Omer Kovač, Danka Šikuljak, Tamara Evđić, Jadranka Vujica

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THE INFLUENCE OF BIODIESEL ON ENGINE OIL PROPERTIES WHEN CONDUCTING HIGH-TEMPERATURE ENGINE TEST

Abstract
As renewable and alternative fuel, biodiesel is in the last 15 years the subject of numerous studies, including the research of the influence on engine performances and engine oils. Usage of biodiesel has a number of advantages, however in its application, biodiesel shows also some deficiencies. The application of biodiesel leads to its accumulation in the oil, and thus to the dilution of the oil. Excessive dilution of oil can create problems in the engine operation. Accumulation of biodiesel in the oil leads to oil viscosity fall, formation of oxidation products, deposits and deterioration of low-temperature properties. In this study the influence of biodiesel on the quality of engine oil when conducting high-temperature engine test has been monitored. For this test engine oil of SAE 15W-40 viscosity grade was used. Tested engine oil fulfills quality requirements of leading engine manufacturers, such as: MB, MAN, Volvo. During the test, the engine was run on mixture of diesel and biodiesel.
Key words: biodiesel, engine test, engine oil, oxidation, corrosion.

1. Introduction

High global interest in fuels produced from renewable resources encourages a numerous studies and usage of biodiesel as one of alternative fuels. In addition to reducing dependence on fossil fuels, an important aspect of usage of biodiesel is environmental protection. Compared to fossil diesel, biodiesel burns cleaner, has higher cetane number, contains no aromatics and contributes to reducing of environmental pollution. It is derived from triglycerides by transesterification, i.e. by chemical reaction of triglycerides from vegetable oils and animal fats with methanol in the presence of catalyst [1,2]. However, when talking about the usage of biodiesel there are still numerous limitations. Besides its advantages biodiesel shows a negative impact on engine and engine oil. As regards the effect of biodiesel on engine performances and engine oil, its main downsides are incompatibility with certain materials, tendency to form deposits in injector nozzles, causing of corrosion, etc. When using biodiesel at concentrations below 20% the effect of above mentioned occurrences is significantly reduced.

Due to its properties, it has a tendency to accumulate in the crankcase leading to dilution of engine oil. Oxidation processes which occur due to the presence of biodiesel in oil lead to deposits build-up and cause corrosion of non-ferrous metals [3-5].

The aim of this study is to determine the negative impact of biodiesel on the quality of engine oil when conducting engine test under real operating conditions. In addition, the results will be compared with those obtained by laboratory test of biodiesel corrosivity according test method ASTM D 6594, whose results were expressed through measured concentrations of cooper, lead and tin in engine oil.

2. Experimental part

2.1. Methods and materials

Engine oil

For determination of influence of biodiesel on engine oil, when performing high-temperature engine test, engine oil with the main characteristics shown in Table 1 was used.

Table 1: Quality level and properties of tested engine oil

ENGINE OIL			
Quality level			API CI-4/CF/SL; ACEA E7/E5/E3/A3/B4; MB 228.3/229.1; MAN 3275-1; VDS-3
Viscosity grade			SAE 15W-40
Characteristics	Method	Unit	
Viscosity at 100 °C	BAS ISO 3104	mm^2/s	14.76
Viscosity index	BAS ISO 2909	-	147
Density at 15 °C	ASTM D 5002	kg/m^3	867
TBN	BAS ISO 3771	mg KOH/g	10.30
TAN	ASTM D 664	mg KOH/g	3.87
Flash point	ISO 2592	°C	238
Pour point	BAS ISO 3016	°C	-27
Apparent viscosity at -20 °C (CCS)	ASTM D 5293	mPas	5500

Engine test

In real operating conditions engine test on VW 1.9 SDI engine was performed, according to procedure CEC-L-78-T99. This procedure was prescribed by the engine manufacturer, with duration of 56 testing hours. During testing changes in physical and chemical properties of engine oil were controlled, as well as changes in wear metals concentrations in oil (Cu, Pb, Cr, Fe). In addition, according to prescribed standard procedure for this test, the evaluation of vital engine parts was performed.

