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TRIBOLOGICAL PROPERTIES OF VEGETABLE AND MINERAL OILS

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Abstract: *As a result of the increasing environmental pollution and reduction of crude oil reserves, has intensified the development of environmentally friendly lubricants. Environmentally friendly lubricants are rapidly biodegradable and non-toxic to living organisms. The most important raw materials for the formulation of environmentally friendly lubricants are vegetable oils.*
Vegetable oils are triglycerides that make up the complex mixture of fatty acids with different chain length and number of double bonds. Triglycerides are rapidly biodegradable and have excellent lubricity properties. Advantages of vegetable oils compared to mineral are reflected in the following characteristics: toxicity, rapid biodegradability, good lubricity, high flash point, high viscosity index and low volatility. Disadvantages of vegetable oils compared to mineral are: poor oxidative stability, poor flow ability at low temperatures and poor hydrolytic stability that limits their application.
The paper presents the tribological properties of vegetable oils, which was compared with the tribological properties of mineral oil.

Keywords: *environmentally friendly lubricants, vegetable oil, biodegradable oil, tribological characteristics, wear*

1. INDRODUCTION

The louder and more justified environmental requirements for the protection of the environment causes introduction of increasingly stringent requirements, rules and regulations. The two main aspects: saving and preservation of non-renewable resources and reduce the harmful effect of lubricants on the environment are core tasks. All these issues have increased public awareness and environmental conscience for the development of environmentally friendly lubricants. Terms of the environmental acceptability are biodegradability and non-toxicity lubricants. The most important raw materials for the formulation of environmentally friendly lubricants are vegetable oils, which, in addition to biodegradability and non-toxicity, is a renewable resource. Research suggests that vegetable oils have advantages and disadvantages in relation to the mineral.

Vegetable oils have a great advantage over mineral because they are non-toxic, biodegradable, less polluting, and they are particularly interesting because they are made from renewable raw materials. Besides that, they provide lower consumption due to the lower loss by evaporation, a better lubricating properties, higher viscosity index, higher resistance to fire because higher flash temperature, a higher solubility for additives and oxidation products.

The disadvantages of vegetable oils, comparing with a mineral are: they are less thermally stable, in the presence of moisture are susceptible to hydrolysis forming corrosive acids, have a considerably higher pour point and a much greater tendency to foam, and have a shorter shelf-life and period of use.

With high probability it can be supposed that in the near future environmental requirements further increase and intensify. The direct and important role of tribology is the development of environmentally friendly lubricants. In this complex and long process tribology plays a very important role and can not be, as until now, considered a science or profession which deals with the reduction of friction and better lubrication.

2. EXPERIMENTS

2.1 Preparation of sample

Tests should show the difference that exists between the mineral and vegetable base oils in terms of their tribological properties, and their ability to additive. As a mineral oil was taken SN 150 base oil, which is used for the production of mineral lubricants. This mineral base oil will be in the following text labeled as MIN 30, and has a viscosity that is comparable to the viscosity grades of vegetable oil from the rapeseed which is labeled as REP 30. Physico-chemical characteristics of MIN 30, and the REP 30 are shown in Table 1, and physico-chemical characteristics of anti-wear additive in table 2, and the additive for extreme pressures in table 3. These additives are conventional and they use in the production of mineral lubricant.

Table 1. Physico-chemical properties of vegetable oils used in the experiment

Phisicalchemical characteristics	Unit	MIN 30	REP 30	Metods
Density at 20^{0}C	g/cm^3	0,89	0,92	ISO 3675
Kinematic viscosity, 40^{0}C	mm^2/s	29,15	34,07	ISO 3104
Kinematic viscosity, 100^{0}C	mm^2/s	5,3	7,84	ISO 3104
Index viscosity		98	213	ISO 2909
Flash point	^{0}C	207	322	ISO 2952
Pour point	^{0}C	- 15	-8	ISO 3016
Neutralisation number	mgKOH /g	0,007	0,3	ISO 6618

Table 2. Physicochemical properties of AW additives used in the experiment

Characteristics	Unit	AW additives	Metods
Density at 15^{0}C	g/cm^3	0,930	ISO 3675
Kinematic viscosity, 40^{0}C	mm^2/s	45,0	ISO 3104
Kinematic viscosity, 100^{0}C	mm^2/s	8,3	ISO 3104
Flash point	^{0}C	180	ISO 2952
Zink content	% w/w	4.5	ASTM D4628

