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Study Rheological Behaviour of Biodegradable Lubricants

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ABSTRACT

In this article we presented the study of the rheological behavior of two oils used in biodegradable lubricants. Depending on the shear rate and the shear stress, it is found that *Olive oil* has a greater slope than *Coconut oil*. If the viscosity dependence of the shear stress or shear rate is shown graphically, it is found that the viscosity decreases exponentially with both the shear speed and shear stress. The *Coconut oil* and *Oil olive* have investigated using a Haake VT 550 Viscotester developing shear rates ranging between 3 and 120 s^{-1} and measuring viscosities from 10^4 to 10^6 mPa•s when the HV_1 viscosity sensor is used. The temperature ranged between 40 and 100°C and the measurements were made from 10 to 10°C. The accuracy of the temperature was 0.1°C.

Keywords: Rheology, *Oilve oil*, *Coconut oil,* Biodegradable Lubricants.

INTRODUCTION

Lubrication, a process absolutely necessary for any machine or mechanical construction with movable elements, concerns the technicians of all categories, from the offices of studies, research and design, to the simple or very complex industrial systems. The universality of the problem and the diversity of applications recommend lubrication as one of the most complex aspects of modern technology. For a long time the absence of data and theoretical generalizations was supplemented by the experience gained often with the price of some faults or failures in the operation of the machines or of some technical systems.[1] Moreover, the existing empirical data used exclusively, have slowed the emergence of new types of machines, with increased speeds and loads, required by the rapid progress of the technique. With all its significance, lubrication has long been considered, quite wrongly, as a minor branch of machine construction, which was given only passing attention. The dizzying development of recent times has, however, also produced a reversal of conceptions in this area. Lubrication has detached itself as a stand-alone science, the results of which condition the progress of the technique. In the last decades, the scientific and technical literature has been enriched with numerous works in this branch, sometimes giving it a dominant place among those who carry innovative ideas, with particularly valuable implications.[2] The continuous increase of the complexity of the technological systems, the creation of their multiple functions, the identification of the relations between their component elements and the operating conditions, their increasing computerization have led to the systemic approach of the lubrication process so that, at present, a great emphasis is placed on rigorous management. of the process in order to achieve the most efficient productivity, but at the same time, and to permanently maintain control over the equipment and processes.[3] The purpose of the scientific design and organization of the lubrication process is to keep the equipment in working order, avoid accidental shutdowns and eliminate the possibility of triggering damage, systematically reduce maintenance and repair costs, collect, select and maintain a large volume of data and information that allows calculating the reliability and maintainability of the machines and, in particular, ensuring the best conditions for the production process.[4] The correct selection of a lubricant is a complex action, due to a series of factors that must be taken into account: constructive factors (the type of tribosystem, its accessibility for lubrication, the quality and quantity of lubricant, the lubrication method, etc.), factors of working regime (load, speed), environmental factors (temperature and pressure of the environment, presence of contaminants). The development of modern lubrication materials and their proper use are of great importance for a country's economy. Selected judiciously for solving a specific problem can bring billions of dollars in economically developed countries, due to the energy saving, the reduction of wear, the reduction of maintenance costs and the prolongation of the operating times between repairs, machines and machinery.[5] The most important problem of tribology is the correct choice of lubrication materials, the elaboration of optimal constructions for industrial tribosystems, especially for lubrication systems. Even some problems regarding the protection of the environment under the conditions of globalization may have solutions related to the quality, the quantity of lubricant and the design of the lubrication systems.

