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THE FULL OR PARTIAL REPLACEMENT OF MINERAL MARINE ENGINE OIL WITH VEGETABLE OIL, ON THE EXAMPLE OF RAPESEED OIL

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Abstract

The demand for petroleum products is increasing day by day, but mentioned products have limited sources and they are hazardous for environment. Therefore international organizations for example: International Maritime Organization, start to make restrictive requirements application petroleum products for safety environmental, what is the main reason of the use of the alternative liquids. One of the most popular environmental friendly, renewable and less toxic oils is vegetable oils. They can used as fuels and lubricants. The vegetable oils are mainly triglycerides, which contain three hydroxyl groups and long chain unsaturated free fatty acids attached at the hydroxyl group by ester linkages. They have good properties of lubricity, viscosity and thermal.

In this article focused only on lubricants. Among a wide group of vegetable oils chosen rapeseed oil. Rapeseed is the most important and most efficient oilseed crop in Europe and it is the most common basestocks for vegetable-based lubricants. It conducted research into pure rapeseed oil and its different quantity additives to traditional marine motor oil – Marinol RG 1240. The two basic physic-chemical parameters, they were flash point and dependence of viscosity and temperature, were compare and assess. It has been proven that vegetable oils have a higher ignition temperature than mineral oils and a smaller viscosity change in the range of temperature presented.

Keywords: *vegetable oil, rapeseed oil, engine oil, marine, mineral oil, lubricant, viscosity, flash point, environmental protection*

1. Introduction

The petroleum resources are diminishing rapidly and the rate of production from older domestic oil fields and decrease in the rate of finding new reserves are one of the main problems of the 21st century. Unfortunately, in the maritime industry, most of operating fluids are based on the use of petroleum products, especially in the case of fuels and lubricants. Petroleum products are poorly degradable and cause severe environmental hazards when released to environment [16]. The spilling of petroleum products causes negative changes in areas of the sea and they are danger for plants, animals and humans. On the other hand, the demand of fuels and lubricants are increasing tremendously which forces the industry to find more effective, biodegradable, less toxic sources [4, 17].

One of the alternatives to be explored it is use the oils from natural sources. Vegetable oils have a capability to contribute towards the goal of energy independence and security since they are a renewable resource. Vegetable oils with high oleic content are considered to be potential candidates as substitutes for conventional petroleum products and synthetic [4]. In the fuel, industry has been talk for a long time about use Biofuels [3, 8, 15]. It is also possible to replace traditional engine mineral oil on vegetable oil [10, 16]. In the article, the author draws attention to marine engines, which have a very high demand for lubricating oils. It compares two important properties of lubricating oil: the flash point and viscosity of traditional Marinol RG 1240 marine motor oil with rapeseed oil and their blends.

2. Vegetable oils

The vegetable oils also called green oils or natural esters. They are mainly triglycerides, which contain three hydroxyl groups and long chain unsaturated free fatty acids attached at the hydroxyl group by ester linkages [5, 18]. These triglycerides molecules in vegetable oils orient themselves with the polar end at the solid surface making a closed packed monomolecular or multi-molecular layer resulting in a surface film that provides desirable qualities in a lubricant [1, 2].

The content of unsaturated free fatty including to green oil of various origins varies within quite wide limits [20]:

- for oleic acid esters ($C_{18}H_{34}O_2$) 14 – 86%,
- for linoleic acid esters ($C_{18}H_{32}O_2$) 4 – 75%,
- for linolenic acid esters ($C_{18}H_{30}O_2$) 0 – 54%.

Thanks to the wide content of unsaturated free acids, it is possible to adapt vegetable oils to be used as substitutes for mineral oils in the production of lubricants, by means of genetic engineering (regulation of plants cultivation) or chemical modification [20]. The others advantages of green oils as lubricants are [4, 17]:

- non-toxic,
- biodegradable,
- include very low volatility due to the high molecular weight of the triglyceride molecule,
- excellent temperature – viscosity properties,
- good lubricity, because their polar ester groups are able to adhere to metal surfaces, and therefore,
- have high solubilizing power for polar contaminants and additive molecules.

The vegetable oils can derived from very different natural source, for example: sunflower, rapeseed, palm oil, coconut, peanuts, olive, grape seed etc. The Tab. 1 shows several type of vegetable-based lubricants developed for industry applications.