Table 3. Physico-chemical properties of EP additives used in the experiment

Characteristics	Unit	EP additives	Metods
Density at 15^{0}C	g/cm^3	1,036	ISO 3675
Kinematic viscosity, 40^{0}C	mm^2/s	42,0	ISO 3104
Kinematic viscosity, 100^{0}C	mm^2/s	6,3	ISO 3104
Flash point	^{0}C	70	ISO 2952
Sulfur content	%w/w	30	ISO 8754
Phosphorus content	%w/w	0.5	ASTM D4628

Anti-wear (AW) additives

For protection metal surfaces, which are in contact, from wear occuring under conditions of moderate temperature and pressures standard anti-wear additives is used (Zinc alkyldithiophosphate). These are polar materials that form a film on the metal surface, wherein the polar ends directed at right angles to the metal surface, and which together make a more or less strong adhesive joint, Figure 1. The film formed between the metal surfaces reduces friction and provide metal to relatively easily slide one after the other. These additives act only under mild conditions of loading and temperature conditions.

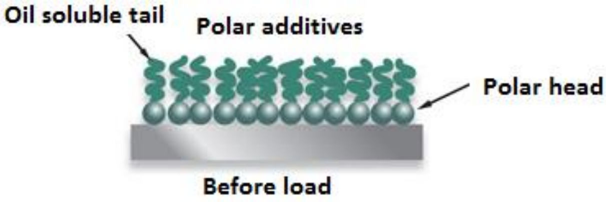


Figure 1. Polar additive

Additive for improving the capability of resistance to the extreme pressure (EP additives)

Due to the extreme pressures and shock loads in particular of gear transmissions, it happens the interrupt of oil layer. In that case, there is the danger that in touch points of gears happens destructive friction and wear and because of the high temperatures, which develops in the contact zone, welding metal surfaces is happening. In order to prevent that, an additive for improvement the capability to resistance the extreme pressures (Phosphoric acid esters / amine salt) is added.

In condition of shock loads and extreme pressures this additive chemically reacts with the metal surface and builds a solid compound with high shear stability than of the metal, Figure 2.

This compound effectively performs the function of a solid lubricant and prevents the destructive friction and welding of contact surfaces of gear until new a layer of oil is form, that is a boundary lubrication.

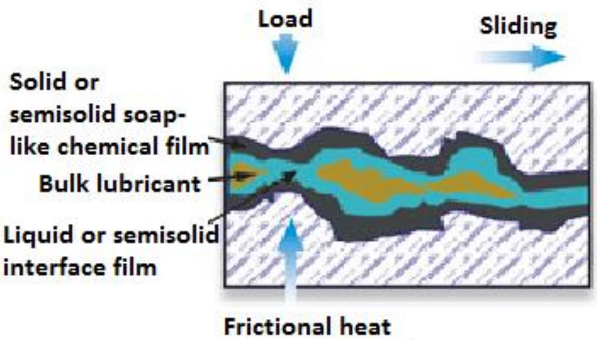


Figure 2. EP additive

2.2 Equipment and test methods

Antiwear properties (Four Ball Wear Test)

The test of wear resistance is done by the standard method ASTM D4172. This test show the efficiency of protection against wear, and it is used for determining the resistance to load of lubricating film in the mixed and mild boundary lubrication conditions. Basic test element consists of four balls that are in the form of a regular tetrahedron immersed in test oil. The three are beads in the carrier and fastened by a ring and immersed in oil. Fourth ball is attached with handle, which along with it, rotates around a vertical axis with 1,500 rpm, Figure 3. The load of 40 kg is transmitted through the upper rotating balls evenly on three immovable balls. Test duration was 60 minutes at a temperature of 65ºC. At the end of test, diameter of worn surfaces (which is dome-shaped) of immovable three balls is measured, and the result is expressed as the average wear diameter in mm.
Wear of ball directly indicates the load resistance of the lubricating film. As the value of the mean diameter is smaller, resistance of the lubricating film is higher and inversely.

