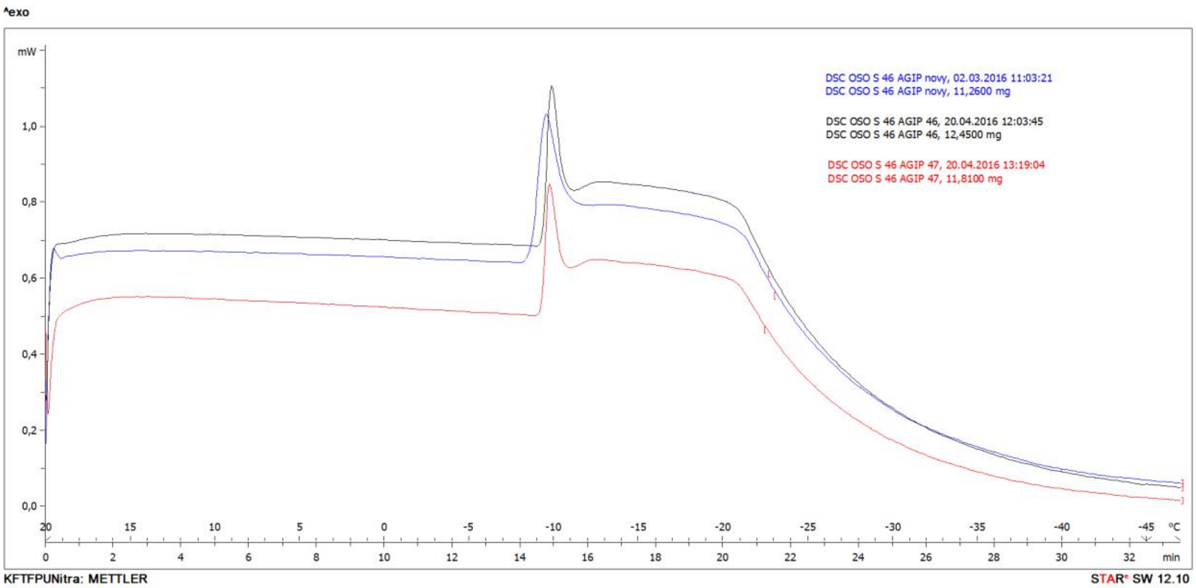

Fig. 4. – Pour point monitoring by DSC method of OSO S 46 Agip hydraulic oil – new and used oil samples

In the process of oil freezing and in the case of a new oil sample, we observed exothermal peak at the temperature -9.51 °C. This point is defined as a freezing point and temperature is nearly equal to the melting point (depending on the material purity). Since oil is an amorphous matter, the pour point takes place not only in one point, but in the range of temperatures which shows the graph (onset at -8.73 °C and endset -10.87 °C). In the case of oil from press line No. 46 (sample 1), the temperature of peak was -9.84 °C (onset at -9.39 °C and endset -10.65 °C). In the sample, where was used oil from press line No. 47 (sample 2), the temperature of exothermal peak was -9.71 °C (onset at -9.32 °C and endset -10.53 °C).

As it can be seen from the graph, there is a small difference between new sample and used samples of hydraulic oil in the view of pour point. The experiment shows that the new sample has higher temperature of pour point. Interesting fact is that new sample has wider interval of freezing. On the contrary, used samples have narrower interval of solidification, which is probably result of two years of continuous work of press lines using the same hydraulic oil.

CONCLUSIONS

Our results of pour point are significantly different as indicated by producer. The pour point introduced in the specifications of the producer is -27 °C. This difference may be caused by several factors (incorrect data of producer, inappropriate storage conditions or other unknown factors, for example thermal history). It should be experimentally verified in the next research. Press lines are located in halls with temperatures above zero, so this difference in temperature between the information from the producer and the measured values is not so significant in the case of using oil in hydraulic systems. But this information should be taken into account, in the case of the storage of oil, because the warehouse is not heated, practically oils are exposed to the outside temperature. If the winter temperatures are below -10°C, it may change the characteristics of the oil.

It can be concluded that knowledge of viscosity behaviour of a hydraulic oil as a function of temperature is of great importance, especially when considering running efficiency and performance of press line. Consequently, its function can be sensitive to the viscosity characteristics of the oil. Viscosity influences the oil’s ability to flow through the hydraulic system, therefore affects the pressure required to push the oil sufficiently to develop the necessary flow. The rate of oil flow is important to the life of the hydraulic system. Dynamic viscosity of hydraulic oils is decreasing exponentially with increasing of temperature in accordance with theory (Arrhenius equation) and other authors (WAN NIK ET AL., 2005; VALACH ET AL., 2015; VOZÁROVÁ ET AL., 2015; HLAVÁČ ET AL., 2014; HLAVÁČ AND BOŽIKOVÁ, 2014; SEVERA ET AL., 2012). Viscosity results are also in accordance with results of ferrographic analysis that showed no metal particles. All samples of hydraulic oils were clean, they probably content no particles (neither non-metal), which should change viscosity of used oils. Our results are part of the analysis of hydraulic oils needed for correct operation of pressing equipment guarantee.

