IOP Conf. Series: Materials Science and Engineering **148** (2016) 012088 doi:10.1088/1757-899X/148/1/012088

Research on the 2nd generation biofuel BIOXDIESEL in aspects of emission of toxic substances in exhaust gases

M S Struś[1], W Poprawski[1] and M Rewolte[2]

[1] Wrocław University of Science and Technology, Faculty of Mechanical and Power Engineering, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland; tel.+48713204965,
[2] Proagroenergia Przedsiębiorstwo Innowacyjno-Wdrożeniowe Sp z o.o. Chwałowice, ul. Szkolna 49, 55-220 Jelcz Laskowice, Poland, tel.+48 501486121

E-mail: mieczyslaw.strus@pwr.edu.pl

Abstract. This paper presents results of research of Diesel engines emission of toxic substances in exhaust gases fuelled with a second generation biofuel BIOXDIESEL, which is a blend of Fatty Acid Ethyl Esters obtained from waste resources such waste vegetable and animal fats, bioethanol and standard Diesel fuel. Presented results are very promising, showing that the emission of toxic substances in exhaust gases are significantly reduced when fuelling with BIOXDIESEL fuel in comparison with standard Diesel fuel.

1. Introduction

Manufacturers of on and off highway vehicles, agriculture and construction machinery as well as power generators find many ways to reduce emission of toxic substances in exhaust gases. They use advanced systems of accurate fuel injection, catalytic converters, particulate matter filters, engines supercharging to selective catalytic reduction. They also design fuel feeding systems to enable application of biofuels.

One of the ways to reduce negative impact of combustion engines on environment is using biofuels, which are made from waste feedstock, such as animal and vegetable resources.

Current Polish and European Union law allow addition of up to 7% of biocomponents containing Fatty Acid Methyl Esters (FAME) to the fuel used for Diesel engines.

The main components of the BIOXDIESEL fuel are based on the Fatty Acid Ethyl Esters (FAEE), which are manufactured from waste resources like animal and vegetable fats, which cannot be further processed in food industry.

2. Description of fuel used for testing

For testing purposes the experimental fuel BIOXDIESEL has been blended. It is three component mixture 70% of biocomponents containing Fatty Acid Ethyl Esters (FAEE) manufactured from waste animal and vegetable fats, rapeseed oil, bioethanol with 30% of standard Diesel fuel. The properties of BIOXDIESEL fuel are meeting the requirements of the PN-EN 590:2013. Currently there are no legal or standard requirements regarding FAEE, this is why the properties of the ethyl esters are compared with PN-EN 14214 standard, which is designed for methyl esters.

The Fatty Acid Ethyl Esters (FAEE) are manufactured in transesterification process with bioethanol in presence of alkali catalyst. The feedstock for the process has been carefully selected from wide range of resources [1].

Table 1 presents selected properties of the BIOXDIESEL fuel compared to the PN-EN 590:2013 and PN-EN-14214 standards.

Table. 1. Selected properties of BIOXDIESEL requirements of the PN-EN 590:2013 and PN-EN 14214+A1 standard.

Parameter	Units	Properties of BIOXDIESEL fuel	PN-EN 590:2013 requirement		PN-EN 14214+A1 requirement	
			min	max	min	max
Cold Filter Plugging Point	[°C]	-17	From April 16 to September 30: **0°C** From March 1 to April 15 and October 1 Novermber 15: **-10 °C** From November 16 to end of February: **-20 °C**		From April 16 to September 30: **0°C** From March 1 to April 15 and October 1 Novermber 15: **-10 °C** From November 16 to end of February: **-20 °C**	
Cetane number		51,9	51		51	
Density at 15°C	kg/m^3	868	820	845	860	900
Flash point	°C	24	55		101	
Viscocity at 40°C		2,33	2	4.5	3,5	5
Calorific value	MJ/kg	38,5	42,8		38	

3. Description of engines used for testing

The efficiency of engines fuelled with BIOXDIESEL fuel has been a subject of previous research. The results presented in [2] and [3] show that the development of the BIOXDIESEL fuel may be crucial in terms of the reduction of impact of exhaust gases on environment.

