ECOLOGICAL IMPACT OF BIODIESEL USE
BIODĪZEĻDEGVIELAS PIELIETOŠANAS EKOLOĢISKĀ IETEKME

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Abstract. *The paper presents a study of biodiesel application and its ecological impacts. Our study is based on the comparison of exhaust emission composition produced by the combustion of rapeseed oil methyl ester (RME) and conventional diesel fuel (DD) and its blends in a direct injection diesel engine XD2P (YTT). The engine was tested in biofuels laboratory of LUA Motor Vehicle Institute. Fueling the engine with biodiesel and biodiesel/diesel blend reduced oxides of nitrogen by 17.5% (100RME) and by 5.6% (35RME) and carbon monoxide by 49.8% (100RME) and by 45.3% (35RME). Fueling the engine with biodiesel and different biodiesel/diesel blends reduced the absorption coefficient by 33.9% (5RME), by 44.3% (20RME), by 48.3% (35RME) and by 51.2% (100RME) on free acceleration regime. In these tests soot reduced by 28...76.7% at full opened throttle position with 100RME.*

Keywords: *renewable energy, biodiesel, exhaust emissions, smoke, test bench.*

Introduction

In Latvia now there are more than 173 000 diesel vehicles (CSDD, 2005), and the total number of them is increasing according to the diesel engine popularity. The widespread use of diesel powered vehicles and machines not only in Latvia, but also in all world, has caused many different environmental problems (acid rains, smog) and human health problems. Diesel exhaust is a complex mixture of gaseous constituents (including CO, NO_x, NO_2, CO_2) and particles, which have been classified as probable human carcinogen by International Agency for Research on Cancer (IARC, 1989). Due to this diesel widespread use, the possibilities to expose to diesel exhaust is not only to people whose work is directly connected with diesel equipment – railroad workers, truck and bus drivers and garage workers – but also to everybody who drive by car or go to work by bus every morning.

One of the possibilities to reduce environmental, economical and social problems caused by usage of fossil diesel fuel is to introduce biodiesel instead of fossil diesel fuel in diesel engines. Biodiesel can be made of such renewable resources as rapeseed oil, palm oil, waste cooking oil and others. These fuels have many characteristics, what makes them attractive for use in compression ignition engines, and the main advantage of biodiesel over fossil diesel is that it can be used in diesel engines without modification. These fuels also have some other essential advantages, what makes biodiesel more competitive to diesel. Biodiesel has higher flash point, what makes it safer for transport and storage; it reduces not only carbon dioxide, carbon monoxide, carcinogenic aromatic hydrocarbons (PAH) and others, but also sulfur dioxide emissions due to very low sulfur content in fuel.

Now biodiesel is applied in different areas: transport, commercial construction equipment and space heating. In Europe, U.S.A. and other countries biodiesel and its blends are used in diesel cars, light trucks and heavy trucks with few or no modifications. In some countries, such as U.S.A., biodiesel is used in different off-road equipment (bulldozers, excavators and cranes) and as heating oil for boilers operation or house heating. These application areas could be primary candidates for substitution of biodiesel due to a widely usage of high sulfur diesel fuel in these application areas.

Biodiesel is also successfully used in boats in many countries. For this application area there could also be some advantages noted. Firstly, the biodegradation rate of biodiesel is about twice as high as for diesel fuel; it degrades by 98.3% in 21 days (Williams, 2002). Secondly, the toxicity of biodiesel to plants and animals is lower compared with conventional diesel fuel. For

ISBN 9984 – 779 – 06 – 8

example, tests with larval forms of fish and shell fish showed that the toxicity of biodiesel is 20-40 times less than that of fossil diesel fuels (Zhou et al., 2003).
As the production of biodiesel (rapeseed methyl ester RME) is started now and is planned to grow rapidly, it is necessary to investigate the impacts of biodiesel and fossil diesel fuel blends on engine running and exhaust parameters. In this paper the results of biodiesel engine tests, which were carried out in engine testing and biofuels laboratory of the LUA Motor Vehicle Institute, are discussed.

