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# LUBRICATE PROPERTIES OF BIO-FUELS

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**Summary**. The paper presents selected results of research on the wear of metal elements of a diesel engine fuel supply system operating on green bio-mass fuels. The tests were conducted on a original test rig using a new methodology. Several bio-fuels were tested, including rapeseed oil and various mixtures of rapeseed oil and the standard diesel oil. BIODIESEL oil, rapeseed oil esters (FAME) and various blends of the esters and the standard diesel fuel (including commercially available blends) were also tested. The test results show significant differences in lubricating properties of bio-fuels.

**Key words:** abrasive wear, testing facility, bio-fuels, vegetable oils, esters

## INTRODUCTION

Today, alternative fuels, such as vegetable oils are not just increasingly fashionable, but are also more commonly used as a power source for Diesel engines. This is connected with the rise of oil prices. The objective of the research was to determine whether the use of pure vegetable oils and blends of rapeseed oil, which because of its price is the most common in Poland, may cause premature wear of the fuel injection system elements. Some other vegetable oils cheaper than 10 zł/dm$^3$ were also taken into consideration. The values of friction factors that could influence the proper work of this system were determined as well. The alternative fuel tests described in the paper were conducted on a original test rig as a part of a research project, carried out between 2004 and 2006.

Generally, a HFRR (High Frequency Reciprocating Rig) method (at the temperature of 60ºC) is used to test properties of lubricant fuels for Diesel engines. In the test, high frequency horizontal vibrations are applied to a 6mm steel ball, loaded from the above, which is placed on a stable steel plate and dipped in the tested fuel. Then, the diameter of the resulting ball defect (wear scar) is measured. The maximum diameter of this scar for Diesel fuels should not be higher than 450 μm. According to the technical specifications of the several fuels tested, it was approximately 390 μm. For esters and their blends (FAME content 30%), according to [Kowalski 2006], it is below 200 μm. Similarly, for ready bio-diesel blends, sold at petrol stations (FAME content about 20%), the diameter of the scar measured by normative method is 163–175 μm, as specified by the producers. In the tests described here and those carried out by the author earlier on a simpler facility [Gardyński and Kiernicki 2002], the results were reverse, showing esters at a disadvantage. It poses a question whether the used normative method is right, considering that in [Kowalski 2006] it is suggested that adding an amount of gasoline to Diesel fuel increases its lubricity as determined by this method.

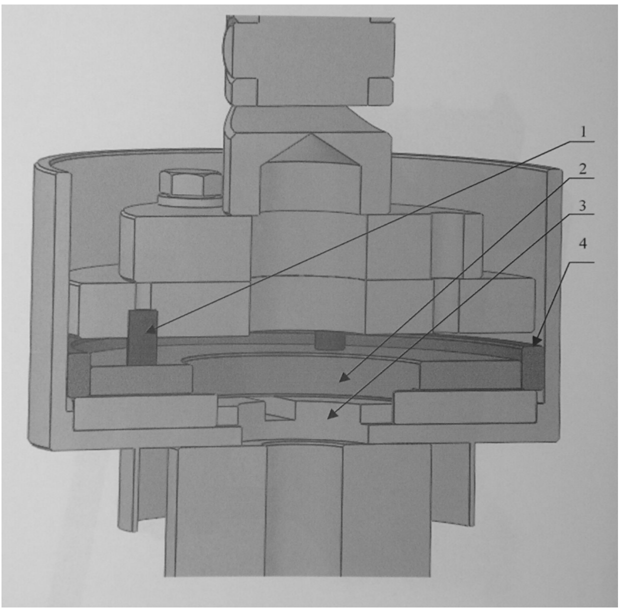


Fig. 1. The test rig used in the research 1 – specimen, 2 – co-specimen, 3 – overflow opening, 4 – spacer

## DESCRIPTION AND THE RESULTS OF THE RESEARCH

The tests were performed on six types of refined vegetable oils and rapeseed oil of unknown origin, most probably pressed, delivered by a private person to determine whether it would be suitable for fuel.

The results for vegetable oils are shown in Table 1. For more detailed description of the test procedure, please refer to [Gardyński 2006]. The results of wear resistance and friction coefficient for tested blends of rapeseed oil refined with diesel fuel are shown in Table 2. Table 3 presents the results of the tests of 3 ready-made blends of a BIO-DIESEL type and three samples of pure esters, produced by Trzebina refinery and by Józef Sawa from the Department of Process Engineering, Lublin University of Technology.