For testing purposes the 1.3 SCE turbocharged Diesel engine was used. This is modern 4 cylinder turbocharged engine equipped with Common Rail fuel injection system, displacement 1248 ccm, 69,6 bore. It generates maximum 51 kW (70 BHP) at 4000 RPM. Maximal torque generated by the engine reaches 180 Nm at 1750 RPM. This engine is also equipped with exhaust gases recirculation (EGR) system controlled by the ECU. The pressure in the Common Rail system is 1400 bars. This engine is commonly used for small and compact passenger vehicles and small vans.

4. Description of testing procedure

The emission tests were carried out in 20 points which were derived from the EUDC testing cycle on the engine test bed. The EUDC test procedure reflects the road driving conditions, combining urban and highway duty cycle. The measurement were taken on the engine installed on test bed equipped with the exhaust gases analysis equipment. Additionally there were also performed another load tests at 1500, 2500 and 3500 RPM engine crankshaft speed at various loads.

In order to compare the two fuels (BIOXDIESEL and standard Diesel) the following quantities were measured during the tests:

- Concentration of CO (carbon oxide) in exhaust gases;
- Concentration of HC (hydrocarbons) in exhaust gases;
- Concentration of NOx (nitrogen oxides) in exhaust gases;
- Smoke (with an opacimeter);
- Soot concentration.

During the testing performance of the engine fuelled with BIOXDIESEL and standard Diesel fuelled was measured.

In table 2 the measurement points of the EUDC test cycle are presented. There are also presented vehicle speed and corresponding gear at which such engine load is achieved. The points also present the constant driving speed parts of the test.

Table. 2. List of measurement points according to EUDC testing procedure

Measurement point	Engine revolution [RPM]	Engine Torque [Nm]	Corresponding vehicle speed/gear [km/h /gear]
1	820	45	
2	850	20	
3	1050	15	
4	1250	20	
5	1400	40	
6	1550	4	35/III
7	1590	10	50/IV
8	1650	37	
9	1730	11	70/V
10	1740	26	
11	1800	38	
12	1920	3	15/I
13	2050	26	
14	2200	4	50/III
15	2260	4	32/II
16	2400	55	
17	2500	34	100/V
18	2700	73	
19	2930	80	
20	3020	55	120/V

5. Results of engine performance and emission measurement

The emission measurement was performed according to the EUDC procedure, the points listed in table 2. Below, figure 1 presents comparison of engine efficiency, obtained during fuelling with standard Diesel fuel and BIOXDIESEL. The results show, that majority of measurement point of EUDC test the efficiency measured with experimental biofuel is bigger in comparison with standard Diesel fuel.
Figure 2 presents comparison of the value of fuel dose. The values are very similar, when measured in the points of the EUDC test. This shows, that the engine was very accurately controlled by the ECU. Even though the calorific value of the BIOXDIESEL fuel is about 10% lower in comparison with standard Diesel fuel the unit fuel consumption and hourly fuel consumption are very similar for both fuels (figures 3 and 4). The accuracy and repeatability of the engine control can be seen on the comparison of the position of the EGR valve (figure 5). Both values follow each other for most of the points of the EUCD test.

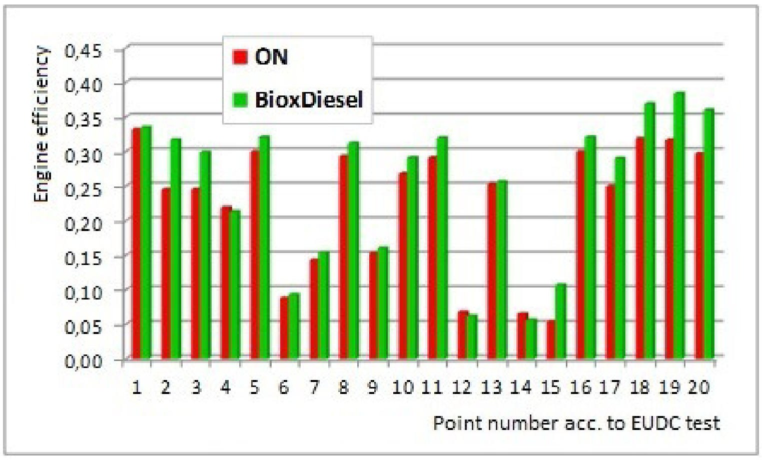

Figure. 1. Comparison of engine efficiency for BIOXDIESEL and standard Diesel fuel.

