ON THE FUTURE OF BIODEGRADABLE VEGETABLE LUBRICANTS USED FOR INDUSTRIAL TRYBOSYSTEMS

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ABSTRACT

Recently, the ecological lubricants based on vegetable oil and, other tendency is to use synthetic lubricants, both applications reducing the field of mineral oil.

Biodegradable lubricants will be more used in environment with ecological risk, as for instance, equipment functioning in hygroscopic protected medium, in agriculture, food and wood industry as well as for those with lubricant leakage.

The success of vegetal oils is related to their biodegradability and reduced toxicity but a wider use is limited by their insufficient stability in time.

This paper presents first experimental results on lubricating capacity of rape seed oil compared to that obtained for a usual mineral oil. From these results it seems that rape seed oil has actual capacity for being used in industrial applications.

KEYWORDS: Rape seed oil, Tribological behaviour.

1. INTRODUCTION

Until the XIX-th century lubricants had been manufactured using mainly, even exclusively vegetable oil and animal fats. When the internal combustion engines appears, these "classical" lubricants were gradually replaced by mineral oils. The main cause of this change is the stability in time of the latest ones, for both stocking and functioning.

An evolution of application involving vegetable oils and animal fats is presented in figure 1, compared to other lubricants [19].

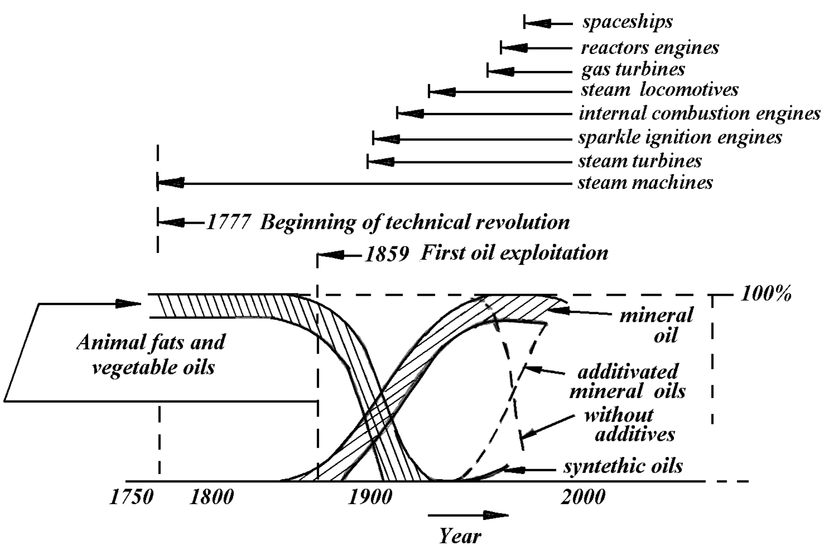

Figure 1 Evolution of lubricant application

In the last 15 years, the research for manufacturing new products being neutral as concerning their influence on the environment makes the vegetable oils attractive again for lubricating purpose.

Classical examples of using rape seed oil are hydraulic devices and chain and saw lubrication, etc. [6], [8], [9], [11], [15], [16].

At presents, the success of the vegetable oils may be explained by characteristics of actual interest: biodegradability and low toxicity. In Germany, introduction of these oils is sustained by governmental institutes [1].

A larger use of vegetable oils is restricted due to their insufficient stability in time (they age more quickly than the mineral oils) and even in functioning if the thermal field exceeds critical limits usually lower that those characterising the mineral oils.

It is estimated that from total quantity of lubricants, ~85% is represented by products containing mainly mineral oils. The remaining 15 % is considered to be products with vegetable and expensive synthetic oils. The actual use of vegetable oils on lubricant market was under 0.5% in European Community.

Biodegradable lubricants will be more intensively used in environment with ecological risk, especially for protected areas or food and light industry and when lubricant leakage could not be entirely eliminated.

2. BASIC MATERIALS FOR NATURAL LUBRICANTS

Basic materials for obtaining the natural lubricants have vegetable and animal character.

Natural oils and fats is a supply of basic materials that, by hydrogenation or dissociation reaction may give intermediate products that may combine, resulting complex esters and polyesters and, finally, the basic oil of a good lubricant. (figure 2) [1].

