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Communication

Characteristics of Ecological Energy Carriers Used in Agricultural Technology

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Abstract: This article focuses on the properties of ecological energy carriers, which are used in agricultural and forestry technology. The aim of the article is to describe the degradation of the working fluid from the point of view of the atomic emission spectrometer, which is used for the purpose of monitoring contaminants and additive elements. The working fluid examined was Shell Naturelle HF-E 46, a universal ecological transmission–hydraulic fluid, which was tested on laboratory test equipment. The laboratory measurement was performed for 200 h, during which the gear hydraulic pump with external gearing was cyclically loaded according to the Vickers standard. The analysis of the transmission–hydraulic fluid was performed after every 50 working hours, where the analysis of the working fluid showed that there were no significant changes in the properties of the working fluid and fluid is suitable for work in agricultural and forestry machines operating in environmentally sensitive environments.

Keywords: ecological transmission–hydraulic fluid; working fluids; ecological energy carriers; atomic emission spectrometry; laboratory test equipment; environmentally sensitive environments

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1. Introduction

Environmental pollution is not a new phenomenon or a problem of the present; its roots go back to the first human communities [1]. Therefore, working fluids used in agricultural and forestry machinery are currently subject to increased requirements in terms of reducing environmental pollution. For this reason, the research deals with the use of such liquids which will not have a negative impact on the environment or the cultivation of healthy food, nor contribute to water pollution, but will also meet the demanding requirements of use in energy devices. The research of the degradation of working fluids and their effects on the changes of machine parts was dealt with by authors [2–4]. In our work, we focus on the research of the properties of ecological energy carriers which are used in transmission–hydraulic systems of agricultural and forestry machines, where the impact of working fluids on the environment in the event of a machine failure is significant. At present, it is not uncommon for modern types of tractors to be equipped with a three-point hitch control [5]. It is important to notice that tractors use various types of lubricating oils, which can be contaminated by different ways. That depends on how, and where the whole system works [6]. Ecological transmission–hydraulic fluids do not always achieve the properties required for safe and reliable operation of a given piece of mobile handling equipment at higher outputs and higher operating temperatures. Therefore, we have expanded our focus to research changes in the individual properties of transmission–hydraulic fluids, as well as to monitor their impact on individual elements of the hydraulic circuit.

2. Materials and Methods

The measurement was performed on laboratory test equipment designed to test the service life of hydrostatic transducers and to test various types of hydraulic fluids. The scheme of the hydraulic circuit of the laboratory test equipment is shown in Figure 1 [7]. The methodology for measuring the working fluid by loading the gear hydraulic pump was implemented according to the Vickers standard at 200 operating hours and corresponded to a dynamic load of 480,000 cycles, during which the GHD1-17R-S2D1-SG05G04-N hydraulic pump was loaded with pressure of 22.5 MPa for 0.5 s, with pressure of 18.5 MPa for 0.5 s, and with pressure of 0 MPa also for 0.5 s. The system itself was, thus, cyclically loaded. A similar approach was used in the work of the authors [8].

