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PHYSICAL AND CHEMICAL PROPERTIES OF THE BIODEGRADABLE UNIVERSAL TRACTOR OIL BASED ON THE VEGETABLE OILS

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Abstract: *This paper presents development and testing of the biodegradable universal tractor oil based on the vegetable oils. The agricultural equipment is ideal for the use of biodegradable oils based on vegetable oils because it is used in the very proximity of the environment where the lubricant can come into contact with the soil, water and crops. This is the ideal opportunity to create permanent cycle where the agricultural equipment is lubricated by the oil from the plants grown in the fields cultivated by the very same equipment. Universal tractor oil (UTTO) is the multipurpose oil for the lubrication of the transmission, rear axle, differential, wet brakes, and hydraulic system fed by the common oil reservoir.*

Keywords: *biodegradable universal tractor oil, oil analysis, physical-chemical characteristics, tribological characteristics.*

1. INTRODUCTION

Vegetable oils are base oils for production of ecologically acceptable lubricants. In fact, they are triglycerides made up of complex mixtures of fatty acids having different chain lengths and number of double bonds. Triglycerides are very quickly biodegraded and have excellent lubricity properties. The advantages of vegetable oils versus mineral oils are in the following characteristics – no toxicity, biodegradability, good lubricity, high flash point, high IV and low volatility. The disadvantages of vegetable oils versus mineral oils are low oxidation stability, low fluidity on low temperatures, low hydraulic stability and the price which is 1.5 to 2 times higher than the price of mineral oils [1-6]. Lubricants based on vegetable oils are suitable only for low temperatures not higher than 80 °C.

In the field of the application of ecologically acceptable lubricants, attention should be given to the technical requirements including protection from the wear, corrosion protection, high load carrying properties, heat transfer capability and fulfilment of all the requirements imposed by the producer of the mechanical system [7-8].

2. PHYSICAL AND CHEMICAL PROPERTIES OF THE TRACTOR OIL

The features of oils based on rapeseed oil, sunflower oil, soybean oil and a mixture of rapeseed oil with mineral oil were, after the corresponding testing, compared with the features of the commercially available mineral-based universal tractor oil, UTTO (Table 1).

Table 1. Oil samples

Sample	Oil name	Oil code
1.	Rapeseed oil without additives	RE
2.	Soybean oil without additives	SO
3.	Sunflower oil without additives	SU
4.	Rapeseed oil with additives	REA
5.	Soybean oil with additives	SOA
6.	Sunflower oil with additives	SUA
7.	Rapeseed oil + additives + 10 % SN150	REAM10
8.	Rapeseed oil + additives + 20 % SN150	REAM20
9.	Mineral UTTO	MIN

The physical and chemical properties of the vegetable oils were examined in accordance with standard methods (Table 2).

The results of experimental testing of physical-chemical properties are presented in Table 3. Experimental work was carried out in accordance with the manufacturer specifications and proper standards, by using the necessary testing equipment.

2.1 Kinematic viscosity

Most tractor lubricants possess kinematic viscosity between 9 and 11 mm^2/s at 100 °C (Fig. 1). This viscosity is found to provide sufficient thickness to promote good protection for the transmission system and anti-squawk performance, yet still to be a suitable viscosity for the hydraulic system.

Table 2. Laboratory test methods

Method No.	Physical and chemical characteristics	Test method
1.	Density [kg/m^3]	ASTM D 1298
2.	Kinematic viscosity at 40 °C [mm^2/s]	ASTM D 445
3.	Kinematic viscosity at 100 °C [mm^2/s]	ASTM D 445
4.	Viscosity index	ASTM D 2270
5.	Pour point [°C]	ASTM D 97 or ISO 3016
6.	Flash point [°C]	ISO 2592, ASTM D 92
7.	Foaming [ml/ml] 24 °C; 94 °C; 24 °C	ASTM D 892
8.	Deaeration [minutes]	DIN 51381
9.	Oxidation stability [minutes]	ASTM D 2272
10.	Corrosion on copper, 3 hours at 121 °C	ASTM D 130
11.	P content [%]	ASTM D 4927
12.	S content [%]	ASTM D 2622
13.	Ca content [%]	ASTM D 4628
14.	Zn content [%]	ASTM D 4628
15.	Wear (1h; 65 °C; 40 kg and 1500 rpm) [mm]	ASTM D 4172
16.	4-ball EP test – scuffing [kg]	ASTM D 2783