Oils containing both naphthenic hydrocarbons and paraffinic hydrocarbons are called mixed base oils and these can be classified as predominantly paraffinic or predominantly naphthenic oils.[6] Naphthenic oils contain significant amounts of cycloparaffins and aromatic hydrocarbons, while paraffinic oils contain more paraffinic hydrocarbons, have lower density and a higher viscosity index, the latter being characterized by unfavorable properties at low temperature as a result of paraffin separation. (if they were not subject to deparaffinization) and usually have a lower sulfur content. The base oils of different origin, but of the same type, are similar, but by no means identical. Oxidation-resistant oils can be obtained from petroleum distillation. The technological process of oil production is conducted according to the field of its subsequent use, which determines the required level of the viscosity index, the properties at low temperatures, the resistance to oxidation. Of course, the process must be economically profitable. In order to meet the different quality conditions with rational costs, different crude oils are used to obtain two, three types of base oils, with different viscosity characteristics and properties at low or relatively higher temperatures.[7] The number of fractions of the oils obtained from each assortment of crude oil varies between the limits of four to seven. These fractions may comprise the range of viscosity from light distillation oil to residual oil; at the same time, the viscosity and the ignition temperature of these fractions depends on their fractional composition and on the weight of the fraction in the final product. Many properties of today's oils are obtained by adding chemicals, without which they could not meet the required requirements. Additives can improve oxidation and aging resistance, low temperature and wear resistance properties, corrosion resistance and viscosity-temperature characteristics.[8] These can lead to new properties, for example, washing-dispersing, anti-seizing, emulsifying, etc. Mineral-based oils are used not only for lubricating and transmitting power at high and low temperatures, but also for transmitting heat (thermal agents) or as dielectrics, as additives to typographic paints, for auxiliary textile materials, as plasticizers for rubber and plastics, such as white oils for the preparation of cosmetics and pharmaceuticals. This wide range of application areas denotes the diversity and flexibility of the use of natural hydrocarbon mixtures, with all the necessary compromises under extreme working conditions. Petroleum products, as a rule, are products that result from mass fabrication and are usually cheaper compared to similar synthetic products (synthetic lubricants). In cases where the petroleum product does not fully meet the requirements imposed by the application, many engineering solutions propose synthetic fluids, characterized by the presence of particular lubrication and durability properties.[9] Synthetic oils are obtained from comparatively homogeneous raw materials, under controllable conditions and may refer to different classes of chemical compounds. The costs for the raw materials and the manufacture of synthetic oils are much higher than for the manufacture of petroleum oils, but for some applications, the share of the synthetic ones begins to increase. Engineers, specialists in materials and chemistry studies must collaborate in the planning and design of engines, machines and appliances, as well as in their exploitation for the optimal solution of the lubrication problems and to ensure the safe and uninterrupted operation of the mechanisms.[10-12]

The composition of coconut oil is presented in Table 1.

Table 1: The approximate concentration of fatty acids in *Coconut oil*[6,7]

Fatty acid content of *Coconut oil*	%
Caprylic saturated C8	7
Decanoic saturated C10	8
Lauric saturated C12	48
Myristic saturated C14	16
Palmitic saturated C16	9.5
Oleic monounsaturated C18:1	6.5
Other	5

The composition of oil olive is presented in Table 2.

Table 2: The approximate concentration of fatty acids in *Olive oil*[6,7]

Fatty acid content of *Oilve oil*	%
Palmitic acid	13
Stearic acid	1.5
Oleic acid	70
Palmitoleic acid	0.3-3.5
Linoleic acid	15
α-Linoleic acid	0.5

In this article we presented the rheological behavior of biodegradable lubricants such as seed oil and *Coconut oil*.

MATERIAL AND METHODS

Coconut oil and *Olive oil* are commercial oils produced in Romania. The *Coconut oil* and *Oil olive* have investigated using a Haake VT 550 Viscotester developing shear rates ranging between 3 and 120 s^{-1} and measuring viscosities from 10^4 to 10^6 mPa•s when the HV_1 viscosity sensor is used. The temperature ranged between 40 and 100°C and the measurements were made from 10 to 10°C. The accuracy of the temperature was 0.1°C.

RESULTS AND DISCUSSION

Figure 1 shows the dependence of the shear rate on the shear stress at different temperatures. It is observed that as we increase the shear rate the shear stress of the two known biodegradable lubricating oils increases. The addiction is almost linear and the *Olive oil* has a higher slope compared to the *Coconut oil*.

