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VEGETABLE OILS IN ENGINE LUBRICANTS FORMULATION

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ABSTRACT
The paper present results regarding vegetable used in engine oils formulation and modalities to enhance their properties in order to be suitable for special applications.
The new formulated engine oils exhibit physico-chemical performances similar with those based on mineral oils. To enhance the oxidation stability additives with special antioxidants properties and addition of mineral oils where used.
The new lubricants can be successfully used in application with high environmental risqué and moderate working conditions, such as: chain saws and other portable implements, sawmill blade, two stroke engines for moped, motorcycles, outboards (water cooled) and snowmobiles, any other applications where the lubricant is used on "once through" basis.
Keywords: *lubricants, additives, engine, vegetable oil*

1. INTRODUCTION

Nowadays 50% of the total quantity of lubricating oils used for different applications ended up in the environment through various channels—pipe or drum leaks, accidental spills, discharging of used oil into drains. More than 95% of these products are based on mineral oils and they are a considerable treat for environment. The world lubricants demand forecast is about 41.7 million metric tons for 2010, in advance with 2.3% per year, due by increasing rates of motor vehicle ownership world-wide and a rising number of kilometres travelled per vehicle [1]. For environmental and cost reasons, the global trend is to reduce the amount of lubricant consumption and to utilise new low toxicity and biodegradable products anywhere these are suitable.

The increased interest in vegetable oil-based lubricants is explained by:

- Environmentally regulations that demand ready biodegradable and low toxicity lubes;
- The need to substitute the commonly petroleum based lubes with renewable products;
- The effort of agricultural producers to promote their products for more applications.

Vegetable oil based lubricants are an environmentally friendly alternative to petroleum oil lubricants. Properly choose these lubricants can perform as well as petroleum oils. Studies about market opportunity for vegetable oils as lubricants reveal a high level of acceptance for these products as commercial alternative to mineral-based oils, for different applications. Such an example is presented in table 1 [2].

Table 1. Market potential – Soybean Oil Opportunities

Application	Probability of Acceptance, %	Possible Market Share	
		%	mil. Bu.*
Hydraulic Fluid	40	5	8,0
Two-Cycle	20	10	1,5
Bar / Chain	60	50	1,0
Crankcase	10 / 80**	10	87,3
Drip Oil	65	80	0,8
Rail and Flange	55	50	0,4
Wire Rope	70	70	1,1
Metal Cutting	30	10	2,8
Dedusting	50	50	0,4

** 1 U.S. bushel = 35.23907017 liters; **Automotive water-cooled-engine use / air cooled-engine use.*

According to the mentioned study, this is the potential penetration once a technically and economically competitive product is developed and introduced.

Base oil is the major component of lubricants and imposes directly the quality, the cost and the biodegradability of the final product. Commonly used mineral oil exhibit a poor biodegradability (20-40% by CEC L33–A90) in comparison with vegetable oil (90-98 %) or synthetic esters (90-100 %). Vegetable oils are obtained in large quantities worldwide and they are available at reasonable price also for other purpose than food.

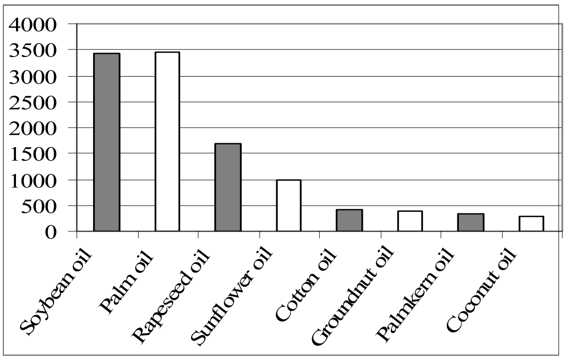

Figure 1. Oils World Production 2005/06 (1000 T)

Figure 1 shows the world production of the major vegetable oils and fats for the campaign of 2005/06 [3]. Among all, soy oil, compared with the rest of vegetable oil has one predominant position, alongside palm oil.

2. EXPERIMENTAL WORK

The biodegradable, low toxicity and renewable vegetable oils have excellent lubricity properties, superior than that of mineral oil, a very high viscosity Index (over 170°C) and high flash/fire points (over 300 °C in some cases compared to a flash point of approximately 200°C for mineral oils). On the other side, natural vegetable oils exhibit poor oxidative stability. That means that the oil will oxidise during use, becoming thick and polymerising. This problem is difficult to solve, nowadays trends indicating the chemical modification of vegetable oils, genetically modification of the plant and / or use of antioxidants additives [4].