The average conditions achieved during the test are given in Table 2.

Table 2: Engine test conditions

AVERAGE ENGINE TEST CONDITIONS		1 cycle	2 cycle
Duration	min	30	150
RPM	o/min	900	3600
Temperature of oil in crankcase	°C	80	140
Temperature of water (output)	°C	57	89
Oil pressure	bar	2.8	2.5
Temperature of exhaust gasses	°C	125	640

2.2. Results and discussion

In order to make the results comparable two engine tests were performed. In both of them the same engine oil was used. In the first engine test engine was run on conventional diesel fuel and in second on B10 fuel. In further text engine tests are labeled as follows:

TD-1	Engine powered on conventional diesel fuel
TB-1	Engine powered on B10 fuel

Upon completion of these tests, engine oils were completely analyzed. The obtained results are given in Table 3 and Table 4.

Table 3: TD-1 test results

Characteristics	Unit	Fresh sample	Sample after 12 h	Sample after 24 h	Sample after 36 h	Sample after 48 h	Sample after 56 h
v (40 °C)	mm^2/s	104.26	109.05	114.97	122.79	123.7	128.94
v (100 °C)	mm^2/s	14.76	15.46	16.16	16.84	17.53	17.44
IV	-	147	151	153	151	158	151
TBN	mgKOH/g	10.77	10.23	10.37	10.24	10.15	10.20
TAN	mgKOH/g	3.87	3.72	4.25	4.68	4.80	5.22
Flash point	°C	238	253	240	244	242	249
Fe	ppm	-	19.8	36.93	48.03	72.9	93.64
Pb	ppm	-	8.59	19.81	23.26	27.58	34.44
Cr	ppm	-	0	0	0	0	0
Cu	ppm	-	1.25	2.99	3.24	4.87	5.49
Soot (4000 cm^{-1})	%	-	0.82	1.238	1.74	2.254	2.134
Oxidation DIN (1710 cm^{-1})	Abs/cm	-	0.455	1.343	3.885	5.474	5.45

Table 4: TB-1 test results

Characteristics	Unit	Fresh sample	Sample after 12 h	Sample after 24h	Sample after 36h	Sample after 48 h	Sample after 56h
v (40 °C)	mm^2/s	104.26	104.08	111.34	119.68	127.23	125.61
v (100 °C)	mm^2/s	14.76	14.67	16.43	16.71	17.20	17.40
IV	-	147	146	159	151	148	152
TBN	mgKOH/g	10.77	10.72	10.33	10.25	10.15	10.09
TAN	mgKOH/g	3.87	4.76	5.48	5.61	5.37	5.75
Flash point	°C	238	237	255	267	255	265
Fe	ppm	-	12.9	33.5	53.1	68.8	72.3
Pb	ppm	-	1.0	2.1	2.9	3.4	3.5
Cr	ppm	-	1.0	2.6	3.7	4.6	4.8
Cu	ppm	-	2.3	2.8	3.5	4.2	4.0
Soot (4000 cm^{-1})	%	-	0.472	1.254	1.882	2.558	3.071
Oxidation DIN (1710 cm^{-1})	Abs/cm	-	0.44	1.508	3.275	9.853	11.407

Figure 1 shows how viscosity changed with increasing of working hours; limit values for the viscosity grade SAE 40 (12. 5 - 16.3 mm^2/s) also were indicated.