Animal oils and fats are obtained from pork, sheep and cow fats and are used for lubricating fine mechanisms and for manufacturing consistent greases. This group includes bones and hoofs oil, seal fats, oil extracted from whale brain and spinal cord, suet, pork fat, bone fat, stearine and olein, fish oil and woollen fat.

Basic material of vegetable origin are obtained from oleaginous plants: sunflower, soy been, rape seed, castor, cotton and in the tropical zone, from palms, coconut tree, olive, nuts.

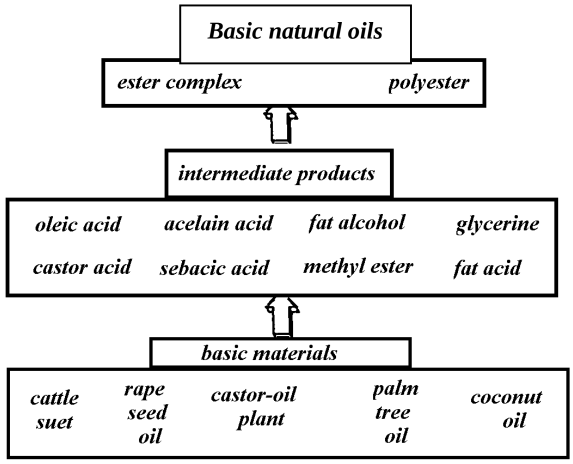

Figure 2 Basic natural oils

In Romania the oil plants of most interest are, sunflower, castor, rape, soy been, cotton.

From analytic and economic reason, the rape seed oil are the most important as lubricant. Therefore, the lubricants based on rape seed oil are used in hydraulic power transmission and in lubricating cutting raw.

3. STRUCTURE, COMPOSITION AND PROPERTIES OF VEGETABLE OILS

Generally, all refined vegetable oils by the help of alkalis have more than 99% threeglicerydes, except few ones obtained from exotic plants. Threeglycerides are esters of fat acids. Fat acids (with or without double link) may be classified as following [7]:

- saturated (without double link): myristic, palmitic, stearic;

-mono-non-saturated (with only one double link): oleic, erucic;

-poly-non-saturated (with more than one double link): linoleic, linolenic;

-special (contains other groups as hydroxyl in ricin oleic and epoxy in vernolic).

By combining the fat acids and the glycerine, a large diversity of complex esters is obtained. Such a complex glycerine esters are the groups: β-CH and ester. If the glycerine is replaced by three-methyl-propane, the complex ester three methyl-propane does not contain the group β-CH and it is obtained the more useful threemethylpropane (figure 3) [1].

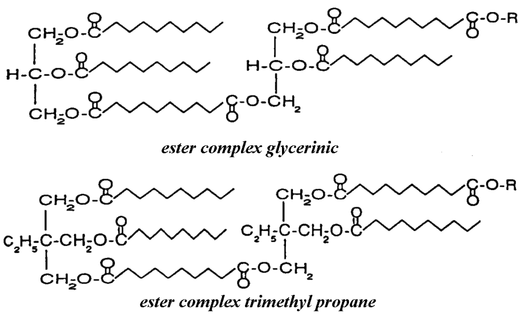

Figure 3 Complex ester

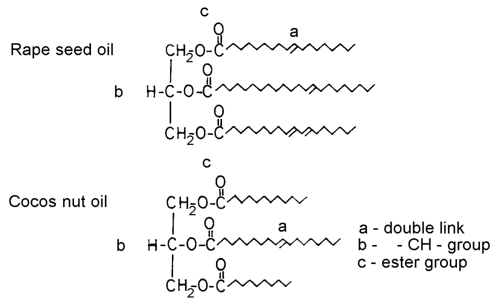

Figure 4. Labile structure of vegetable oils.

From a chemical point of view, vegetable oils are threeglycerides containing elements with labile structure generally with "double-link", "group β-CH" and "group ester". These labile structural groups are generally favourable to transform into resins the vegetable oils (that mean a thickening tendency) when they are used as lubricants.

