EVALUATION OF EMISSIONS OPERATING DIESEL ENGINE WITH RAPESEED OIL AND FOSSIL DIESEL FUEL BLENDS

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Abstract. Due to global warming during the recent years the average temperature of the world has essentially increased. The main reason for the global warming is carbon dioxide, and motor vehicles are one of the main emitters of CO_2. Considering different arguments on adaptation of engines of transport vehicles for operation with different fuels it can be concluded that it would be more rational to create cheap fuel that could be used in the already existing transport vehicles with minor modifications. Rapeseed oil in the conditions of Latvia is the most economically efficient; it belongs to the fuel group of the first generation and it is certified by law in Latvia. It is allowed to be used in diesel engines having regard to the determined emission requirements. One of the branches where rapeseed oil can be used as fuel is agriculture. In land cultivation high power machinery is used and it is operated for a long time with high load so creating a considerable amount of exhaust gasses. Usually such machinery has no catalytic converters that help decrease the amount of the toxic emissions. Using rapeseed oil as fuel in motor vehicles for land cultivation that is mainly done in summer there is no need to worry about the rapeseed oil viscosity, but as the number of investigations is rather small, additional research is needed in the content of the rapeseed oil fuel emissions. Therefore, an experiment was made on the changes of the composition of the exhaust gases using rapeseed oil as fuel and its blends with fossil diesel fuel. In the research it was stated that rapeseed oil 50 % blend with fossil diesel fuel was the most optimal as at average revolutions the emission of CO_2 is comparatively the smallest, the amount of NO_x and SO_2 is decreased using all blends but the amount of CO, mechanical particles and unburned hydrocarbons is approximately the same in the emissions for all fuel samples.

Keywords: rapeseed oil, diesel fuel, exhaust gases.

Introduction

With development of technologies pure plant oil as well as in blends with fossil diesel fuel is increasingly used as diesel engine fuel in Latvia. From the results of the previous research it can be concluded that plant oil that complies with the EU standard requirements can be used continuously in diesel engines and its usage does not cause damage of the engine or its systems. In turn, research in the composition of plant oil fuel emissions shows that the content of toxic substances in exhaust gases similarly as it is for biodiesel fuel decreases in comparison with fossil fuel and the amount of separate toxic emission components is even smaller than for biodiesel fuel. But the decrease of separate toxic components does not mean that the emissions in total are less harmful [1; 2]. Therefore, a pilot study was performed in which the composition of the toxic components of exhaust gases using rapeseed oil fuel, fossil fuel and blends of these fuels was compared. The choice of the fuels was based on the following main criteria: rapeseed oil – most economically efficient biofuel, fossil diesel fuel – most common diesel engine fuel.

Materials and methods

During the research two fuels were tested – rapeseed oil and fossil diesel fuel as well as three blends of these fuels – 25 %, 50 % and 75 % rapeseed oil and fossil diesel fuel blend (Fig. 1).

Fig. 1. **Fuels used in the experiment**

The experimental tests were performed in the Scientific Laboratory of Biofuels (Latvia University of Agriculture). The exhaust emissions were determined by the *AVL SESAM FTIR* analytical system. It is possible to determine or calculate 25 different emission components. The main of them are: C_2H_2; C_2H_4; C_2H_6; C_3H_8; C_4H_6; C_4H_8; CH_4; CO_2; CO; H_2O; mechanical particles; N_2O; NH_3; NO_2; NO; SO_2 etc. With the AVL analytical system it is possible to measure and register the composition of emissions in idling as well as in different movement and load regimes. In continuous measuring mode the equipment is able to operate for 60 minutes.

Emissions were determined on an engine test bench that was equipped with an *Opel 16 DA* one row four cylinder *OHC* diesel engine and a 'two tank system'. The engine working capacity is 1598 cm^3, the compression rate – 23 and power 40 kW. In the engine fuel system a high pressure pump *Bosch VE 4/9R215* is used.

Before starting the experiments the fuel blends that were used in the tests were prepared, an exhaust gas suction pump was added with an *AVL SESAM FTIR* emission analyser detection probe and a stroboscope *Strobotester DG85* for measuring of engine revolutions. After preparation the engine was started and warmed up with fossil fuel to the working temperature 85 – 87 ºC.

In the process when the experimental fuel is replaced, the drainage pipe is turned to a new tank and the next fuel is fed for inflow. In order to be sure that the replacement of fuel has been complete and in the flow-out there is a clean blend, not mixed with the previous blend, a glass pipe is put into the drainage channel through which the fuel and its colour are seen. The fuel system capacity of this equipment is 1300 ml, but for provision of complete replacement of fuel 1500 ml of the new fuel are pumped through the system.