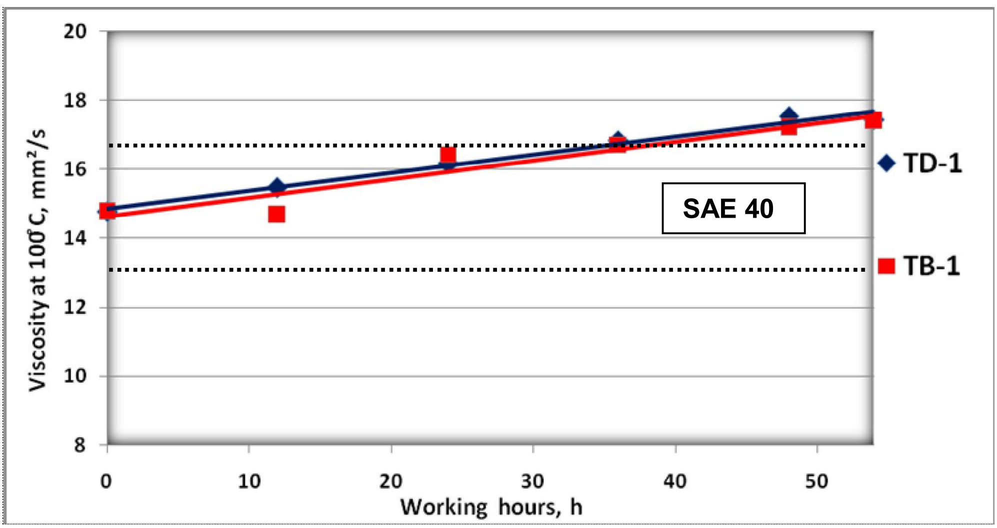

Figure 1: Change in viscosity during engine tests

During engine test viscosity was constantly increasing. After 30 working hours, viscosity of both oils exceeded the limit for viscosity grade SAE 40. Oil thickening was caused by oxidation and polymerization processes as well as due to the high soot content.

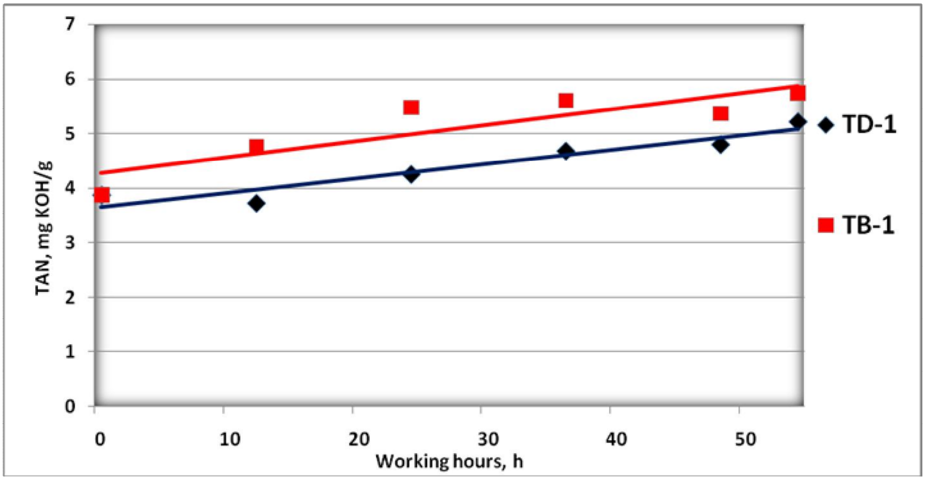

Figure 2: Change in TAN during engine tests

Figure 2 shows change in Total Acid Number (TAN). It can be noticed from diagram that acid number was constantly increasing with working hours. Higher acid values were measured in engine oil from B10 powered engine test.