Tab. 1. Several type of vegetable-based lubricants developed for industry applications [19]

Type of oil	Application
Canola oil	Hydraulic oils, tractor transmission fluids, metalworking fluids, food grade lubes, penetrating oils, chain bar lubes
Castrol oil	Gear lubricants, greases
Coconut oil	Gas engine oils
Olive oil	Automotive lubricants
Palm oil	Rolling lubricant,-steel industry, grease
Rapeseed oil	Chain saw bar lubricants, air compressor-farm equipment, Biodegradable greases
Safflower oil	Light-coloured paints, diesel fuel, resins, enamels
Linseed oil	Coating, paints, lacquers, varnishes, stains
Soybean oil	Lubricants, biodiesel fuel, metal casting/working, printing inks, paints, coatings, soaps, shampoos, detergents, pesticides, disinfectants, plasticisers, hydraulic oil
Jojoba oil	Grease, cosmetic industry, lubricant applications
Crambe oil	Grease, intermediate chemicals, surfactants
Sunflower oil	Grease, diesel fuel substitutes
Cuphea oil	Cosmetics and motor oil
Tallow oil	Steam cylinder oils, soaps, cosmetics, lubricants, plastics

Unfortunately, on the other hand, vegetable oils have couple of drawbacks: poor oxidative stability, which causes insoluble deposits and increases in oil acidity and viscosity [6], poor corrosion protection [14], susceptibility to hydrolytic breakdown, at low temperature ($< -10°C$) undergo cloudiness, precipitation, poor flow, and solidification [4], gumming effect [17].

The green oils can used as only oil-base or much more common practice as additives to mineral or synthetic oil. The blends mineral – vegetable are very interesting issue.

3. Samples oil

The research was conducted using samples of mineral oil – Marinol RG 1240, vegetable oil – rapeseed oil "Kujawski" and blends of them. The describes all oil samples are shown in Tab. 2.

Tab. 2. Composition of tested oils

Samples	Composition
Sample 1	100% mineral oil – Marinol RG 1240
Sample 2	100% vegetable oil – rapeseed oil
Sample 3	5% – rapeseed oil and 95% Marinol RG 1240
Sample 4	10% – rapeseed oil and 90% Marinol RG 1240
Sample 5	25% – rapeseed oil and 75% Marinol RG 1240
Sample 6	50% – rapeseed oil and 50% Marinol RG 1240

Marine motor oil Marinol RG 1240 is TPEO (*Trunk Piston Engine Oil*) and it is designed for lubrication of marine anhydride light fuel engines. It is formulated on the base of deeply refined, solvent dewaxed and hydrorefined oil distillates received from crude oil. They contain a properly selected package of washing and dispersing additives as well as auto-oxidising, anticorrosion, antirust and anti-wear attributes. Parameters Marinol presents in Tab. 3. The oil fulfils the API CD requirements (*American Petroleum Institute*, category CD) for marine engines [21].

Tab. 3. Parameters of engine oil – MARINOL RG 1240 [9]

No.	Requirements	Research methods by	Unit	RG 1240
1	Kinematic viscosity at 100°C	ASTM D-445	mm^2/s	14.3
2	Pour point	ASTM D-5950	°C	-24
3	Flash point	PN-EN ISO 2592	°C	260
4	Base number	ASTM D-2896	mgKOH/g	12.5
5	Viscosity index	ASTM D-270		96
6	Corrosion effect at 100°C, 3h, Cu	PN-EN ISO 2160 ASTM D-130	degree	1

The author choose from among a large group of vegetable oils – rapeseed oil. Rapeseed is the most important and most efficient oilseed crop in Europe and it is the most common basestocks for vegetable-based lubricants. It is obtained by pressing the rapeseed [8]. The polar nature of rapeseed oil makes good lubricants, as they readily fasten to metal surfaces. The triglyceride structure gives these esters a high natural viscosity and viscosity index [9]. The several parameters of rapeseed oil presents in Tab. 4.

Tab. 4. Parameters of vegetable oil – rapeseed oil [8, 10]

No.	Requirements	Research methods by	Unit	RG 1240
1	Kinematic viscosity at 100°C	PN-EN ISO 3104:2004	mm^2/s	7.5
2	Pour point	ASTM D-5950	°C	-20
3	Flash point		°C	> 300
5	Viscosity index	PN-ISO 2909:2009		192
6	Composition		C,% H,% O,% S,%	77.6 11.7 10.5 0

During conducted researches notice, that blends of Marinol RG 1240 and rapeseed oil were durable oil mixtures that did not stratify in time.

4. Experiment

The aim of this work was to compare and to assess two basic physio-chemical parameters: flash point and dependence of viscosity and temperature of oil Marinol RG 1240, rapeseed oil and them blends.

- The **flash point** gives an indication of the presence of volatile components in the oil and it is the temperature which oil must reach under specified test conditions to give off sufficient vapour to form a flammable mixture with air [7],
- The **viscosity** of a fluid is a measure of its resistance to flow. It is the measure of internal friction in a fluid, which acts as a resistance to change of molecule position in moving fluid exposed to shear stress [11, 12]. Viscosity is one of the most significant properties of any engine oil because the lubrication quality during mixed friction as well as the opportunity to create and maintain hydrodynamic conditions for fluid friction depends on it. Indirectly, it influences efficiency, durability, reliability of engine. Viscosity decreases significantly while the temperature rises [13].