Materials and methods

In the engine testing and biofuels laboratory of the Latvia University of Agriculture investigations of a commercial direct injection diesel engine XD2P (YTT) were carried out. It was a four-cylinder diesel engine with industrial application, manufactured by Ford CO., LTD. The engine was tested on the test bench VEM-100. The specification for this engine is shown in Table 1. The engine was operated on diesel fuel (DF), rapeseed oil methyl ester (100RME) and on its blends: 35% RME with 65% diesel (35RME), 20% RME with 80% diesel (20RME), 5% RME with 95% diesel (5RME). The exhaust emission characteristics were investigated at a variety of steady state engine speeds on full opened throttle position, namely 800, 1000, 1500, 2000, 2500 and 3000 rpm. The exhaust emission characteristics for DD and RME include smoke emissions (opacity) and gaseous emissions (NO_x, NO, CO, CO_2, O_2).

Table 1.

Engine Specifications

No. of cylinders	4
Bore	94 mm
Stroke	83 mm
Compression ratio	22:1
Max. power	49 kW/4200 rpm
Max. torque	139 Nm/2000 rpm

The exhaust emissions of NO_x, NO, CO, CO_2, O_2 were measured using the KM9104 exhaust gas analyser, but the PM related exhaust gas opacity (smoke) was measured using the gas analyzer BOSCH BEA-350 with opacimeter RTM 430. The diesel engine smoke opacity was measured at full opened throttle position at various engine speeds and than during free acceleration, but other exhaust emission components were measured at nominal rpm and only for DF, 5RME, 35RME and 100RME.

Results

The results showed that the smoke emissions obtained from the engine operated on biodiesel and on its blends with fossil diesel fuel were considerably lower than smoke emissions from conventional diesel fuel. Figure 1 shows soot concentration characteristics for biodiesel, conventional diesel and its 20% blend at engine full opened throttle position. As it is seen from the given characteristics by using biofuels soot concentration was reduced by 28% at engine speed 800 rpm to 76.7% at 3000 rpm. The measured smoke emissions were converted to the soot concentration (g/m^3) in exhaust gases by special correlation table (Грехов et al., 2004).
Figure 2 indicates the absorption coefficient of the tested engine running on free acceleration regime with different fuels: DF, 20RME and 100RME. All the measured absorption coefficient levels decrease with increasing the biodiesel percentage in the blend. Maximum reduction of the absorption coefficient (by 51.2%) has been recorded for 100% biodiesel usage. Quite good results have been almost recorded for 20RME, and it is 44.3% reduction of absorption coefficient compared to diesel fuel.

ISBN 9984 – 779 – 06 – 8

The results of the measured exhaust emission components are presented in Table 2.