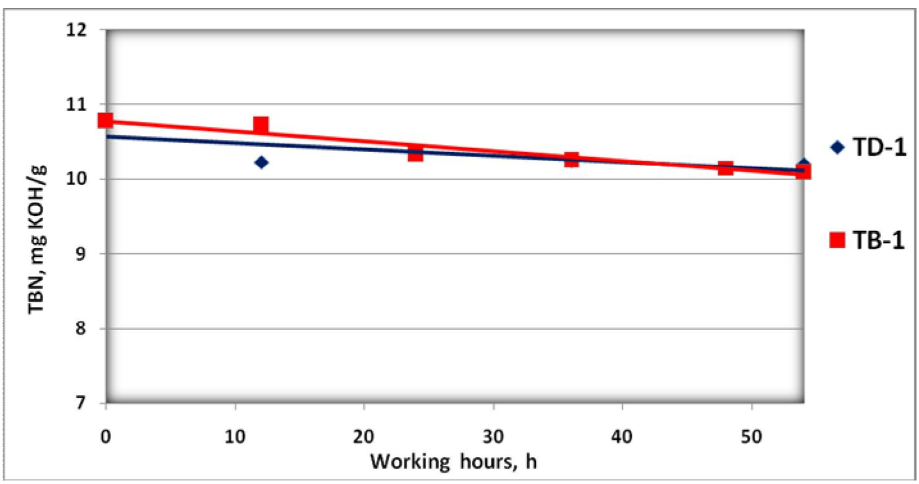

Figure 3: Change in TBN during engine tests

Figure 3 shows change in Total Base Number (TBN). During the test there was observed slightly decrease of the base number. At the end of both tests the measured values of TBN were still high (min. 10 mg KOH/g) what indicates that oils still have ability to neutralize acid products.

Measured flash point of oil from TB-1 test has significantly increased during the test. This occurrence is most likely a consequence of accumulation of biodiesel in the crankcase whose presence leads to oxidation and polymerization processes. These processes produce high molecular compounds with high flash point.

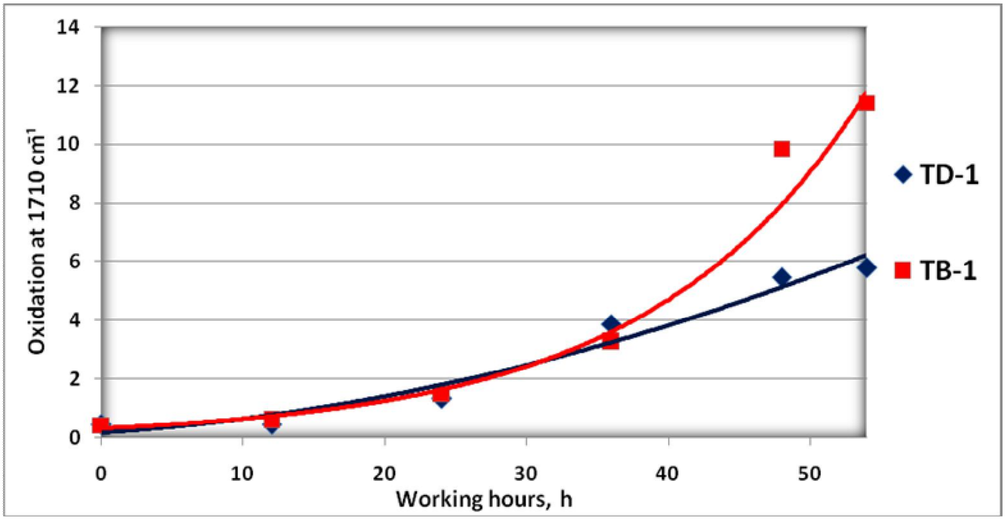

Figure 4: Absorption at 1710 cm^{-1}

By infrared spectroscopy method increase in the amount of carbonyl compounds absorbed at 1710 cm^{-1} with working hours increase was measured (Figure 4). Here, in the second half of test more significant changes were observed in oil from TB-1 test. However, these values are within allowable limits.

Test results showed trend of increasing of soot level with working hours (Figure 5). Higher soot level was measured in engine oil from B10 powered engine test. In this case soot content was increased up to maximum value of 3.5%. High soot level has caused significantly increase in viscosity during the engine test.