4.1. Flash point measurement

To conduct the measurement, researcher used the ERAFLASH device, which uses the closed-cup method. The temperature measuring range of device lies between – 25°C and + 420°C. The ignition in the apparatus starts from electric arc and the measure of ignition is the increase of exhaust gasses pressure. The results of the flash point test are shown in Tab. 5.

Tab. 5. Test results of flash point

Samples	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Flash point [ºC]	232.1	292	237.2	247.8	248.7	254.9

The flash point for Marinol RG 1240 measurement by close-cup method is equal 232.1 degrees Celsius. The vegetable oils have the higher value of mentioned temperature, for pure rapeseed oil it is 292 degrees Celsius. For subsequent oil blends, the flash point increases and for last sample with 50% addition of rapeseed oil it is 254.9ºC (22.8ºC increase over Marinol RG 1240). During exploitation the flash point of engine oil decrease, due to fuel leaks. The operators can use this property of vegetable oil, to refreshment of oil in lubricating system to avoid excessive fall the flash point. The addition only of 5% rapeseed oil increases the temperature by more than 5 degrees.

On the based on this flash point, the possibility of forming explosive oil vapour-air mixtures is assessed. Higher its value means safer work.

4.2. Oil viscosity measurement

To test the dependence of viscosity and temperature at 5 to 65ºC range, researchers used the Vibro Viscometer SV 10 (see Fig. 1). The device has 2 thin sensor plates that are driven with electromagnetic force at the same frequency by vibrating at constant sine-wave vibration in reverse phase like a tuning fork. Vibro Viscometer can measurement from very low to high dynamic viscosity in the range 0.3-1000 mPas.

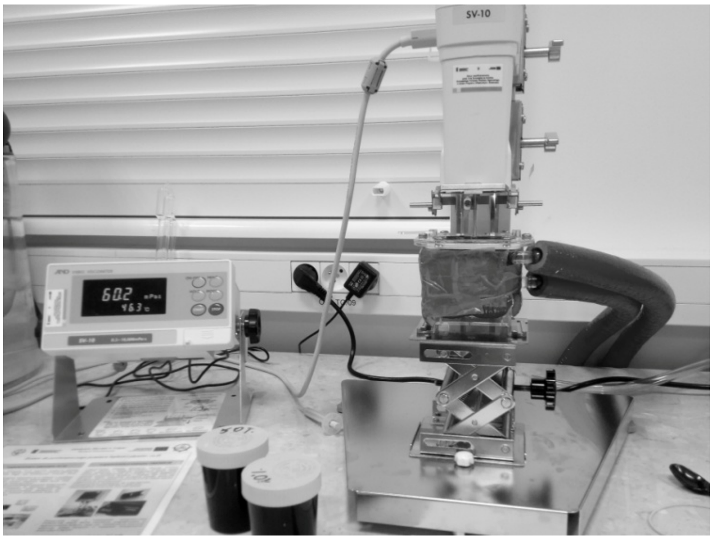

Fig. 1. The Vibro Viscometer SV 10

Motor oil Marinol RG 1240, rapeseed oil and all blends operate as typical liquids and in all tested samples the viscosity decreases while the temperature rises at completely tested range (Fig. 2).

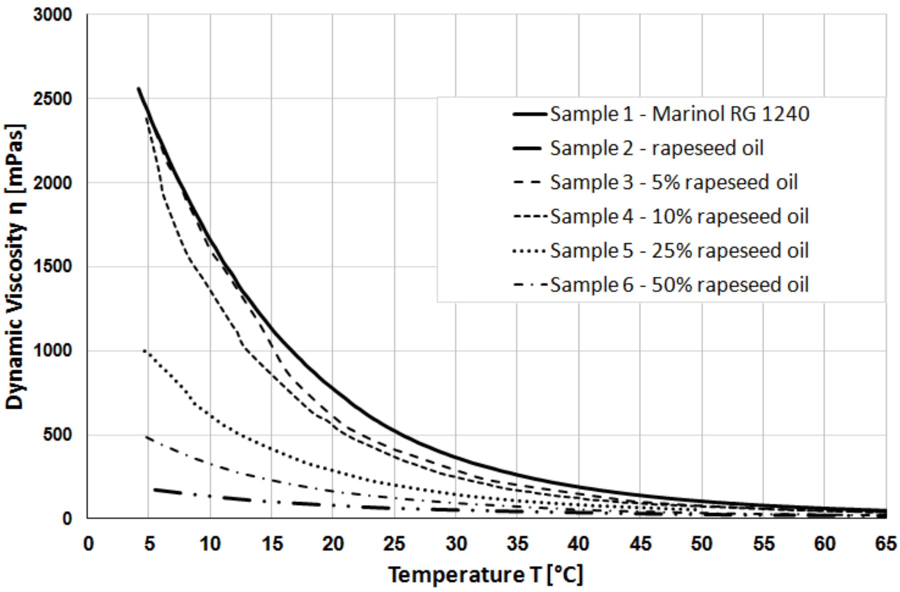

Fig. 2. Graph of viscosity-temperature changes for all samples

The results can also be presented on a more interesting graph that shows curves of characteristic temperatures i.e.: 5°C, 10°C, 20°C, 40°C and 60°C. This approach allows determining precise differences between samples (see Fig. 3).