Structural elements with "double-link" or "group β-CH" are unstable especially at thermal field and oxidant environment but the "ester groups" are easily dissociated in water (hydrolysis).

On the other hand the ester group is mainly responsible for quick biological decomposition of vegetable oils (figure 4).

A future acceptance of vegetable oils on lubricant market depends, among others, on their capacity for being additivated in order to reduce or to eliminate the great and undesired oil reactivity of the labile structural groups [2], [3], [7] [13].

Research has to be done for establish which additives most being non-ecological, may be added in order to influence in a very reduced way the non-pollution characteristic of the vegetable oils.

Main physical and chemical characteristics of the most used vegetable oils are presented in table 1.

Vegetal oils are a resource for many products after hydrogenation or other dissociation reactions. These substances may be further more combined with special agents (as threemetilolpropane) and the results are polyesters and complex esters.

Rape is one of the most common sources for vegetal oil. Rape seed oil has good lubricating and protective (anti-corrosive) properties. Its viscosity index is IV 200 meaning a low dependence of the viscosity on temperature. This viscosity index is not obtained for any additivated mineral oil.

As the rape seed oil has a high molecular mass comparing to mineral oils, it has low mass loose because of vaporisation and a higher inflammability point, above ~250°C.

Table 1 Physical and chemical characteristics of some vegetable oils

Oil	Density g/cm^3	Viscosity mm^2/s		Visco-sity index (IV)	Freezing point (^{o}C)	Inflamma-bility point (^{o}C)	Saponi-fication number	Iodine value	Siccativity
		ν^{40}	ν^{100}						
Sun-flower	0.920-0.930	28.0	7.3	202÷250	-12	168-202	180-195	119-144	semisiccative
castor	0.950-0.975	252	19.9	90	-10÷-18	275-295	170-187	81-88	nonsiccative
rape seed	0.921-0.938	32.6	7.9	210	-5÷-40	182…230	-	94-112	nonsiccative
soy been	0.924-0.930	93	11.35	-	-10÷-15	204	180-190	107-137	simisiccative
cotton	0.922-0.930	130	13.2	-	10÷-10	216	190-200	101-117	semisiccative
olives	0.897	76	9.5	-	-7÷-10	135	170-180	78-95	nonsiccative
in	0.897	47.6	4.7	-	-	120	-	168-192	siccative
fluid B	0.904	42.55	8.29	147÷211	<24	242	-	71.9	-
fluid M	0.875	46	6.91	103	<24	222	-	-	-
MIN1	0.864-0.891	70.89	8.55	95	-6÷-30	-	-	-	-

The advantages of rape seed oil are a low level of toxicity and a great degree of biodegradability. In aerobic conditions, the biodegradability is gradually achieved by oxidation and hydrolysis. If the oxidation has a light form, the molecule is decomposing quicker resulting only CO_2, H_2O and organic mass.

Modifications due to oxidation of the rape seed oil molecule generate, among others, acid products that may attack metallic materials and seals. Furthermore these products usually initiate an acceleration of ageing process (due to catalytic agents), diminishing very much the exploitation interval.

Oxidising processes of the mineral oils may be reduced by introducing special additives and thus these oils may have very long period of functioning.

This stability can be improved with some antioxidising admixture like: DPA-amine (preventing oxidation due coupling two radical peroxy) and BHT-phenol (preventing oxidation due elimination two radical peroxy and one radical alkyl)

Using same additives for rape seed oil is not possible as most of these additives are toxic and not biodegradable and transfer these undesirable properties to the vegetal oil.

4. TESTING METHODOLOGY

Tribological behaviour of rape seed oil was studied by loading steps using a sliding tribomodel.

The tribomodel has a steel roller and a shoe made of cast iron grade Fc 200 as it is presented in Figure 5.

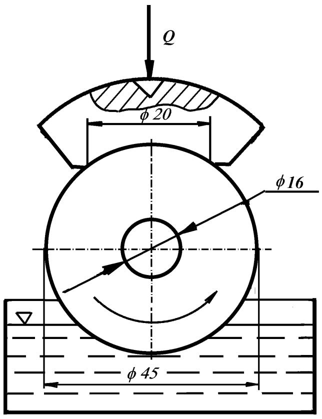

Figure 5. Sliding tribomodel.