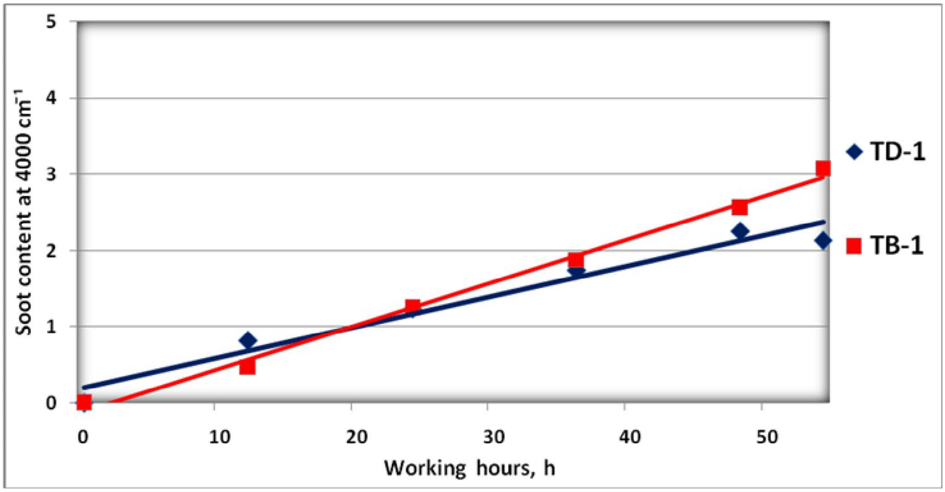

Figure 5: Soot content in oils

In Figure 6 concentrations of iron (Fe) in investigated oils are shown. In both oils concentrations were below 100 ppm. Such low values indicate relative low wear rate of engine parts and indicate good lubrication.

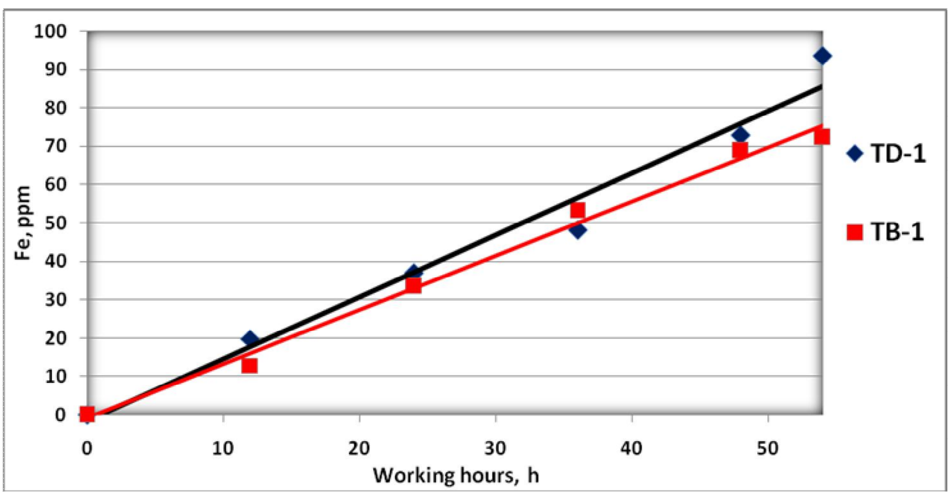

Figure 6: Concentration of iron in oils

From Figure 7 can be noticed very low concentrations of cooper in the oils. It indicates very low wearing of bearings and low cooper corrosion.