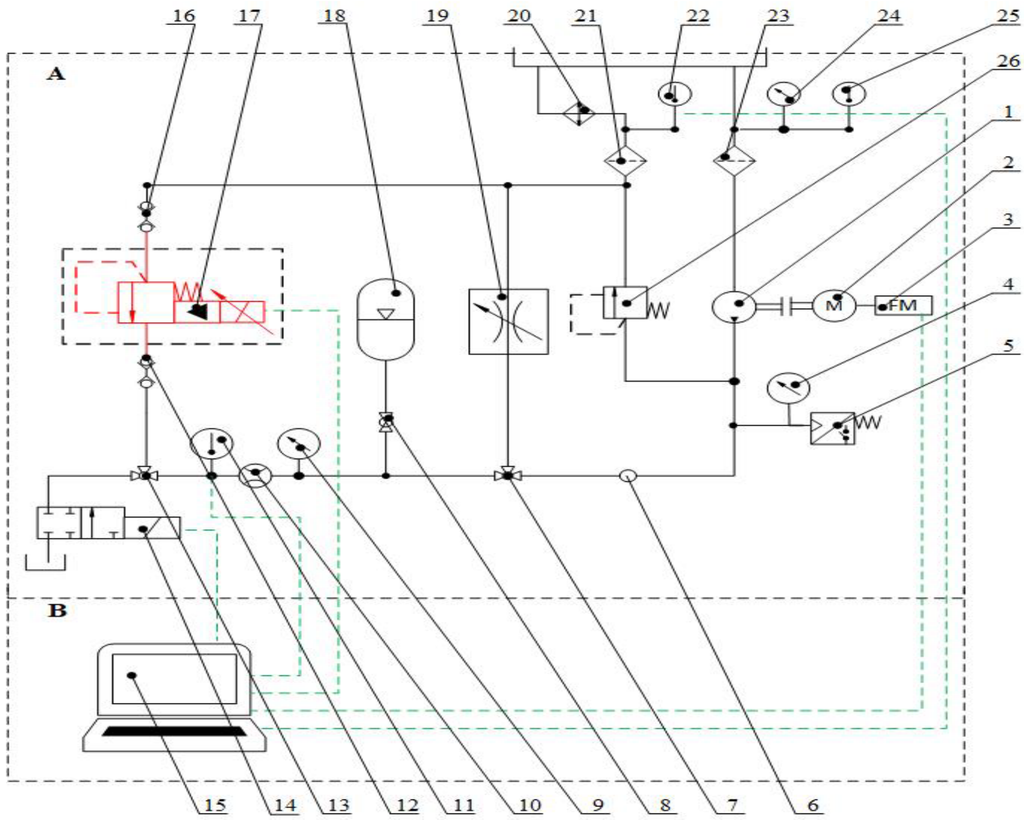
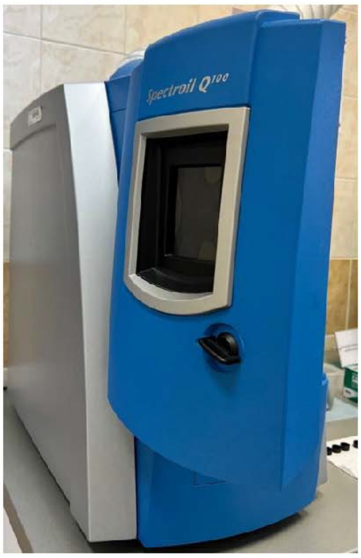


Figure 1. Scheme of hydraulic circuit for testing hydrostatic transducers and hydraulic fluid [7] (**A**)—hydraulic circuit; (**B**)—control and evaluation circuit; 1—hydraulic pump; 2—electric motor; 3—frequency converter; 4, 9, 24, 5—pressure sensors; 6—measuring point of evaluation of the fluid indicator; 7, 13—three-way valves; 8—ball valve; 10—flow sensor; 11, 22, 25—temperature sensors; 12, 16—quick couplers; 14—hydraulic switchboard; 15—computer; 17—electro-hydraulically operated proportional pressure valve; 18—accumulator; 19—throttle valve with stabilisation; 20—cooler; 21, 23—filters; 26—pressure valve.

After 50 working hours, corresponding to 120,000 cycles, a sample of the working fluid was taken. The temperature of the working fluid during the measurement reached a value of 90–95 °C and the speed was set at 1600 rpm. Liquid sampling was performed based on the methodology specified in the standard STN 65 6207.

Atomic emission spectrometry was performed on a Spectroil Q^{100} device. The standard configuration was equipped and calibrated for 32 abrasive metals, contaminants, and additives. Additional elements could be added at any time, even directly at the place of use. Its great advantage was that it could analyse all elements simultaneously, and the analysis process itself took only approximately 30 s. Figure 2 shows Spectroil Q^{100} devices in laboratory.



Dimensions (H × D × L)—706 × 384 × 66 mm
Weight—70 kg
Methodology—ASTM D6595, D6728
Optic system—Pashen-Runge polychromator
Spectral range—203–810 mm
Temperature control—temperature stabilization, 40 ± 1 °C
Detectors—CCD detectors
Relative humidity—0–90%
Temperature requirements—0–40 °C
Sample volume—1 mL
Data storage—external PC
Software—Windows

Figure 2. Spectroil Q^{100}.

As previously mentioned, the tested working fluid was Shell Naturelle HF-E 46, the properties of which are given in Table 1.

Table 1. Basic properties of the tested transmission–hydraulic fluid Shell Naturelle HF-E 46.