The very important property of vegetable oil it is smaller viscosity change in the range of temperature presented (between 5°C and 60°C, Fig. 3), for Marinol RG 1240 this change is equal 2361.3 degrees, however for rapeseed oil it is only 158.9 degrees. The effect is also visible on Fig. 2, where characteristic of Marinol RG 1240 have exponential decrease, but curve of rapeseed oil is linear. This behaviour is transferred to all blends, so in samples 3, 4, 5 and 6, the change of viscosity in temperature range investigated decreases along with content of rapeseed oil. For sample with 5 and 10 percent of rapeseed oil, this change is little, because respectively 2349.8 and 2331.9 degrees. However, for sample with 25 and 50 percent of rapeseed oil, this effect is particularly noticeable, change of viscosity is very high over mineral oil, respectively 959 and

430.1 degrees. The insignificant impact of the plant additives up to 10% can be used economically. Engine operators can make small refills of lubricating system with vegetable oils without worrying about its influence on the of mineral oil viscosity.

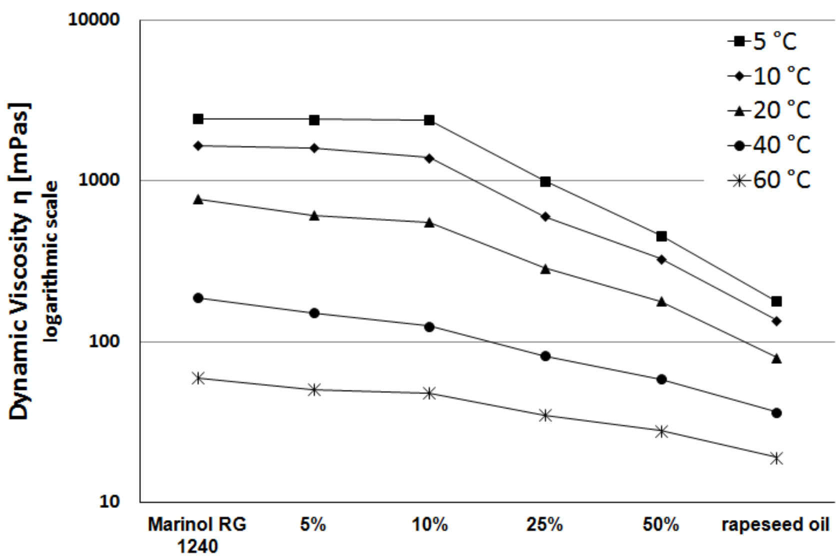

Fig. 3. The curves of characteristic temperatures i.e.: 5°C, 10°C, 20°C, 40°C and 60°C for all samples

5. Conclusion

Today, clean energy is emerging as a new trend in industry, especially marine industry. There is a lot of new source, which can replace traditional petroleum products. The one of them are vegetable oils, which are preferred as operating liquids in fuel and lubricating systems. The vegetable oils have eco-friendly features, they are highly biodegradable, less toxic and renewable and their popular as fuels and lubricants grow in industry due to provide a safe work. Moreover, this due to the ability of the vegetable oils to adsorbed on the surface and forms a layer, with polar head adhering to the surface, provide good features of lubricity.

During the researches, it shown that have very good viscosity index and thermal stability compared mineral oil-base. The viscosity decreases with increase in temperature like in conventionally mineral oil. Furthermore, the change of viscosity with temperature is less for green oils. The important thermal property is flash point, which is higher for rapeseed oil. Therefore, it is possible to provide safer work for devices and operators.

Unfortunately, green oils have disadvantages, for examples they can react with oxygen to form undesirable products like aldehydes and ketones, which reduces the lubricant properties, poor corrosion protection, susceptibility to hydrolytic breakdown, gumming effect etc. However, it is possible improved by chemical modification like epoxidation, hydrogenation and adding antioxidants.

In the next step of the measurements, it is planned to check other parameters of rapeseed oil and its blends with mineral oil, i.e.: total base number, pour point, content of trace elements etc. Then study other vegetable oils, such as sunflower, coconut, peanut, grape seed, olive and select the one that best will fulfils the task of marine engine oil.

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