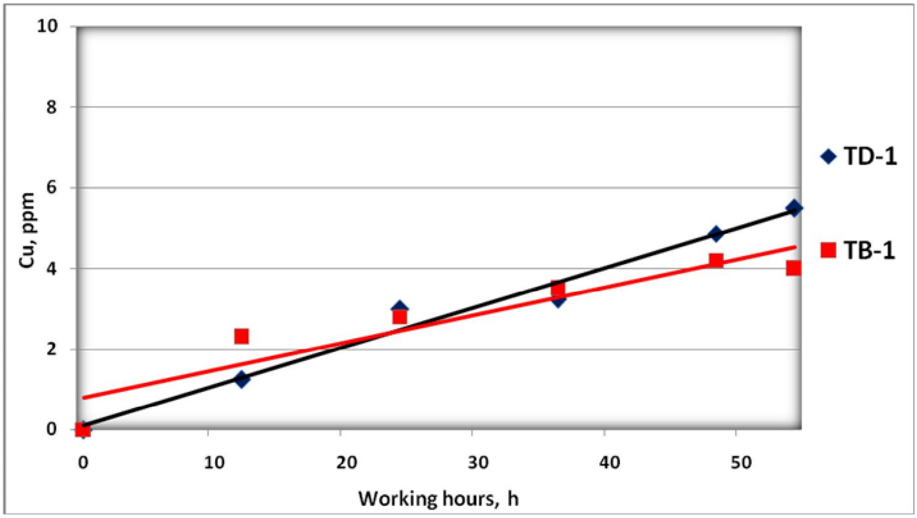

Figure 7: Concentration of cooper in oils

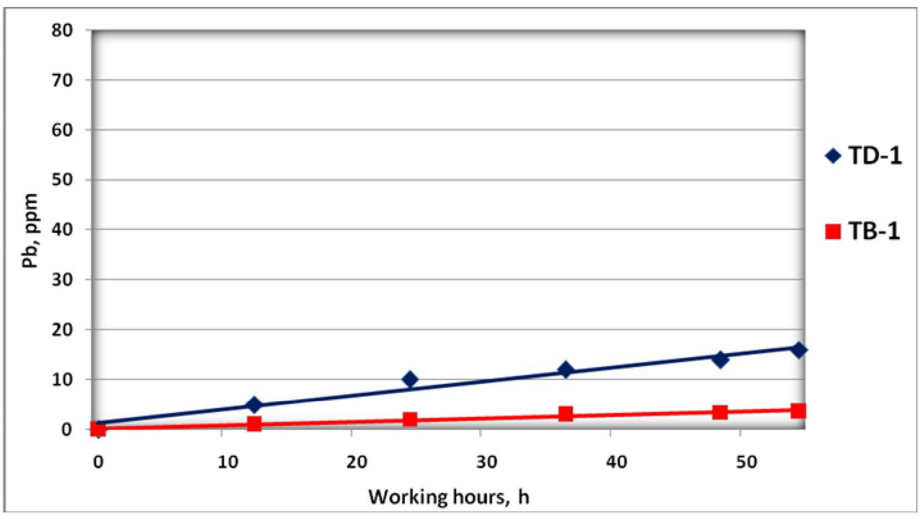

Figure 8: Concentration of lead in oils

Concentrations of lead in oils are also very low. Slightly higher concentrations were measured in oil from engine test, which has run on conventional petrol diesel. However, these values are still below the allowable limits.

From the results shown in Figure 9 it can be concluded that chrome content was only insignificantly increased.