Figure 3. Four ball tests

Extreme pressures properties (Four Ball Extreme Pressure Test)

Testing the ability to resistance extreme pressures is done according to the standard method ASTM D 2783, a device with four balls. The difference from the previous wear test is that the load are gradually increased until scuffing or welding balls, Figure 4.

EP-device with four ball is used to determine the load that may be carrying by lubricants, or the strength of lubricants film in the boundary conditions of lubrication (EP properties). The basic test element consists of four balls that are in the form of a regular tetrahedron immersed in oil which is tested. Upper ball rotates at a constant speed around a vertical axis, touching the other three balls which are fastened to the base of the tetrahedron. With specific load of balls, the test takes 10 seconds. The load is increased until balls do weld. Load at which the ball is welded is expressed as the welding point and it is expressed in Newton (N). As the value of the point of welding is greater, greater is the strength of lubricating film.

Figure 4. Appearance of weld balls

2.3 Test results and explanations

Results of mesurements of testing samples

Measured values which were obtained in a device with four balls for rapeseed (REP 30) and mineral oil (30 MIN) are located in tables 4 and 5.

Table 4. Resistance to wear

Treat level of additives (%w/w)	REP 30 (mm)	MIN 30 (mm)
0,0	0,68	0,80
0,5	0,66	0,67
1,0	0,62	0,50
1,5	0,60	0,42
2,0	0,58	0,34
2,5	0,58	0,33

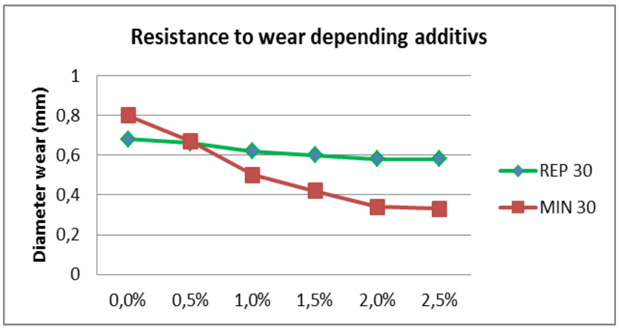
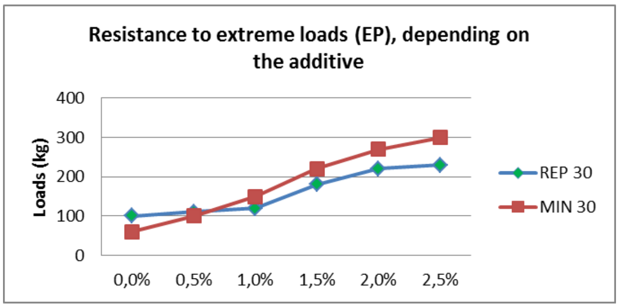


Figure 5. Resistance to wear

Tabela 5. Capability to resistance to extremely high pressures

Treat level of additives (%w/w)	REP 30 (N)	MIN 30 (N)
0,0	100	60
0,5	110	100
1,0	120	150
1,5	180	220
2,0	220	270
2,5	230	300



Slika 6. Resistance to load EP

Results and Discussion

The research results showed the following observations:

- Vegetable oil has a better natural anti-wear characteristics and a better ability to resistance the extreme pressures and high loads compared to mineral base oils.
- By Adding of AW and EP additives improves the corresponding characteristics of the anti wear and the extreme pressures and high loads carrying capabilities of the tested vegetable and mineral oils.
- By Adding AW and EP additive has greater effect on the enhancement of mineral oil compared to vegetable oil. The same

percentage of the additive effectively improves wear characteristics of the mineral oil comparing to the vegetable oil, Figure 5. In the same way, the same percentage of the additive more effectively improves the mineral oil characteristic of high pressure carrying than comparing to the vegetable oil, as shown in Figure 6.

3. CONCLUSION

From the present research, it can be concluded that, although vegetable oils have better natural characteristics of the load carrying and anti-wear, they are less susceptible to additive compared to mineral oils. This could be explained by the different chemical structure of vegetable oils compared with mineral and because different mechanism of interaction with the additives that are designed to mineral base oils.

Vegetable oils can reach a much better performance by using additives that are intended for vegetable oils. The best known manufacturers have been developing additives and they already can offer efficient additives intended to improve the characteristics of vegetable oils that are increasingly in use.

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