Our proposal is to obtain engine lubricating oil based on vegetable oil.

Table 2. The Characteristics of sunflower based oil lubricants

Characteristics	**Base oil**				**Test methods**
	sunflower	sunflower + mineral	sunflower + synthetic	reference commercial oil	
Cinematic viscosity at 40°C, cSt	36,39	55,58	28,26	-	ASTM D-445
Cinematic viscosity at 100°C, cSt	8,09	9,68	6,81	9,4 - 12,5	ASTM D-445
Viscosity index	205	160	215	min. 90	ASTM D-2270
Pour point, °C	- 15	- 30	- 24	max. - 24	ASTM D-97
Flash point, °C	254	260	220	min. 220	ASTM D-92
Sulphated ash, %	0,55	0,52	0,53	max. 1,1	ASTM D-874
Total base number, mg KOH/g	6,18	6,20	6,19	min. 6,0	ASTM D-2896
Copper corrosion, 3 h at 100°C	1 a	1 a	2 b	max 1 b	ASTM D-130
Dynamic viscosity, mPa·s: ▪at - 15°C / at - 20°C	- / -	2250 /3080	2150 / -	- / -	ASTM D-5293

Table 3. The Characteristics of soybean based oil lubricants

Characteristics	**Base oil**				**Test methods**
	soy	soy + mineral	soy + synthetic	reference commercial oil	
Cinematic viscosity at 40°C, cSt	36,69	56,62	29,34	-	ASTM D-445
Cinematic viscosity at 100°C, cSt	8,33	9,77	7,06	9,4 - 12,5	ASTM D-445
Viscosity index	213	159	217	min. 90	ASTM D-2270
Pour point, °C	- 21	- 30	- 24	max. - 24	ASTM D-97
Flash point, °C	252	250	223	min. 220	ASTM D-92
Sulphated ash, %	0,53	0,55	0,55	max. 1,1	ASTM D-874
Total base number, mg KOH/g	2,72	2,75	2,73	min. 6,0	ASTM D-2896
Copper corrosion, 3 h at 100°C	2 b	2 b	2 b	max 1 b	ASTM D-130
Dynamic viscosity, mPa·s: ▪at - 15°C / at - 20°C	950 / -	1860 / 3420	1980 / -	- / -	ASTM D-5293

Thus, there were formulated lubricants with soybean oil, sunflower oil, and antioxidant, anti corrosion, antiwear, detergent-dispersant, depressant and antifoaming additives. The characteristics of obtained lubricants are presented in tables 2 and 3.

Viscosity index over 159, high flash point, appropriate pour points, cinematic viscosity and dynamic viscosity was obtained for all formulated lubricants. The out of limit copper corrosion characteristics can be easily corrected with supplementary additives.

3. RESULTS AND DISCUSION

Based on the above results, the products formulated with blending of vegetable and mineral oils were selected for oxidation stability tests by specific engine oils "Mobil test" and "Rotary bomb test".

The "Mobil test" consists in heating the samples at 150°C for 60 hours with 13 litters per hour air. The degree of oxidation was evaluated by measuring the data presented in table 4: cinematic viscosity, total acid number and volatility.

Table 4. Results at Mobil oxidation stability tests

Oxidation data		Sample		
		S1 (sunflower + mineral)	**S2** (soy + mineral)	reference commercial oil
Fresh oil weight, W_F, g		166,5	167,0	141,9
Oxidised oil weight, Wo, g		166,0	166,2	141,8
$\Delta W = W_F - W_O$, g		0,5	0,8	0,1
Volatility = $\Delta W \times 100 / W_F$, %		0,30	0,48	0,14
Characteristics				
Fresh oil	Cinematic viscosity at 40°C, cSt	56,03	56,03	99,94
	Cinematic viscosity at 100°C, cSt	9,67	9,75	10,85
	Viscosity index	158	160	91
After oxidation test	Cinematic viscosity at 40°C, cSt	619,2	753,6	104,8
	Cinematic viscosity at 100°C, cSt	56,12	62,73	11,14
	Viscosity index	154	150	90
	Total acid number, mg KOH/g	15,73	18,64	2,00

The conclusion from "Mobil test" is that the new formulated lubricants based on vegetable oils shows high modification of cinematic viscosity and acidity, therefore the sample was supplementary additivated with special antioxidants additives, such us different types of alkyldithiophosphate (ADTPh I and II) and ashless phenols- diphenylamine complex (F+DFA). As it is presented in Figure 2, the Rotary bomb test (ASTM D-2272) was used to evaluate the oxidation behaviour of these final samples. The "Rotary bomb tests" indicate that even with extra antioxidant additives, the new formulated lubricants based on vegetable oils do not perform as well as mineral oils regarding the antioxidant performances.