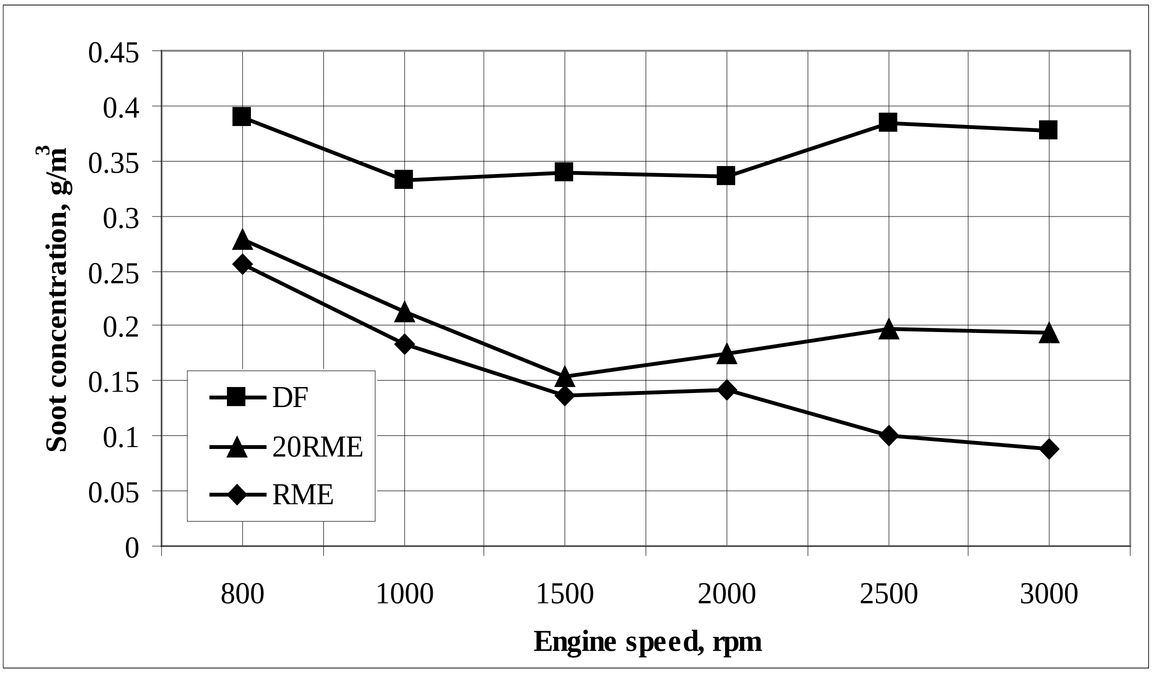

Fig. 1. **Soot concentration relationship with engine speed at full opened throttle position**

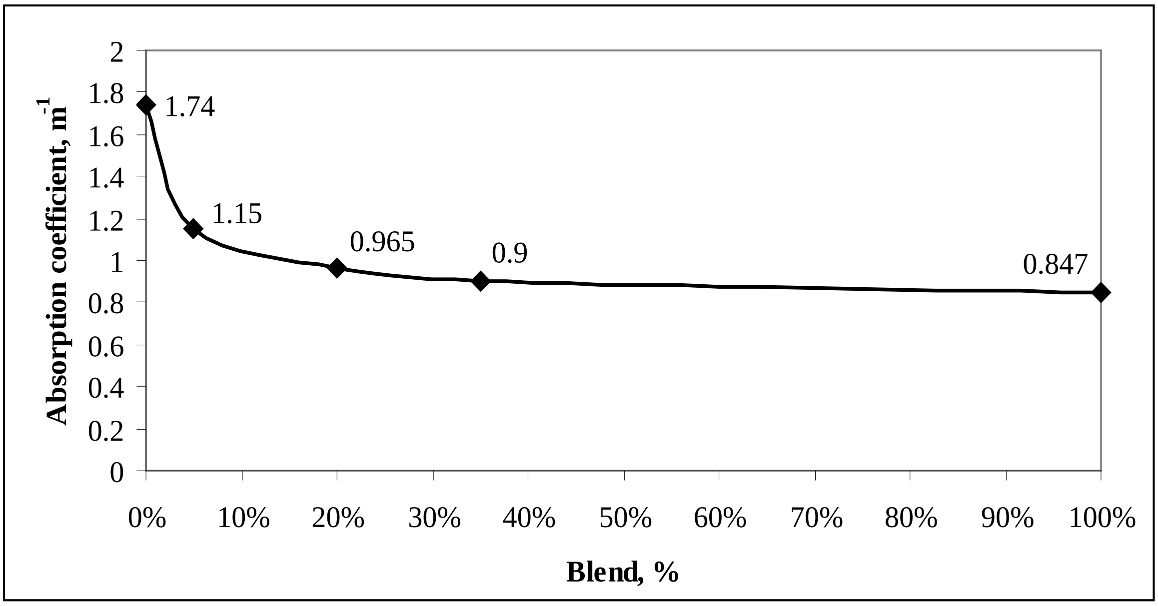

Fig. 2. **Absorption coefficient relationship with biodiesel quantity in the blend on free acceleration regime**

As it is seen from the Table 2, using biofuels carbon monoxide (CO) emissions were reduced by 49.8% (100RME) and carbon dioxide emissions (CO_2) – by 7.8% (100RME) in comparision with DF. This reduction could be related to the fuel composition – biofuels contain less carbon and more oxygen than fossil diesel. In summary the reduction of these components changed on the percentage basis of biodiesel.

Monoxides of nitrogen (NO) and oxides of nitrogen (NO_x) emissions (Table 2) from rapeseed oil methyl ester were generally slightly lower than those from the diesel fuel. NO_x emissions were

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reduced by 17.5%, when the engine was fueled with 100% rapeseed oil methyl ester and only by 0.3%, when the engine was fueled with 5% biodiesel blend.
The values recorded for oxygen (O_2) for biodiesel and its blends were higher than those for conventional diesel fuel. It can also be expected due to the oxygen content of biodiesel fuels.

Table 2.