Parameter	Unit	Value
Density at 15 °C	$kg{\cdot}m^{-3}$	921
Viscosity at 40 °C	$mm^2{\cdot}s^{-1}$	47.2
Viscosity at 100 °C	$mm^2{\cdot}s^{-1}$	9.41
Viscosity index	-	188
Flash point	°C	322
Pour point	°C	−42
Biodegradability according to OECD 301 B	%	>60
Biodegradability according to CEC L-33-A 93	%	90
Water hazard class WGK	-	0

3. Results and Discussion

Based on the obtained results of atomic emission spectrometry of the tested transmission–hydraulic fluid after 200 working hours, there was an increase in the chemical elements lead, potassium, iron. The mentioned chemical elements in the working fluid were evaluated as contaminants; however, despite the loading of the working fluid with a temperature in the range of 90 to 95 °C, the limit values set by the ASTM D6595 standard were not exceeded. Concentration of chemical elements as contaminant is shown in Figure 3, for more specific data please check Table 2.

Table 2. Atomic emission spectrometry from the point of view of contaminants.

Concentration of Chemical Elements $Mg{\cdot}kg^{-1}$	Barium	Copper	Iron	Potassium	Lead	Tin
	Ba	Cu	Fe	K	Pb	Sn
0 h	0.27	0.46	0	0.15	0	5.58
50 h	0.06	0.14	0.98	0.29	1.89	0
100 h	0	0.24	1.25	0.45	2.71	0
150 h	0	0.20	1.03	0.29	2.33	0
200 h	0	0.25	1.43	0.56	2.74	0

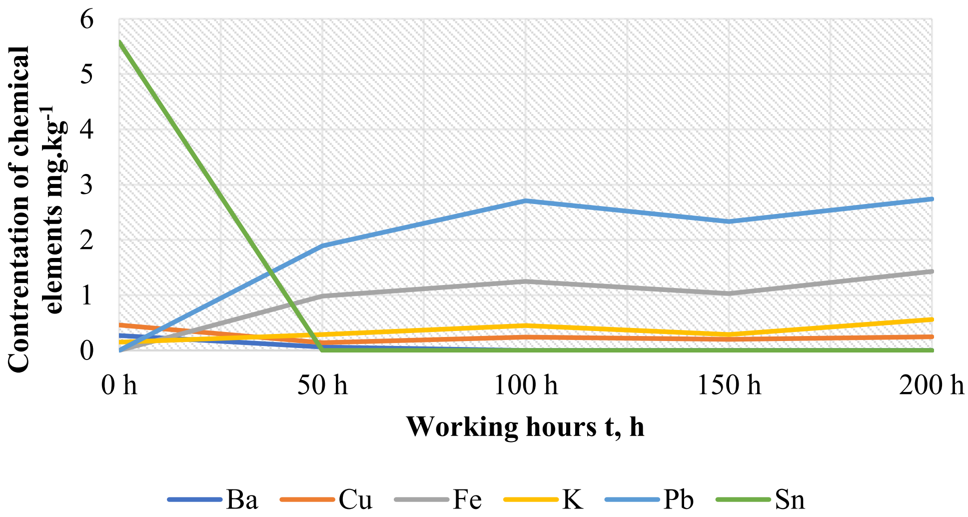


Figure 3. Graph of atomic emission spectrometry after 200 h from the point of view of contaminants.

Gradually, after 50 to 200 working hours, individual chemical elements were involved as additives in the working fluid, where there was an increase in the values of boron, calcium, zinc, silicon, while the value of phosphorus increased within 50 h, and then the values started to decrease. Nevertheless, the value of phosphorus increased by 15.04 mg·kg^{-1} in total, in 200 working hours. The analysis showed that the individual additive elements of the working fluid were gradually activated and increased depending on the number of hours worked. Activation of the additive elements was carried out gradually, without increasing the pressure and temperature determined by the Vickers method. Concentration of chemical elements as additives is shown in Figure 4, for more specific data please check Table 3.