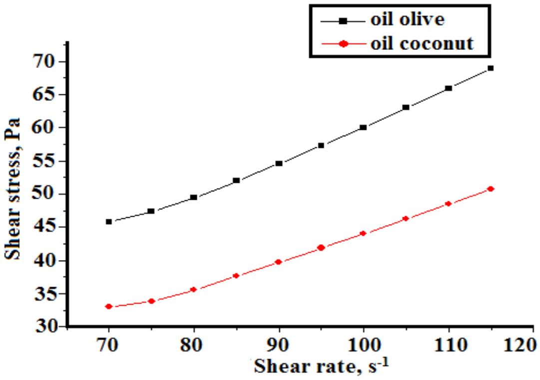

Fig.1. Rheogram of *Oil oilve* and *Coconut oil*

Figure 2 shows the viscosity dependence of shear stress at different temperatures. As can be seen from the graph, the viscosity of the olive oil decreases exponentially with the increase of shear stress at the temperatures at which the biodegradable lubricant was studied. The decrease of the viscosity with the shear stress results from a shape relation:

$$\eta = \eta_0 + A_1 \exp(-\tau/t1) \qquad (1)$$

where η_0, A_1 and t_1 is constants.

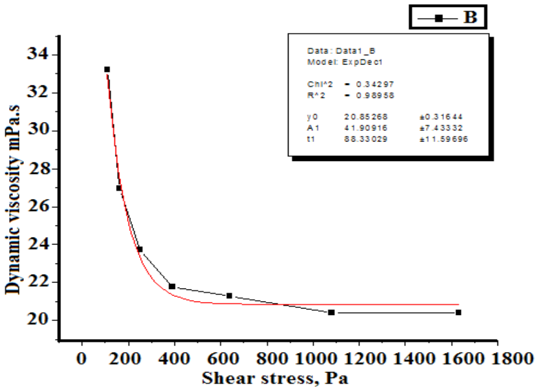

Fig. 2. Dependence viscosity of shear stress for oil olive

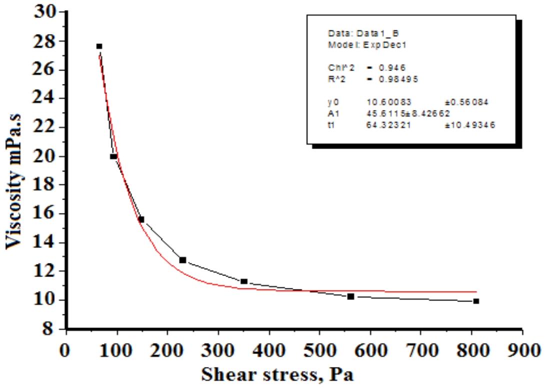

Fig. 3. Dependence viscosity of shear stress for *Coconut oil*

Figure 3 shows the viscosity dependence of the shear stress for the *coconut oil* at the temperatures at which it was studied. The viscosity of the lubricating oil decreases with increasing shear stress at all temperatures. Like olive oil, the decrease is exponential and the parameter values differ.

Figure 4 shows the dependence of the viscosity of the shear speed on the *Olive oil*. The viscosity of the oil decreases with increasing shear speed and has an exponentially dependence.

The dependence of the viscosity on the shear stress for the *Coconut oil* is given by the relation:

$$\eta = \eta_0 + A_1 \exp(\tau / A_2) \qquad (2)$$

Where η_0= 14.3499mPa.s, A1= 108.7158, A_2= 42.9418 Pa and R_2 = 0.9887

Table 3 presents the temperatures, the values of the parameters obtained with equation (2) and the correlation coefficients for the *Coconut oil*.