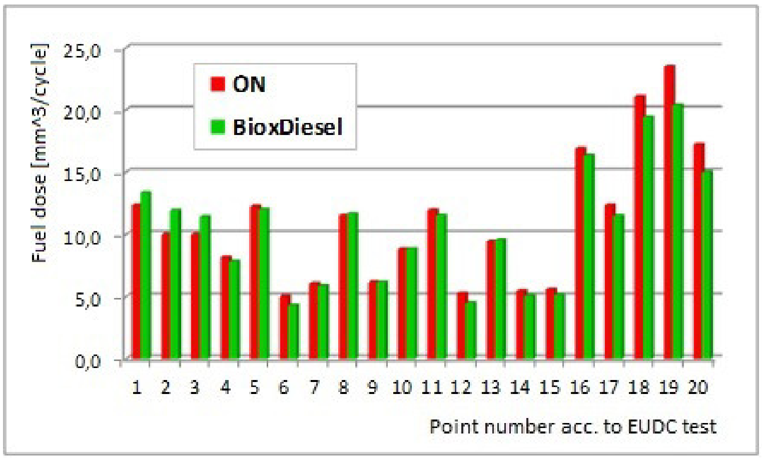

Figure. 2. Comparison of the fuel dose BIOXDIESEL and standard Diesel fuel**.**

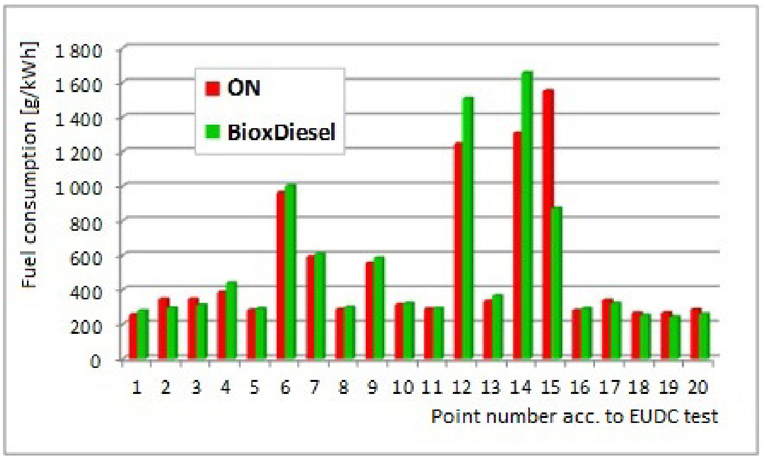

Figure. 3. Comparison of the unit fuel consumption for BIOXDIESEL and standard Diesel fuel**.**

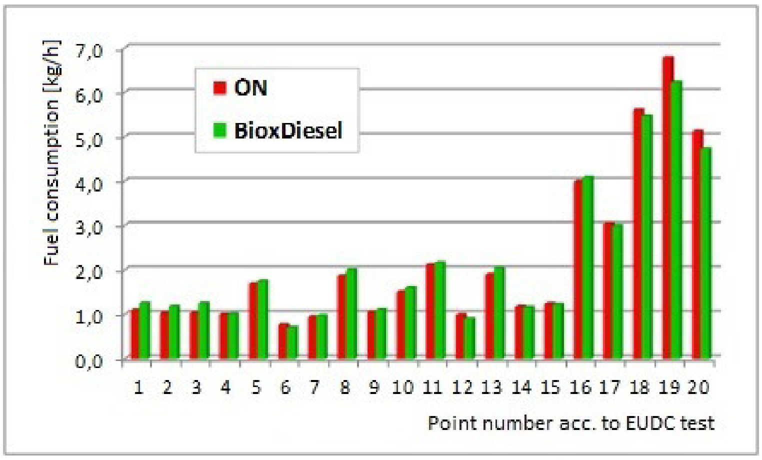

Figure. 4. Comparison of hourly fuel consumption for BIOXDIESEL and standard Diesel fuel.