The tests were performed at 880 min^{-1} – 180 seconds, at 1500 min^{-1} – 120 seconds and at 2500 min^{-1} – 120 seconds. The number of repetitions – 3. Such time ranges and the number of repetitions are chosen based on the previous research that showed that it is enough to have such parameters to get qualitative results with correlation up to 99.9 % [3].

Results and discussion

Increasing the proportion of rapeseed oil in fuel the engine was working with a nicer sound. No mistakes were observed during the whole experiment. All emission components are measured in ppm (particles per million) measuring units.

Comparison of CO and CO_2 emissions of fuels and their blends at different engine revolutions is shown in Figure 2.

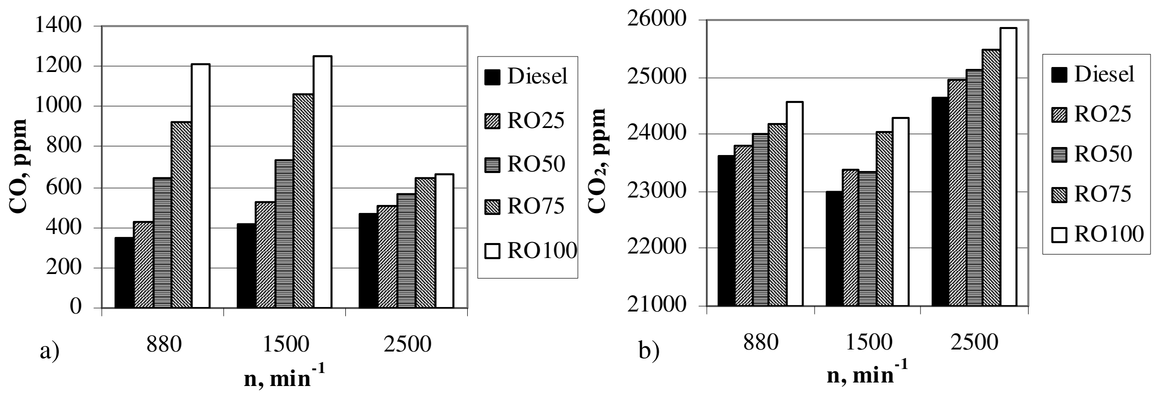

Fig. 2. **Comparison of CO and CO_2 emissions**

The results of the experiment show that CO emission (Fig. 2, a) at 880 and 1500 revolutions using RO50 is almost two times higher than for fossil diesel fuel, but using RO100 – up to three times higher. It can be explained by different fuel ignition temperatures. At 2500 revolutions CO emission using rapeseed oil and its blends is slightly higher in comparison to fossil diesel fuel as in the cylinders the working temperature increases stimulating more complete combustion.

CO_2 emission gradually increases almost at all revolutions (Fig. 2, b). Only at 1500 min^{-1} 50 % blends CO_2 emission is lower than for the rapeseed oil 25 % blend with fossil diesel fuel. The lowest

CO_2 exhaust gas concentration compared by revolutions is at 1500 min^{-1}. In average it is 1.8 % lower than at 880 min^{-1} and 6.32 % – than at 2500 min^{-1}.

The smallest SO_2 emission is for rapeseed oil at 1500 min^{-1}. Compared to 880 min^{-1}, it has in average decreased by 37 % but at 2500 min^{-1} its amount has reduced by 72 %. The largest amount of SO_2 emission, operating the engine with fossil diesel fuel, is observed at revolutions 2500 min^{-1} (Fig. 3, a).

Nitric oxide emissions at 880 and 1500 revolutions gradually decrease with increasing the rapeseed oil concentration (Fig. 3, b). Only using RO25 blend it is slightly higher than for fossil diesel fuel – by 3.57 %. At revolutions 2500 min^{-1}, NO_x is similar for all blends and the difference does not reach 10 %.