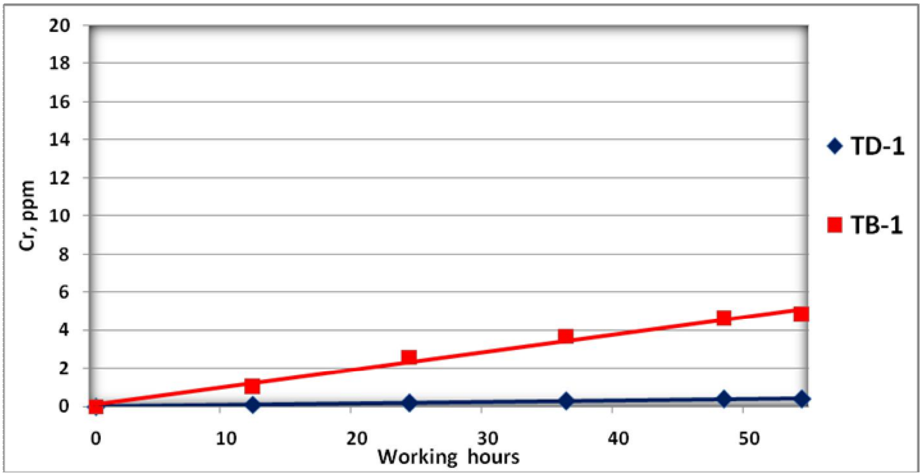

Figure 9: Chromium concentration in oils

In previoius studies laboratory test was performed in order to determine the corrosion on non-ferrous metals in biodiesel. For this purpose High Temperature Corrosion Bench Test (ASTM D 6594) was used. This test method is characterized by following working conditions: test duration of 168 hours, temperature of 135 °C and air flow of 5 L/h. The engine oil used in test was blended with 5%, 10%, 15% and 20% of FAME biodiesel. Upon completion of the test, concentrations of cooper, tin and lead in oil were measured.

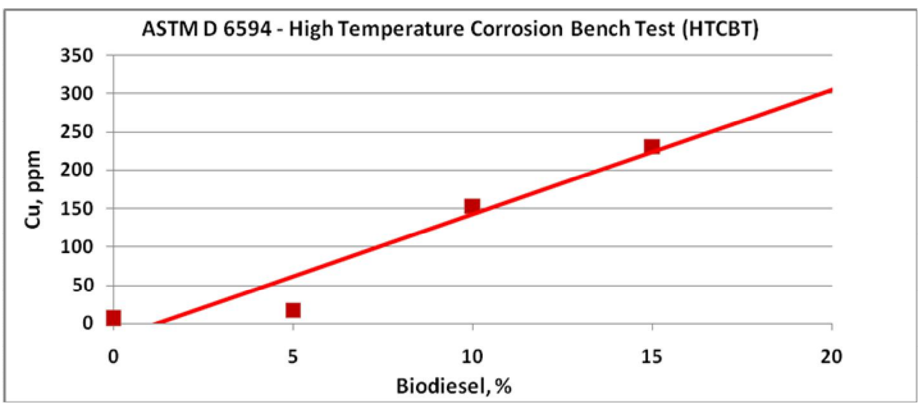

Figure 10: Cooper concentration in oil

Measured concentrations of cooper and lead are shown in Figures 10 and 11. As can be seen measured concentrations of cooper and lead are extremely high. Anyway, in this test biodiesel was added directly in engine oil so that is the main reason for very high corrosion rate. Compared to results from engine tests these values are much higher. The tin content in oil was insignificant.

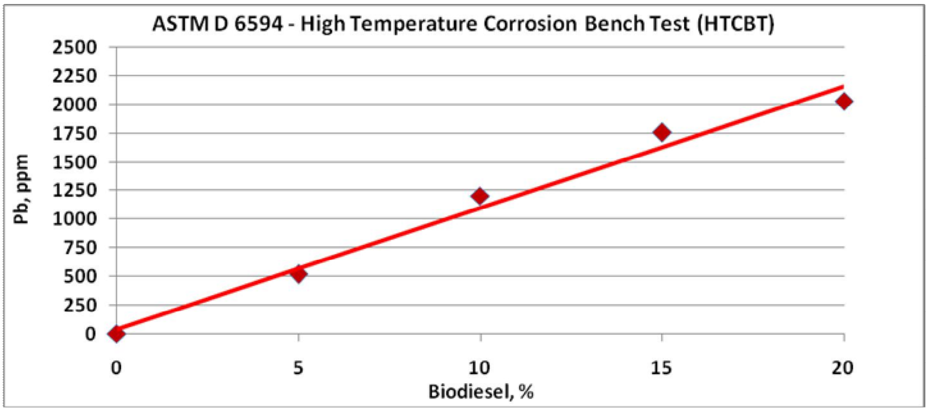

Figure 11: Lead concentration in oil

2.3. Evaluation of engine

After the completion of engine test, complete evaluation of vital engine parts was performed according to standard procedure IP 279/72. The results of the evaluation are given in Table 5 and Table 6.