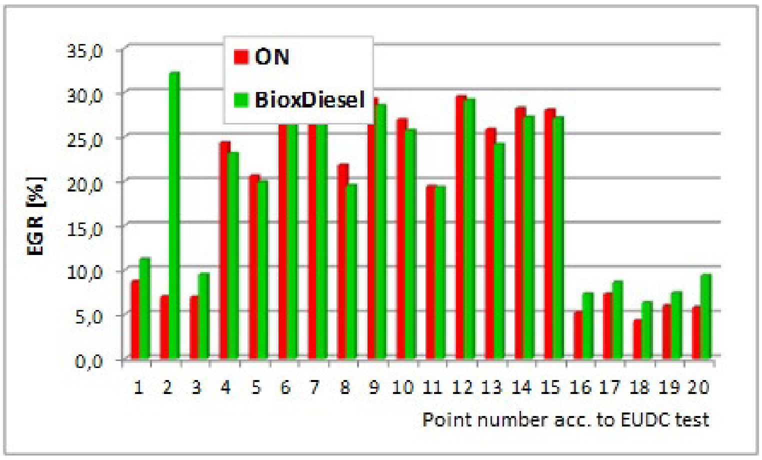

Figure. 5. Comparison of position of the EGR valve for BIOXDIESEL and standard Diesel fuel.

The results of emission tests show the advantage of the BIOXDIESEL fuel over standard Diesel. The emission of carbon oxide and hydrocarbons is much lower over the test for experimental biofuel (figures 6 and 7). Such observation may prove better evaporation of the BIOXDIESEL over standard Diesel fuel.

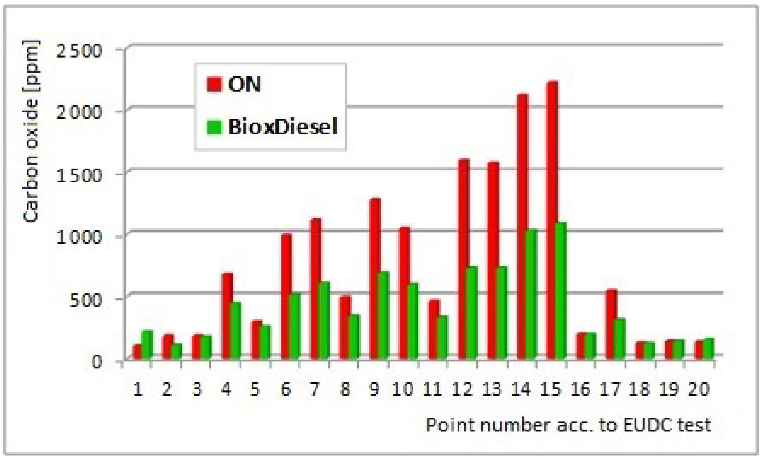

Figure. 6. Comparison of emission of carbon oxide in exhaust gases for BIOXDIESEL and standard Diesel fuel.

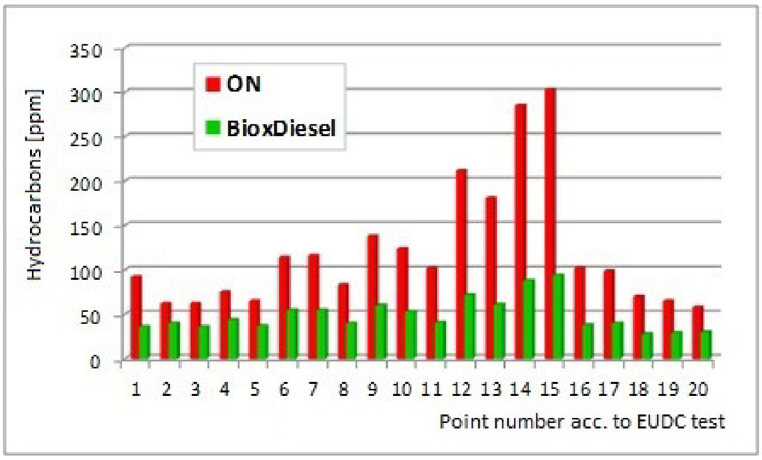

Figure. 7. Comparison of emission of hydrocarbons in exhaust gases for BIOXDIESEL and standard Diesel fuel.