Exhaust emissions from a 2.3 liter direct injection diesel engine running on different fuels

Exhaust emissions components	Type of fuel used						
	DF	**5RME**		**35RME**		**100RME**	
			% +/-		% +/-		% +/-
CO, ppm	2203	*ND	*ND	1205	-45.3	1105	-49.8
CO_2, %	12.9	12.6	-2.3	12.5	-3.1	11.9	-7.8
NO, ppm	332	325	-2.1	317	-4.5	271	-18.4
NO_x, ppm	337	336	-0.3	318	-5.6	278	-17.5
O_2, %	3.1	3.8	+22.6	3.8	+22.6	4.8	+54.8

*ND – Not Detected

Discussion

The results of our investigation showed that the best advantage of biodiesel fuel is it capability to reduce emissions. To compare our results with the results of similar investigations of other authors the analysis of literature was carried out. For example, soot concentration in exhaust gases in our experiments was reduced by 28-76.7% and this agrees with other researchers studies, where a reduction of smoke with the use of biodiesel in vehicles was reported (Reece et al., 1993), (Scholl et al., 1993), (Graboski et al., 1998).
Researchers from the University of Limerick (Gonzalez Gomez et al., 2000) noted reduction in smoke density approximately by 48% when fueled with a WCOME (waste cooking oil methyl ester) as compared to conventional diesel. Researchers (Sams, 1997) found out that carbon from fuel combustion can be reduced in the order of 60-70% using biodiesel with the oxygen content 10-12%. Smoke opacity (absorption coefficient) reduction by 71% was noted fueling a 5.9L Cummins direct injection diesel engine (Peterson et al., 1995), but in our investigations maximum reduction of this coefficient was 76.7%.
Soot or smoke is a primarily component to which the service stations turn their attention. Diesel engine smoke opacity regulation (regulation 24-03) did apply in Europe at full load at various engine speeds and during free acceleration (Guibet, 1999). Nowadays in Latvia, this free acceleration test is applied in CSDD (Road Traffic Safety Department) to determine toxicity of diesel engine exhaust gases; the maximum opacity is at $2.5m^{-1}$ for all diesel vehicles (except turbodiesels, the maximum opacity for them is at $3.0m^{-1}$).
The main part of the experiments in world has shown that biodiesel fuels can significantly reduce exhaust emissions, including carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC) and particulate matter (PM). Some researchers (Niehaus, 1985) noted increases in carbon monoxide and hydrocarbon exhaust emissions, but decreases in oxides of nitrogen exhaust emissions. In other research work (Krahl et al., 1998) decreases in carbon monoxide, hydrocarbon, particulate matter and soot emissions were noted, but increases in oxides of nitrogen exhaust emissions fueling engine with rapeseed oil methyl ester (RME) compared to conventional diesel; Schäfer (Schäfer, 1996) also reported decreases in carbon monoxide, hydrocarbon and smoke emissions fueling the engine with palm oil methyl ester (PME) compared to conventional diesel; their data are presented in Table 3. Comparing dates from Table 3 for 100RME with our results, we can find that decrease of CO is in similar diapason, but NO_x remains higher.

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Table 3.

Exhaust gases components average concentrations from diesel engines operating biodiesel compared with diesel fuel

Results by Krahl	**Components of exhaust gases**				
100RME	CO	HC	NO_x	Particulates	Soot
	90%[A] 100%[B]	70%[A] 80-90%[B]	110%	60-80%[A]	60%

Results by Schäfer	**Components of exhaust gases**			
	CO	HC	Smoke	NO_x
100PME	61%	91%	24%	104%
50/50 PME/DF	74%	90%	58%	99%
100RME	88-117%	50-53%	28-42%	106-119%

[A] – indirect injection
[B] – direct injection

Our results confirmed reduction in smoke opacity, CO, CO_2, NO and NO_x emissions, but it is not similar to those who fueled diesel engines with rapeseed oil, waste cooking oil or soybean oil methyl esters. Most of the reported studies show a difference in the results, which mostly depends on the employed engine technology and the type of the used emission test. These factors mainly have a significant effect on the difference of the emission composition reported by some authors and researchers.

Conclusions

1. For diesel engines running on biodiesel and its blends exhaust emissions tend to be lower for carbon monoxide, carbon dioxide, oxides of nitrogen, and monoxides of nitrogen in comparison with fossil diesel.
2. A compression ignition engine fueled on rapeseed oil methyl ester provides lower smoke opacity on full load and free acceleration regime.
3. Smoke emissions decrease as the biodiesel concentration increases, and the content of smoke for 20% blend is approximately 2 times lower than as it is for the conventional diesel fueled engine.

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ISBN 9984 – 779 – 06 – 8