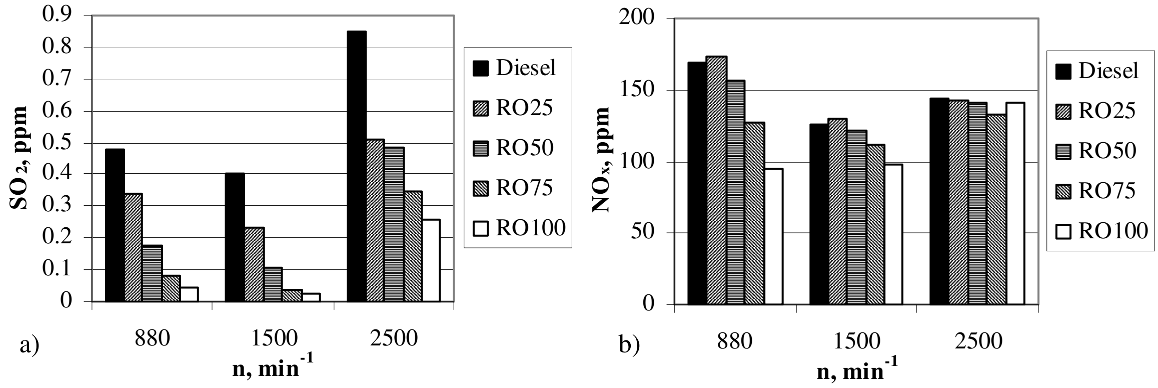

Fig. 3. **Comparison of SO_2 and NO_x emissions**

The amount of mechanical particles increases increasing the proportion of rapeseed oil in the blend (Fig. 4, a). Only at 2500 min^{-1}, using the RO25 blend, the mechanical particles decreased by 5.3 % in comparison to fossil diesel fuel. Using fossil diesel fuel and rapeseed oil up to 75 % blends at 1500 min^{-1} the mechanical particle content is the highest. At revolutions 880 and 1500 min^{-1} the amount of hydrocarbon emissions increases (Fig. 4, b) increasing the concentration of rapeseed oil in the blends. Only using RO25 the hydrocarbon emission is lower than for fossil diesel fuel. At revolutions 2500 min^{-1} the amount of unburned hydrocarbon emissions drops and their lowest value is using pure rapeseed oil.

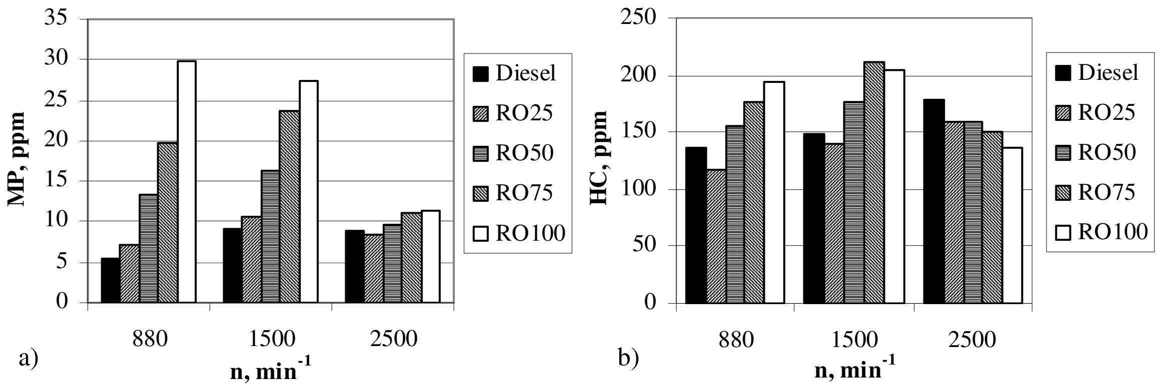

Fig. 4. **Comparison of mechanical particle and unburned hydrocarbon emissions**

Table 1 shows rapeseed oil and blend relative emission variations compared to fossil diesel fuel. It can be seen that using pure rapeseed oil at 2500 min^{-1} the increase of CO emissions is the smallest – 41.27 %. Compared to 1500 and 880 min^{-1} it has reduced up to even six times. The most essential decrease of SO_2 emission is using pure rapeseed oil.

Examining the relative change of unburned hydrocarbon emission it can be seen that at 2500 min^{-1} using rapeseed oil the amount of unburned hydrocarbons has reduced by 23.81 %. But at lower revolutions using this fuel it has averagely increased by 40 %. Using RO25 blend the amount of unburned hydrocarbons has reduced at all revolutions.