ACKNOWLEDGEMENTS

This work was co-funded by European Community under project no 26220220180: Building Research Centre „AgroBioTech“ and it was also supported by the project of Scientific Grant Agency of Slovak Republic (VEGA) under No. 1/0854/14 and 1/0337/15.

REFERENCES

1. FIGURA, L. O., TEIXEIRA, A. A.: Food physics, Physical properties - measurement and applications. USA: Springer. 2007: 550 p.
2. HAINES, P. J.: Thermal Methods of Analysis, Blackie Academic & Professional, London 1995.
3. HLAVÁČ, P., BOŽIKOVÁ, M., PRESOVÁ, R.: Temperature relations of selected engine oils dynamic viscosity. Acta technologica agriculturae., 17, 2014: 104 – 107.
4. HLAVÁČ, P., BOŽIKOVÁ, M.: Effect of Temperature on Dynamic Viscosity and Activation Energy of Milk and Acidophilus Milk. Advanced Materials Research. 1059, 2014: 53 – 59.
5. HUJO, Ľ., KANGALOV, P. G., KOSIBA, J.: Laboratory test devices for evaluating the lifetime of tractor hydraulic components: (proceedings, methods and applications). 1st ed. Ruse: University "Angel Kanchev" of Ruse, 2015: 69 p.
6. HUJO, Ľ., KOSIBA, J., JABLONICKÝ, J., TULÍK, J.: Load characteristics of three-point tractor linkage. In Naučni trudove: zemedelska technika i technologii, agrarni nauki i veterinarna medicina, remont i nadeždnosť: zemedelska technika i technologii, agrarnye nauki i veterinarnaja medicina, remont i nadežnosť. 51 (1.1), 2012: 172-176.
7. KOSIBA, J., TKÁČ, Z., HUJO, Ľ., STANČÍK, B., ŠTULAJTER, I.: The operation of agricultural tractor with universal ecological oil. Research in Agricultural Engineering, 59, 2013: 27–33.
8. MAJDAN, R., TKÁČ, Z., STANČÍK, B., ABRAHÁM, R., ŠTULAJTER, I., ŠEVČÍK, P., RÁŠO, M.: Elimination of ecological fluids contamination in agricultural tractors. Research in agricultural engineering. 60 (1), 2014: 9-15.
9. SEVERA, L., KUMBÁR, V., BUCHAR, J., ČORŇÁK, Š., GLOS, J., HLAVÁČ, P., ČUPERA J.: On the engineering flow properties of used and new engine oils. Applications of physical research in engineering: The renewable energy sources and physical properties of selected industrial materials. Nitra: Slovak University of Agriculture. 2012.
10. TKÁČ, Z., MAJDAN, R., DRABANT, Š., ABRAHÁM, R., VOZÁROVÁ, V., JABLONICKÝ, J.: Hodnotenie vlastností hydraulických kvapalín na základe skúšok s použitím hydrogenerátora (Performance evaluation of hydraulic fluids based on tests using hydraulic generator). Nitra, Slovenská poľnohospodárska univerzita. 2010.
11. TRÁVNÍČEK, P., VALACH, M., HLAVÁČOVÁ, Z., MAREČEK, J., VÍTĚZ, T., JUNGA, P.: Selected physical properties of liquid biofuels. Research in Agricultural Engineering. 59, 2013: 121-127.
12. VALACH, M., HÍREŠ, L., KANGALOV, P.: Biofuels and Biolubricants in Agricultural Machinery. Ruse, University of Ruse. 2015.
13. VOZÁROVÁ, V., KARDJILOVA, K., HÍREŠ, L., VALACH, M., WOLLNER, A.: Temperature Dependence of Dynamic Viscosity and DSC Analysis of the Plantohyd samples. Journal of Central European Agriculture, 16, 2015: 221-230.
14. WAN NIK, W. B., ANI, F. N., MASJUKI, H. H., ENG GIAP, S. G.: Rheology of bio-edible oils according to several rheological models and its potential as hydraulic fluid. Industrial Crops and Products, 22, 2005: 249-255.

Corresponding author:

Vlasta Vozárová, Department of Physics, Faculty of Engineering, Slovak University of Agriculture in Nitra, Slovak Republic