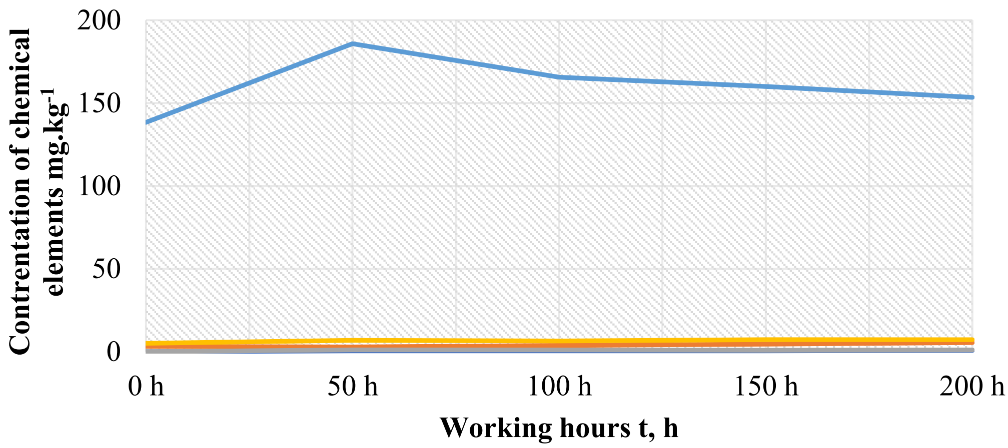


Figure 4. Graph of atomic emission spectrometry after 200 h from the point of view of additives.

Table 3. Atomic emission spectrometry from the point of view of additives.

Concentration of Chemical Elements Mg·kg^{-1}	Boron	Calcium	Silicon	Zinc	Phosphorus
	B	Ca	Si	Zn	P
0 h	0	3.22	0	5.07	138.35
50 h	0.52	2.87	1.01	6.92	185.79
100 h	0.52	3.72	1.08	6.49	165.54
150 h	0.58	4.53	0.96	7.27	160.02
200 h	0.77	5.49	1.02	7.23	153.39

4. Conclusions

Laboratory measurements of hydraulic fluid transmissions show that the content of contaminants increased with lead at 2.74 mg·kg^{-1} and potassium at 0.41 mg·kg^{-1}. Barium, which can be considered as an additive or as a contaminant, appeared immediately at the beginning of the measurement, but only with a low concentration of 0.27 mg·kg^{-1}, and after 50 h, one value decreased to 0 mg·kg^{-1}. Based on the performed analysis, it can be stated that the new working fluid has probably been contaminated, which is stated in the work of the authors [9], and during the work in the hydraulic circuit it was gradually filtered out. The same situation occurred with the chemical element tin, where its value at the beginning of the measurement was 5.58 mg·kg^{-1} and at the next measurement was already 0 mg·kg^{-1}. The observation did not show that the limit values for chemical elements given in ASTM D6595 were exceeded. During the measurement, there was a decrease, but also an increase in individual chemical elements, which can be attributed to a measurement error or an inhomogeneous sample during testing. It should be noted that some additive elements may also act as contaminants, which can be observed in the element boron, whose value at the beginning of the measurement was 0 mg·kg^{-1} and gradually began to increase to 0.77 mg.kgkg^{-1}. Additionally, for the element silicon, which can also act as a contaminant, at the beginning of the measurement the value was 0 mg·kg^{-1}, and at the end of the measurement it was 1.02 mg·kg^{-1}. Silicon is used as an antifoam additive, but from the point of view of a contaminant, it is a dust particle or seal. The gradual increase in the value of the additives can be attributed to the activation, after which the value stabilises and gradually begins to decrease. In the case of phosphorus, an increase in concentration can be seen within 50 h worked, and after exceeding it, the value began to slowly decrease. For zinc, the value increased until the interval of 175 h worked, and then the value began to decrease. Calcium concentration fluctuated during the measurement, but at the end of the measurement the value was higher by 2.27 mg·kg^{-1}, compared to the value at the beginning of the measurement. By comparing the obtained results with the measurements performed by the authors [10], it can be stated that ecological transmission–hydraulic fluid is suitable for use in hydraulic systems of machines and equipment operating in an environmentally sensitive environment. According to the authors [11], for a more accurate evaluation of the results, it would be appropriate to perform an experiment that would include both approaches, i.e., chemical–physical analysis, as well as determining the technical condition of the machine based on component analysis in universal tractor transmission oil. According to [12], environmentally friendly hydraulic fluids offer great potential due to their thermal properties in terms of temperature dependence of viscosity (viscosity index). Author [13] state that ecological hydraulic fluids are biodegraded by microorganisms in the presence of oxygen, phosphorus, and nitrogen, as well as trace amounts of minerals. The tested working fluid is suitable for use in agricultural and forestry machines operating in an environmentally sensitive environment.

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