Table 5: Evaluation of TD-1 test

Rated		Piston			
		1	2	3	4
Overall rating		74.48	66.54	66.18	67.28
Average rating		68.7			
Piston ring	First	10	10	10	10
	Second	10	10	10	10
	Third	10	10	10	10

Based on the above presented results, when using B10 fuel in the real test conditions there is no negative adverse effect of biodiesel on engine and engine oil. By weighing of bearings and piston rings were obtained results given in Table 7 and presented in Figure 12.

Table 6: Evaluation of TB-1 test

Rated		Piston			
		1	2	3	4
Overall rating		69.32	63.61	60.63	67.01
Average rating		65.14			
Piston ring	First	10	10	10	10
	Second	10	10	10	10
	Third	10	10	10	10

Table 7: Wearing of engine parts

	TD-1	TB-1
Crankpin journals wear, g	0.0294	0.0324
Main journals wear, g	0.0120	0.0075
Piston rings wear, g	0.1095	0.1256

Results of evaluation of engine parts have shown that there is no difference between results obtained from these two tests.

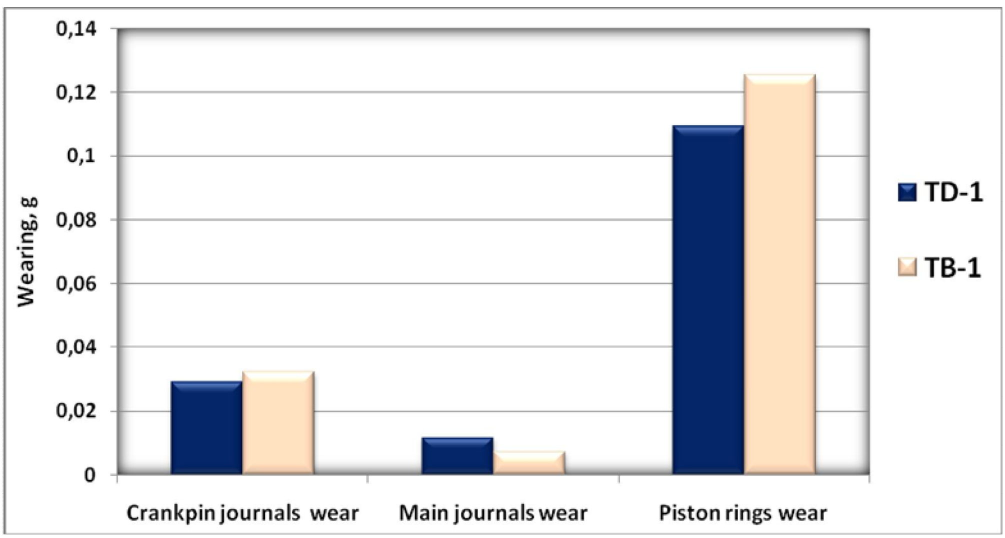

Figure 12: Wearing of engine parts

Conclusion

1. There were no significant differences in physical and chemical properties of engine oils from diesel fuel and B 10 fuel powered engine tests.
2. Wearing of bearings and piston rings as well as the content of wear metals in oil were very low. Based on these values it can be concluded that tested engine oil provides outstanding antiwear properties.
3. By evaluation of the engine parts it was found that all piston rings were completely clean. That indicates that oil has excellent detergent properties.
4. Overall studies have shown that when using high quality engine oil usage of B10 fuel has no negative effects on engine oil and vital engine parts.

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Authors

Omer Kovač, Danka Šikuljak, Tamara Evđić, Jadranka Vujica
Oil Refinery Modriča, Vojvode Stepe 49, Modriča, Bosnia and Herzegovina
E-address: danka@modricaoil.com

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