Figure 8 presents emission measurement of nitrogen oxides during fuelling with BIOXDIESEL follows the emission measured on Diesel fuel. But in the points, when the engine works with higher load (points 18, 19 and 20, which correspond to highway driving) one can observe significantly lower emission when fuelling with BIOXDIESEL.

Similarly, when comparing emission of soot and smoke (figures 9 and 10) it is not possible to clearly point which fuel used for testing has its advantages in terms of lower emission. Similarly to NOx, smoke emission at the points with higher engine load caused lower emission of soot and smoke.

Comparison of the Lambda coefficient show again (figure 11), that the engine was very accurately controlled. The burning efficiency for both fuels was comparable.

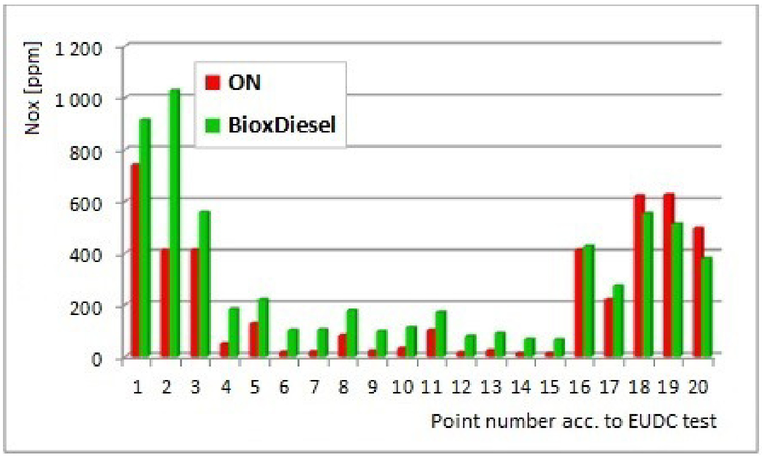

Figure. 8. Comparison of emission of nitrogen oxides in exhaust gases for BIOXDIESEL and standard Diesel fuel**.**

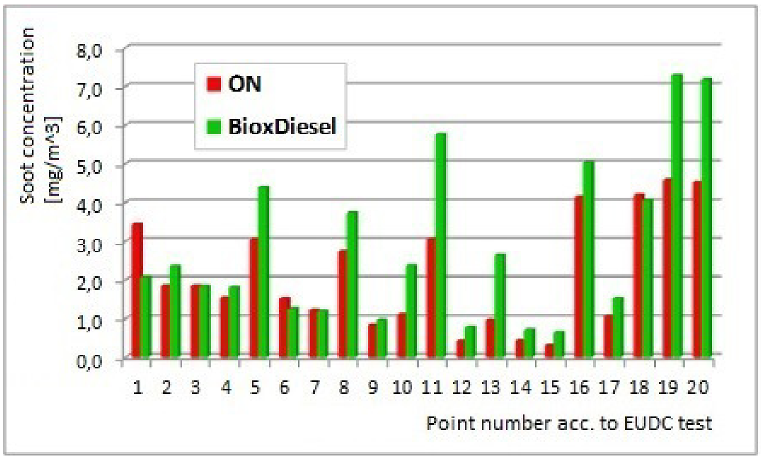

Figure. 9. Comparison of soot concentration in exhaust gases for BIOXDIESEL and standard Diesel fuel**.**