Table 3. Physical-chemical characteristics of oils

Physical-chemical charact.	unit	RE	SO	SU	REA	SOA	SUA	REAM10	REAM20	MIN
Density at 15 °C	kg/m^3	916	918	920	918	921	922	912	907	877
Kinematic viscosity at 40 °C	mm^2/s	34.8	32.7	35.1	42.3	37.7	38.6	42.03	41.00	70.56
Kinematic viscosity at 100 °C	mm^2/s	7.9	7.82	7.93	9.49	9.17	9.27	9.23	9.18	10.05
Viscosity index		210	224	209	218	227	226	211	201	126
Flash point	°C	322	326	328	254	260	250	248	246	234
Pour point	°C	– 8	– 13	– 11	– 23	– 25	– 24	– 26	– 27	– 36
Protection against corrosion, Test B	pass	pass	pass	pass	pass	pass	pass	pass	pass	pass

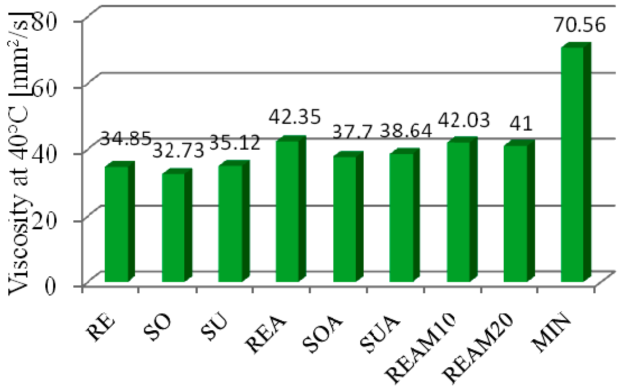

Figure 1. Kinematic viscosity at 40 °C, ASTM D 445

As can be seen from Figure 2, viscosity of vegetable oils, produced from oil seeds, falls between 32.7 and 42.3 mm2/s at 40 °C, and between 7.8 and 9.4 mm^2/s at 100 °C.

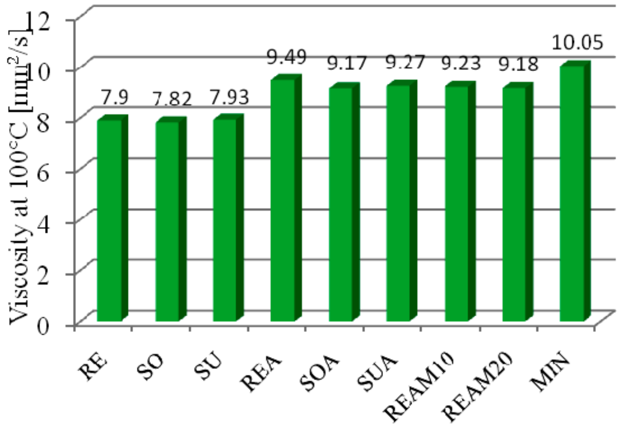

Figure 2. Kinematic viscosity at 100 °C, ASTM D 445

Vegetable oils have a much higher viscosity index (VI > 200) compared with mineral oils, which enables a reliable tractor operation at higher temperature changes. As shown by Figure 3, the viscosity of all vegetable oil based UTTO, reveals them to be thicker at 100 °C, and with significantly higher viscosity index as compared with the mineral based UTTO, labelled MIN.

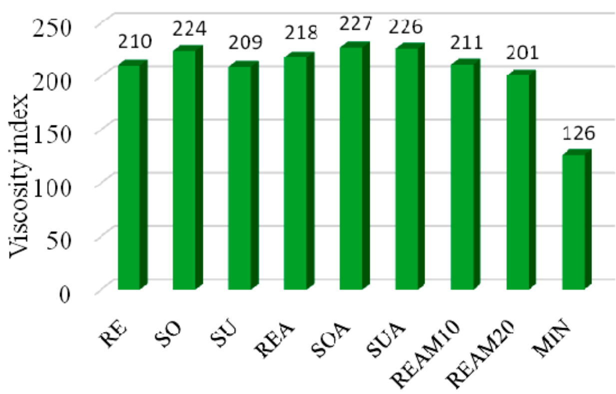

Figure 3. Viscosity index, ASTM D2270

2.2 Flash point

Flash point is important in transport and storage due to risk of fire. Vegetable oils have higher flash point values in comparison with mineral oils (Fig. 4).