Table 1

Relative changes of the amount of different toxic emissions

Relative changes of CO content in exhaust gases compared to diesel fuel				
Revolutions, min^{-1}	**RO25**	**RO50**	**RO75**	**RO100**
880	24.00 %	86.67 %	165.98 %	249.89 %
1500	25.54 %	75.23 %	153.98 %	199.20 %
2500	7.37 %	20.68 %	37.42 %	41.27 %
Relative changes of CO_2 content in exhaust gases compared to diesel fuel				
Revolutions, min^{-1}	**RO25**	**RO50**	**RO75**	**RO100**
880	0.78 %	1.67 %	2.33 %	3.98 %
1500	1.62 %	1.43 %	4.55 %	5.50 %
2500	1.26 %	2.08 %	3.41 %	4.95 %
Relative changes of SO_2 content in exhaust gases compared to diesel fuel				
Revolutions, min^{-1}	**RO25**	**RO50**	**RO75**	**RO100**
880	-29.11 %	-62.61 %	-83.51 %	-90.86 %
1500	-41.63 %	-73.47 %	-90.53 %	-94.10 %
2500	-39.97 %	-42.48 %	-59.00 %	-69.81 %
Relative changes of NO_x content in exhaust gases compared to diesel fuel				
Revolutions, min^{-1}	**RO25**	**RO50**	**RO75**	**RO100**
880	2.50 %	-7.10 %	-24.29 %	-43.32 %
1500	3.57 %	-3.20 %	-10.81 %	-22.24 %
2500	-0.30 %	-2.05 %	-7.80 %	-1.67 %
Relative changes of unburned hydrocarbon content in exhaust gases compared to diesel fuel				
Revolutions, min^{-1}	**RO25**	**RO50**	**RO75**	**RO100**
880	-14.61 %	14.52 %	29.29 %	42.49 %
1500	-6.51 %	17.85 %	41.26 %	36.54 %
2500	-10.96 %	-10.81 %	-15.27 %	-23.81 %

The engine during the experiment was operated in a wide range of revolutions, therefore, the comparison of exhaust gases has been done at 1500 min^{-1}, i.e., at average revolutions. Evaluating the obtained data (Table 2), it can be concluded that the lowest CO_2 emission is using RO50 blend, but NO_x and SO_2 reduces using all blends and pure rapeseed oil.

Table 2

Comparison of exhaust gases

Comparison of exhaust gases at 1500 min^{-1}						
	NO_X	**MP**	**SO_2**	**HC**	**CO_2**	**CO**
Diesel	125.29	9.2	0.40	149.28	23008.32	418.48
RO25	129.76	10.53	0.23	139.56	23381.85	525.37
RO50	121.28	16.31	0.10	175.94	23337.41	733.32
RO75	111.75	23.62	0.03	210.88	24054.58	1062.85
RO100	97.42	27.38	0.02	203.82	24272.96	1252.12

Evaluating the amount of toxic emissions in exhaust gases two basic conditions should be considered:

- influence of exhaust gases on environment considering the topicality of global warming;
- influence of exhaust gases on human health in a short period of time [4].

Considering the influencing factor on global warming, certainly, the priority is given to rapeseed oil as fuel as a renewable resource and rapeseeds in the growing period take more CO_2 than discharge while burning.

Evaluating the influence of toxic exhaust gases on human health not only CO_2 should be considered but also the amount of such emissions as, for example, CO, NO_x, unburned hydrocarbons and mechanical particles that directly influence human health mainly causing respiratory irritation within a short period of time.

Summarising the results obtained in the experiment it can be understood that pure rapeseed oil cannot be referred as less harmful fuel as burning it discharges a big amount of CO, unburned hydrocarbons and mechanical particles. Therefore, a blend of rapeseed oil and 50 % fossil diesel fuel, the content of emissions of which can be considered to be more environment friendly and little harmful to health, is accepted to be the most suitable fuel for environment and human health.

Conclusions

1. Although rapeseed oil is a renewable energy resource and its application is favourable for the surrounding environment, it cannot be considered as harmless fuel. In its emissions there are several toxic gases the amount of which is larger compared to the amount of exhaust gases created by fossil diesel fuel. Therefore, using pure rapeseed oil as fuel it is possible to considerably harm the human health.
2. Rapeseed oil and 50 % fossil diesel fuel blend on the emission level is more suitable fuel as the amount of CO_2 in exhaust gasses is the smallest, but the amount of SO_2, NO_x and unburned hydrocarbons is smaller than operating the engine with fossil diesel fuel.
3. Rapeseed oil and 50 % fossil diesel fuel blend is adequate to the surrounding environment as well as to the safety of human health.

Acknowledgements

Funding support for this research is provided by Europe Social Fund program ‘Support for doctoral studies in LUA’, agreement No. 2009/0180/1DP/1.1.2.1.2/09/IPIA/VIAA/017.

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