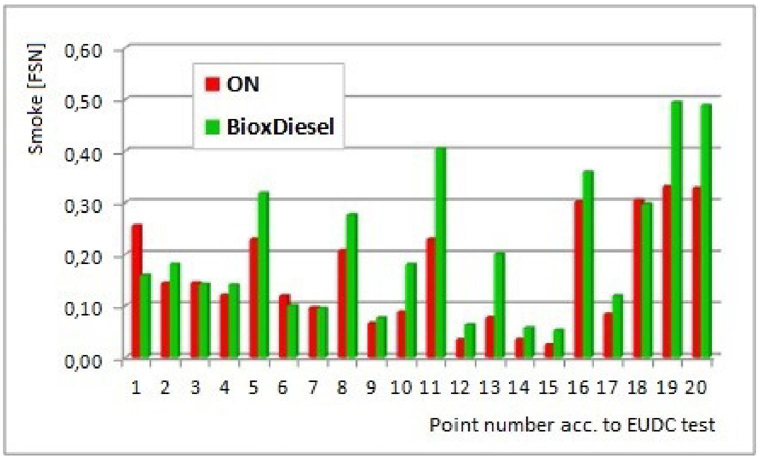

Figure. 10. Comparison of emission smoke exhaust gases for BIOXDIESEL and standard Diesel fuel.

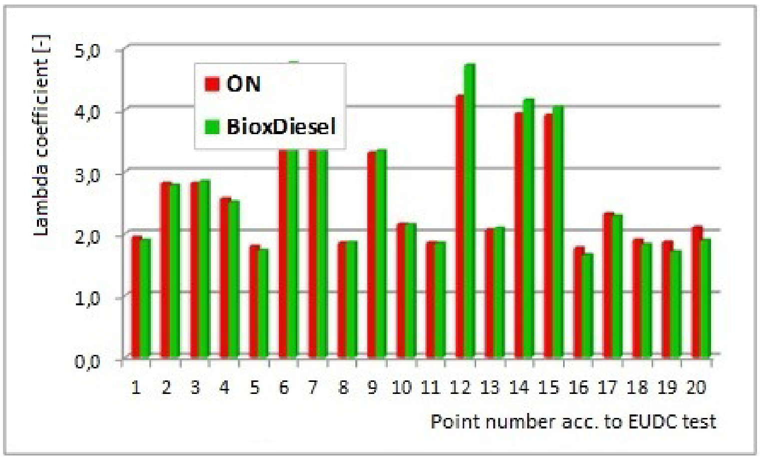

Figure. 11. Comparison of the value of LAMBDA coefficient for BIOXDIESEL and standard Diesel fuel.

IOP Conf. Series: Materials Science and Engineering **148** (2016) 012088 doi:10.1088/1757-899X/148/1/012088

6. Conclusions

Presented results of emission measurement show, that the BIOXDIESEL is very advanced fuel, which can replace standard Diesel fuel without negative impact on environment. The BIOXDIESEL fuel shows its advantage over standard fuel in terms of emission of carbon monoxide and hydrocarbons. This is achieved by very good evaporation properties of the BIOXDIESEL over standard Diesel fuel.

The measurement of nitrogen oxides (NOx) in exhaust gases also proved, that the BIOXDIESEL has an advantage over Diesel fuel for the points of the test cycle, which correspond to the highway driving with higher speed and load. The similar situation was for measurement of soot and smoke in exhaust gases.

Another big advantage of the BIOXDIESEL fuel is higher engine efficiency when fuelled with BIOXDIESEL in comparison with standard Diesel fuel. The differences are the biggest when the load was the biggest. Similarly, the fuel consumption of BIOXDIESEL fuel was lower.

Obtained results of the research on the BIOXDIESEL fuel proves that it is advanced fuel and may be used alternatively for all Diesel engines, however the finite verification can be done after currently realised vehicle durability testing on the distance of 600’000 – 1’000’000 km in the period of 8 – 12 years.

References

[1] Struś M S, Poprawski W and Rewolte M 2015“Efficiency of feedstock selection for the second generation BIOXDIESEL biofuel for Diesel engines,” *Combustion Engines,,* 3/2015

[2] Struś M S 2012 *Ocena wpływu biopaliw na wybrane właściwości eksploatacyjne silników*, Oficyna Wydawnicza Politechniki Wrocławskiej Wroclaw

[3] Struś M S 2014 Efektywność silników spalinowych o zapłonie samoczynnym zasilanych paliwem bioxdiesel z komponentami całkowicie odnawialnymi *Inżynieria Maszyn,,* vol. 2, no. 19, pp. 108-115