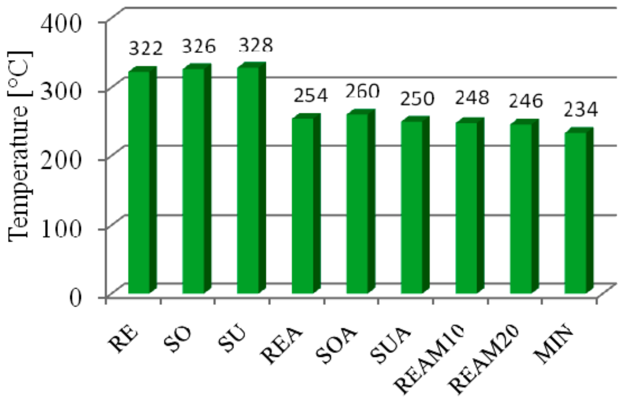

Figure 4. Flash point, ASTM D 92

Flash point for vegetable oils is higher than 300 °C. By adding a package of additives and mineral oil according to the formulation, the flash point is reduced, but it is far above the allowed values according to the specifications of tractor manufacturers (Massey Ferguson CMS M1141, Massey Ferguson CMS M1143; John Deere J20C: Flash point ≥ 200 °C).

2.3 Pour point

The flowability of vegetable oils at low temperatures is extremely low, which limits their use at low operating temperatures (Fig. 5).

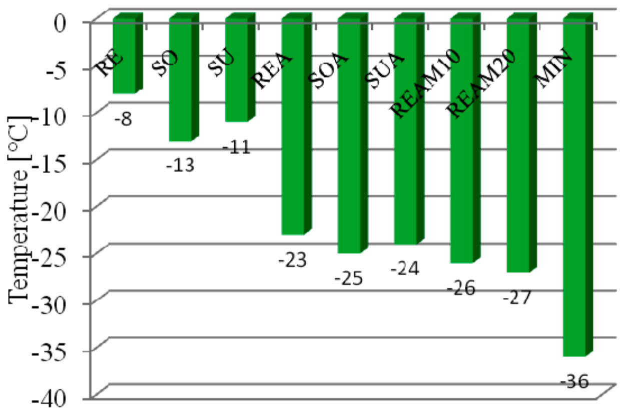

Figure 5. Pour point, ASTM D 97

Vegetable oils form crystal structures at low temperatures, by agglomeration of triglycerides, wherein the oil flowability is reduced. In order to improve the low-temperature characteristics, vegetable oils are added additives labelled as pour point depressants (PPD). The function of these additives is to prevent the crystallization of the triglyceride molecules at low temperatures and their further grouping. The optimal concentration of additive PPD of 1 % in the final formulation of vegetable oils, significantly improves their low temperature properties.

2.4 Rust and corrosion

Rust is a product of reactions between a metal and corrosive environment. Corrosion is an electrochemical process, usually caused by the action of acidic chemical compounds on the metallic surface. Corrosion inhibitors (anti-corrosion additives) protect metal parts that are exposed to the rust and corrosion [9]. The basic mechanism of action of anti-corrosion additives is based on the formation of a protective layer on the metal surface, by physical and chemical adsorption [10]. Rust and corrosion inhibitors are commonly sulfonates, which are surface-active substances and provide good results in vegetable oils. Antioxidant additives are multifunctional and they can also protect metal against corrosion [11].

All of the oil samples showed good results in terms of protection against rust, according to the test B, ASTM D 665 method (the result was “passes”) and corrosion according to the method ASTM D130 (the result was “1A”), as shown in Table 3.

3. CONCLUSION

According to the obtained results for physical-chemical properties of various oil samples, it may be concluded that almost all the investigated properties of biodegradable universal tractor oils, satisfy the John Deere and Massey Ferguson specifications, and some characteristics are even better when compared to the properties of universal mineral based oil.

The vegetable oils show considerably higher viscosity index (VI > 200) than mineral oils, allowing a reliable tractor operation at wider temperature changes.

Flash point is higher for vegetable oils as compared to the mineral.

Low temperature fluidity of vegetable oils is far from satisfactory, thus limiting their use at low temperatures. However, PPD additive lowers pour point for these oils to – 15 °C or even – 23 °C, and these values satisfy most standards.

All vegetable oil samples show good protection against rust and corrosion.

Some of the additives used (PPD and EP) increase foaming above the allowed limits, but after the addition of antifoaming agent, good results are obtained.

By using the methodology developed in the present article, the experimental analysis should be expanded to other lubricants, but the following rule should be obeyed: an ecological lubricant must be developed, which will satisfy all technical, exploitation, and other requests defined by current standards and the application conditions.

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