Table 3: The temperature, value of parameters of described by equation (2) and coefficient correlation for Coconut oil

Temperature, ^{0}C	Value of parameters of the described by equation (2)			Correlation coefficient, R^2
	η_0, mPa.s	A_1	A_2, Pa	
40	14.3499	108.7158	42.9418	0.9887
50	10.3471	16.1177	105.7002	0.9451
60	7.7475	20.3213	46.4978	0.8879
70	7.1654	9.7494	65.5435	0.9478
80	6.6670	5.8933	121.0268	0.9730
90	6.1927	4.5329	185.5252	0.9877
100	5.8749	4.5693	186.0338	0.9927

Parameter η_0 decreases with increasing shear voltage and temperature, parameter A_1 decreases with increasing temperature remaining almost constant at temperatures of 90 and 100^{0}C, and parameter A_2 has a variable value with increasing temperature and shear voltage.

The dependence of the viscosity on the shear stress for the *Olive oil* is given by the relation:

$$\eta = \eta_0 + A_1 \exp(\ / A_3) \qquad (3)$$

Where η_0= 20.8527mPa.s, A_1= 41.9092, A_3= 88.3303 Pa and R_2 =0.9896

Table 4 presents the temperatures, the values of the parameters obtained with equation (3) and the correlation coefficients for the *Olive oil*.

Table 4: The temperature, value of parameters of described by equation (3) and coefficient correlation for Olive oil

Temperature,^{0}C	Value of parameters of the described by equation (3)			Correlation coefficient, R^2
	η_0, mPa.s	A_1	A_3, Pa	
40	20.8527	41.9092	88.3303	0.9896
50	12.1299	25.2464	68.4127	0.9398
60	10.4528	15.0526	81.5311	0.9030
70	9.8129	12.2895	86.2287	0.9365
80	9.2189	10.4342	87.3811	0.9525
90	8.5273	10.2238	88.8474	0.9596
100	8.2514	13.4653	65.0995	0.9821

The value of parameter η_0 decreases with increasing shear voltage and temperature, of parameter A_1 in a similar way, and parameter A_3 has variable but high values.

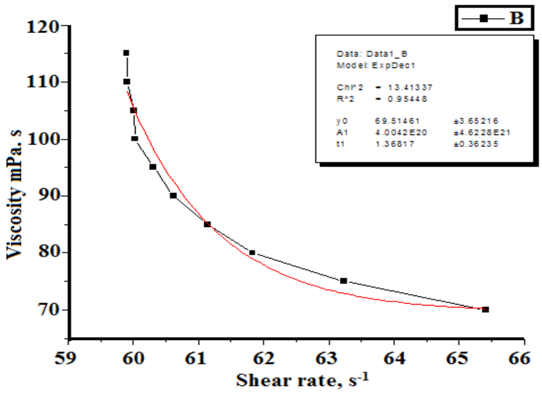

Fig. 4 Dependence viscosity of shear rate for *Oil olive*

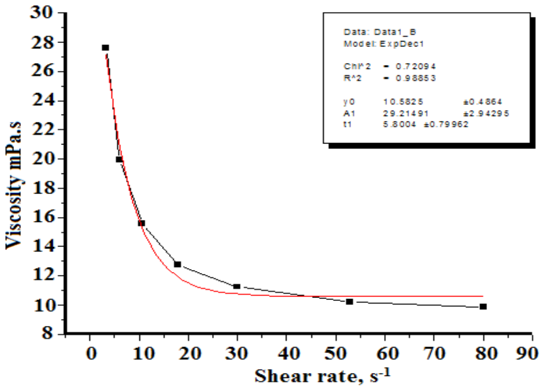

Fig. 5. Dependence viscosity of shear rate for Coconut oil

Figure 5 shows the viscosity dependence of the shear speed on the *Coconut oil*. As can be seen from the graph, the viscosity of the oil decreases with the increase of the shear rate at all the temperatures at which the oil was studied. The dependence of the shear velocity viscosity shows an exponential decrease where the parameters have the meaning that in equation (1) only they have other values.

CONCLUSION

In this article we presented the study of the rheological behavior of two oils used in biodegradable lubricants. Depending on the shear rate and the shear stress, it is found that olive oil has a greater slope than *Coconut oil*. If the viscosity dependence of the shear stress or shear rate is shown graphically, it is found that the viscosity decreases exponentially with both the shear speed and shear stress.

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Conflicts of Interest

The authors declare no conflict of interest.

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