This unsatisfactory oxidation stability of the new formulated lubricants limits their utilisation area to applications that do not need high oxidation stability performances such as air cooled two-cycle engine of moped, snowmobiles, agricultural and forestry machines or for applications such as sawmill blade or chain drive where the lubricants is used on a "once through" basis and where low toxicity biodegradable lubricants are required.

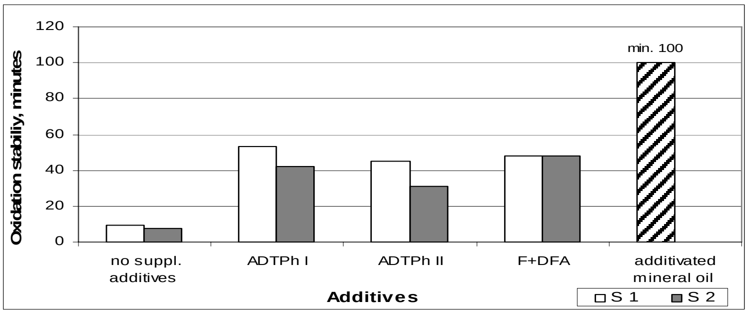

Figure 2. Results at Rotary bomb tests

For these types of applications, namely air cooled two-cycle engine it was formulated two new lubricants based on mixture of vegetable oil and mineral oil, a monograde lubricant suitable for summer use and a multigrade lubricant for all seasons, both at API TC performance level.

The complete characterisation of these new lubricants comparatively with conventional mineral-based lubricants is presented in table 5.

Table 5. The complete characterisation of final formulations

Characteristics	**Lubricating oil**				**Test methods**
	SAE 30 2T-BIO	**SAE 30 2T-mineral**	**SAE 5W/40 2T-BIO**	**SAE 15W/40 2T-mineral**	
Cinematic viscosity at 40°C, cSt	61,05	-	100,04	-	ASTM D-445
Cinematic viscosity at 100°C, cSt	10,4	9,4…12,5	16,6	14,0…16,0	ASTM D-445
Viscosity index	161	min. 90	179	min. 135	ASTM D-2270
Pour point, °C	- 18	max. -24	- 30	max. -30	ASTM D-97
Flash point, °C	260	min. 220	254	min. 210	ASTM D-92
Sulphated ash, %	0,72	max.1,10	0,70	max. 1,10	ASTM D-874
Total base number, mg KOH/g	6,20	min. 6,0	6,27	min. 6,0	ASTM D-2896
Foaming (tendency-stability), cm3: - seq. I - seq. II - seq. III	 10-0 40-0 0-0	 max. 10-0 max. 50-0 max. 10-0	 10-0 20-0 0-0	 max. 10-0 max. 50-0 max. 10-0	ASTM D-892
Dynamic viscosity at -15°C, mPa·s	-	-	3520	max. 7000	ASTM D-5293
Copper corrosion, 3 h at 100°C	1 b	1b	max. 1 b	max. 1 b	ASTM D-130
Biodegradability, %	64,1	29,7	64,2	28,4	CEC L 33-A 92

The final formulated lubricants was submitted to some preliminary tests on a special engine stands, type air cooled two cycle engine for moped to evaluate the behaviour in work conditions. After the tests, the engine presented clean pistons, proper condition for piston rings, functional spark plug and a registered power in admissible limits.

4. CONCLUSION

- Some of conventional additives designed for mineral oils can be used successfully for vegetable based lubricating oil formulations;
- The vegetable based lubricants shows superior lubricity properties and viscosity index, high flash point, appropriate pour points, cinematic viscosity and dynamic viscosity;
- Even with extra antioxidant additives and mixed with mineral oil, the new formulated lubricants based on vegetable oils do not perform as well as conventional oils regarding the antioxidant performances;
- This unsatisfactory oxidation stability of the new formulated lubricants limits their utilisation area to applications that do not need high oxidation stability performances and where low toxicity biodegradable lubricants are required;
- It was formulated two new biodegradable lubricants based on mixture of vegetable oil and mineral oil suitable for air cooled two-cycle engine that perform well at tests on a special engine stands;
- The new lubricants can be successfully used in application with high environmental risqué and moderate working conditions, such as: chain saws, other portable implements, sawmill blade, two stroke engines for moped, motorcycles, outboards (water cooled) and snowmobiles, any other applications where the lubricant is used on "once through" basis

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