Each test set consisted of a friction test of front surface (slightly conical ring of 5 and 2,5 mm in diameter) of three samples against rotating flat counter sample. The samples were placed symmetrically on a 61,5 mm circle and a steady pressure of 2943 N (300 kg) was applied. During the test, the counter sample rotated 100 thousand times within about 11 hours. The samples and counter samples were made of bearing steel ŁH15SG, which is often used in injection system elements, for example in sprayer bodies and pump pistons. Rollers of conical bearing were used as a sample, whereas a flat surface of thrust (axial) bearing raceway was used as a counter sample. The hardness of the elements was about 65 HRC. The tested fuel (in an amount of not less than 1 $dm^3$, normally 5 $dm^3$ or 30 $dm^3$) circulated in a closed circuit, where it was filtered in a paper filter and stabilised thermally. A stable temperature of 60±2ºC was maintained in the test rig. The conditions in which the test was conducted were a result of a compromise between the tendency of some fuels to seize up the samples and the possibility to get the maximum wear in repeatable conditions and the real time of the test. The test, according to the author, can be called a durability test considering the time and the friction distance of three samples of more than 60 km. These testing conditions were approximated during earlier research [Gardyński and Kiernicki 2002] conducted on a much simpler facility. In the research documented in [Gardyński and Kiernicki 2002], a small amount of unfiltered fuel was tested in a similar way at changeable temperature determined by friction and thermal properties of the facility. Additionally, a viscometer was used to measure viscosity ($^oE$) of the tested fuel at the test temperature.

Sample wear was determined by means of a weight method. Three samples were weighed together on scales of 0.0001 g precision. Because the last digit of the scales reading was difficult to determine, due to the minimal weight loss of the test samples, a summary area of wear thread was measured, which made it possible to calculate the final value of unit pressure for each test. The area of the wear thread was also used to calculate the diameter of the wear scar.

Table. 1. Friction and specimen wear parameters for the vegetable oils tested. All tests at temperature 60ºC.

| Tested oil | Sunflower | Soya | Rice | Peanut | Corn | Rapeseed |
|---|---|---|---|---|---|---|
| Test specimen mass loss, g | 0.0011 | 0.0000 | 0.0006 | 0.0001 | 0.0007 | 0.0010 |
| Area of the wear thread, $mm^2$ | 14.46 | 6.23 | 10.42 | 9.51 | 11.73 | 11.62 |
| Diameter of the equivalent wear scar, mm | 4.29 | 2.82 | 3.64 | 3.48 | 3.86 | 3.85 |
| Final pressure, MPa | 204 | 472 | 282 | 309 | 251 | 253 |
| Average value of friction coefficient | 0.072 | 0.068 | 0.065 | 0.063 | 0.070 | 0.076 |

Table 2. Values of friction and specimen wear parameters as functions of the amount of rapeseed oil in a blend with diesel fuel (at temperature 60ºC).

| Composition Rapeseed oil (OR) /Diesel fuel (ON) | relative viscosity at 60ºC, $^0E$ | Specimen weight loss, g | Area of the wear thread, $mm^2$ | Diameter of the equivalent wear scar, mm | Final pressure, MPa | Friction coefficient |
|---|---|---|---|---|---|---|
| 100% OR/0% ON | 2.84 | 0.0010 | 11.62 | 3.85 | 253 | 0.076 |
| 80% OR/20% ON | 2.16 | 0.0015 | 14.69 | 4.32 | 200 | 0.079 |
| 60% OR/40% ON | 1.85 | 0.0019 | 16.15 | 4.53 | 182 | 0.084 |
| 40% OR/60% ON | 1.43 | 0.0020 | 15.80 | 4.49 | 186 | 0.087 |
| 20% OR/80% ON | 1.24 | 0.0022 | 16.15 | 4.53 | 182 | 0.096 |
| 0% OR/100% ON | 1.11 | 0.0010 | 15.03 | 4.37 | 196 | 0.104 |

Tabela 3. Test results for BIODIESEL oils and pure esters

| Tested fuel | Diameter of wear scar (HFRR), µm | Weight loss, g | Area of the wear thread, $mm^2$ | Diameter of the equiva-lent wear scar, mm | Final pressure, MPa | Friction coefficient |
|---|---|---|---|---|---|---|
| BIODIESEL I (ŚWIDNIK) | 175 | 0.0052 | 30.36 | 6.22 | 97 | 0.095 |
| BIODIESEL II (LUBLIN) | 163 | 0.0022 | 14.64 | 4.32 | 201 | 0.102 |
| BIODIESEL III (TRZEBINIA) | 175 | 0.0029 | 18.78 | 4.89 | 163 | 0.101 |
| ESTER I (Trzebinia) | ? | 0.0049 | 23.02 | 5.41 | 129 | 0.082 |
| ESTER II (Politechnika 1) | ? | 0.0049 | 25.78 | 5.73 | 114 | 0.089 |
| ESTER III (Politechnika 2) | ? | 0.0036 | 22.47 | 5.35 | 131 | 0.101 |