Tests were done on a machine type Amsler with loading interval between 0 and 2250 N.

Sliding speed was of 0.5 m/s (a rotational speed of 220 rot/min) and roller diameter of 16 mm. Lubrication was accomplished by roller and bearing immersion in a bath containing the tested lubricant.

Tests were done for different load steps (500, 1000, 1500 N, respectively), that means average contact pressure of 5, 10, 15 MPa; the resulted product (p.v) was between 2.5 and 7.5 MPa.m/s.

During the test, the friction moment was automatically recorded and the values were used to calculate the friction coefficient. All tests were done twice and the repeatability was good. Table 2 contains average value of the friction coefficient obtained after two tests with identical conditions.

Testing time was established after several preliminary tests at 10 minutes that corresponds to a sliding distance of 335 m or to ~2500 rotations of the roller.

The tests were done using as lubricant both rape seed oil and motor oil grade M 15 W/40 Super 2. Properties of tested lubricants are given in table 2.

Table 2. Physical properties of tested oils

Property	Oil 15W/40 Super 2	Rape seed oil
Relative density at 20 °C	0.885-0.890	0.913 at 15 °C
Inflammability point, (°C)	min. 200	300...320 °C
Viscosity at 100 °C (cSt)	14.7(2.27°E)	30-35 cSt (4-4.7 °E) at 50 °C

5. EXPERIMENTAL DATA

1. Friction moments were recorded and they are presented in figure 6 and figure 7

2. Average friction coefficient for stabilised regime for three tests is given in table 3.

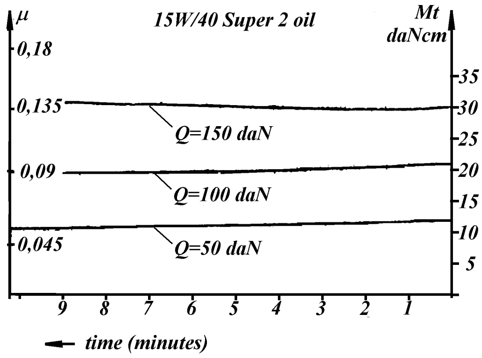

Figure 6. Friction moment and friction

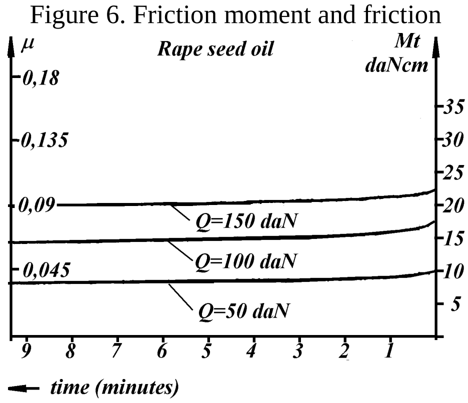

Figure 7. Friction moment and friction coefficient for rape seed oil.

Analysing these diagrams presented in figure 6 and figure 7 and the values in table 3 and figure 8, it results that for a load of 500 N, values of friction coefficient μ are approximately equal for both tested oils but for loading of 1000 N, 1500 N, the friction coefficient μ is lower for the rape seed oil as compared to the motor oil grade M 15W/40 Super 2.

Table 3. Friction coefficient for sliding motion.

Load Q (N)	Friction coefficient	
	M15 W/4o Super 2	Rape seed oil
500	0.048	0.042
1000	0.090	0.070
1500	0.136	0.090

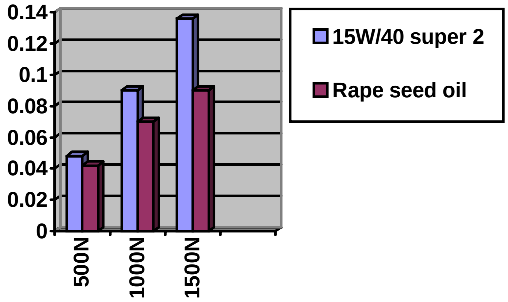

Figure 8. Friction coefficient

6. CONCLUSIONS

From these first tests, it results that there is an actual possibility for using this vegetable oil as lubricant for industrial applications.

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