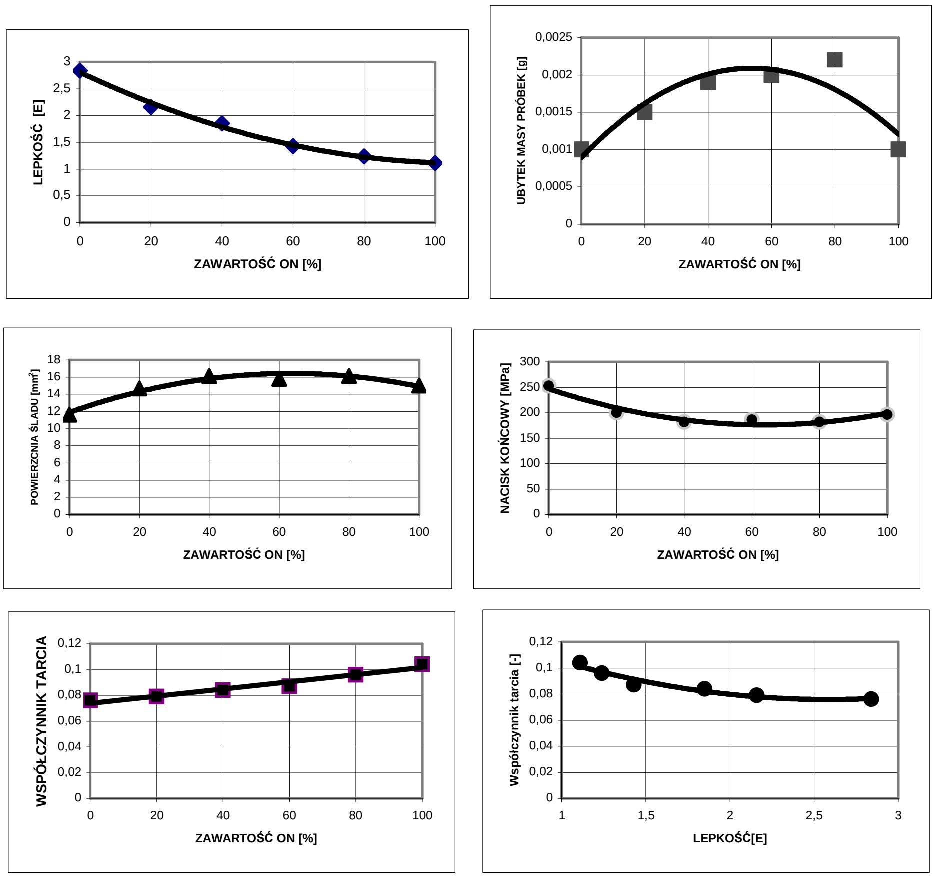


Fig. 2. Test results for BIODIESEL oils and pure esters

## CONCLUSION

The refined vegetable oils used in the research do not increase the wear of the lubricated elements in conditions in which they were tested.

In case of soya oil, no loss in the specimen mass has been observed, which makes this type of oil especially useful. Soya oil was found to transmit the highest unit pressures comparing to all the oils tested. The price of the soya oil is comparable to the standard diesel oil today.

Pure rapeseed oil performs similarly to standard diesel oil at 60ºC. The abrasive properties of both oils are similar but the rape oil has lower friction coefficient. At higher temperatures like the range typical for the fuel injection system, as the results from previous tests show [Gardyński, Kiernicki 2002], the rapeseed oil may have worse lubricative properties than the diesel oil.

The blends of rapeseed oil and Diesel fuel showed a slightly increased tendency to wear the test specimens loosely related to the composition of the blend. The friction coefficient was found to be strongly related to the relative amount of the rapeseed oil in the blend.

Increased wear of the test specimens was observed in the tests of pure methyl ester of rapeseed oil and fuels that contained that ester. The result is contradictory to the HFRR test results and the data published in the literature.

The original test method used for testing seems to be a good, repetitive procedure that can be used to compare properties of a wide range of fuels and lubricants. The test can be considered as a durability test.

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