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EXHAUST EMISSION OF DIESEL ENGINES FOR OPERATION OF AGRICULTURAL MECHANIZATION WHEN WORKING WITH DIFFERENT BIOFUELS

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ABSTRACT

The paper presents the results of the study of the effect of different biodiesel-type fuels produced from the oils of several oilseeds on the exhaust gas composition of a direct injection diesel engine designed to drive smaller agricultural machinery. The fuels obtained in this way are derived from the corresponding oils by the method of esterification using methyl alcohol and a catalyst to give the corresponding methyl esters. The physicochemical characteristics of these methyl esters are approximately equal to the standard Euro diesel diesel fuel. During the research, a comparative measurement of the exhaust gas composition was made, at the propulsion of the engine with these fuels, followed by an appropriate analysis of the results. A suitable research installation has been formed to conduct these studies at the Institute of Motors, Faculty of Mechanical Engineering in Belgrade.

Key words: diesel engine, exhaust emission, biofuel

INTRODUCTION

In modern agricultural production, it is very practical and useful for farmers to be able to independently produce a part of the necessary motor fuel to power their machinery. On the other hand, such eventual production of “off the field” fuel has its significant economic justification. The fuel obtained in this way can be of high quality and without much difference in terms of physico-chemical characteristics compared to commercial diesel produced according to ASTM DE 6751 or European standard EN590, which are of the Euro diesel type.
In this country, the impact of biofuels on the composition of exhaust gases has been conducted previously, but only with one type of fuel [3,4]. Here, research has been extended to a greater number of fuels [1], while the fundamental mechanisms of the formation of toxic components are given in [2]. Many studies have been made in the world on the effect of biofuels on diesel exhaust emission characteristics, as shown in [5,6,7,8,9,10,11]. In the process of biodiesel production, which is described in detail in [1], a feedstock is used, which in the process of esterification is converted to the corresponding oil ester, ie feedstock ester. Depending on the feedstock used for fuel production, different types of biodiesel can be obtained such as rapeseed methyl ester, soybean methyl ester, palm oil methyl esters, waste oil oils, sunflowers, etc. The research presented here used biodiesel made from rapeseed oil labeled RME100, soybean oil SME100 and palm edible oil PME100, and the results obtained were compared with those obtained with D100 diesel fuel.

All of the methyl esters mentioned in the engine were used as pure propellants, as indicated by the code 100 in the name of the fuel in question. It should also be noted that after prolonged operation of these fuels, engine disassembly and visual inspection of vital engine assemblies were performed and no presence of

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larger soot deposits was observed in the combustion chamber at the valves and at the injector indicating a high level of quality of the obtained vegetable oil methyl esters.

TEST PROCEDURE

For the purposes of these comprehensive scientific research activities, an appropriate, very complex, laboratory installation has been formed schematically, which is shown in Figure 1.

The schematic diagram of the installation gives the basic positions necessary to get an impression of how the installation in question works, as well as the position of the corresponding measuring sensors. Some components of this installation will be described in more detail later. Otherwise, this picture shows the complete installation in case of exploration in the supercharged variant, while the intake variant uses the same installation components except the supercharger system. The results of measuring the composition of the exhaust gases in the supercharged engine watt are shown and the recharging was performed by a roots compressor driven by an external energy source.

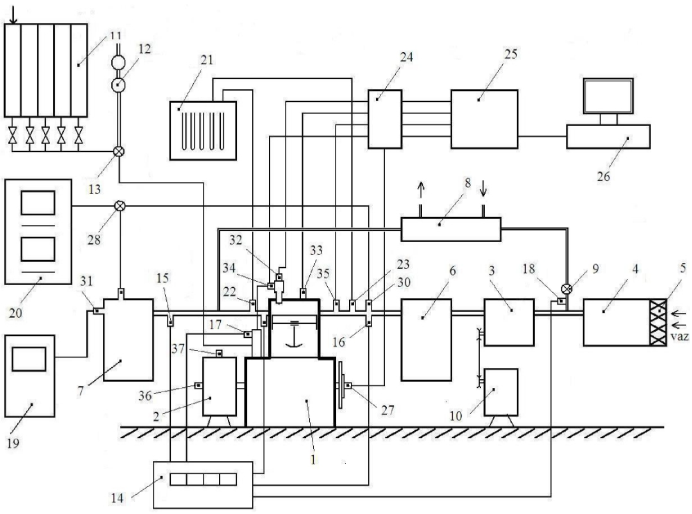

Figure 1. Experimental installation for testing gaseous emission
Main Position: 1-engine, 2- electrical dyno, 4-mass flow for air,
7- exhaust system, 20- gaseous analysers, 24,25,26- acquisition measuring and testing system

Experimental equipment and set up

The engine used for the research was LDA450, domestic production from the factory May 21 - Belgrade, and the technical specifications of the engine are given in Table 1.

Table 1. Main specifications of test engine

Engine type	Diesel 4 stroke, direct injection, air cooled, single cylinder for agricultural application
Bore/stroke	85/80 mm
Compression ratio	1:17,5
Max. power output	5 kW/2500 rpm
Fueling system	High pressure pump, injector with 4 jets, (4 x 0.28 mm)

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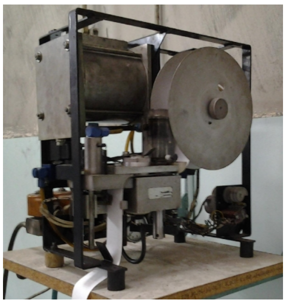
While experimental fuels are produced from suitable vegetable oils by an esterification process in accordance with standard EN14214: 2010. In this way, this fuel, by its physicochemical characteristics, approaches to diesel fuel produced according to the standard SRPS EN 519: 2010, which is important especially in terms of viscosity.

For this type of research, the main component is the gas analyzer. Exhaust composition and smoke were measured with Stargas 898 One and AVL 4010, Figure 2a and 2b. The Stargas 898 Exhaust Gas Analyzer is a portable analyzer that meets the international standard OIML R99 (Class 0), which is designed to analyze the exhaust composition of oto and diesel engines. It allows the determination of CO carbon monoxide, CO2 carbon dioxide, O2 oxygen, unburnt HC hydrocarbons and NOx nitrogen oxides in the engine exhaust. In addition, the device optionally also allows determining some of the sizes by which the technical condition of the engine can be estimated according to the condition of those sizes. Figure 2a shows the external appearance of the exhaust analyzer used in these studies.

a)



b)

Figure 2 a) Gaseous analyser STARGAS 898 One i b)SMOKE AVL 4010

The Stargas 898 gas analyzer is structurally designed with two basic parts:

- part for collecting measurement data
- value reading section with display

There is an option to connect the keyboard to the IC port. The analyzer module used to determine the composition of the exhaust gas is common to the three CO, CO2 and CH gases, while electrochemical cells are used to determine the O2 and NOx concentrations. The microprocessor calculates the composition of the mixture based on the concentration of the analyzed gases. The exhaust gas analyzer consists of two parts:

- Pneumatic sampling and water vapor flow
- chambers for analysis based on infrared radiation.

An infrared-based chamber is used to determine the concentration of CO, CO2, CH, and an electrochemical cell is used to measure O2 and NOx concentrations. The basis of the pneumatic take-up part

The sample consists of a diaphragm pump with a drive part. The sample is filtered before entering the analyzer. The analyzer has an inlet for connecting the calibration gas. The gas mixture passes over the sensor located on the analog-digital circuit and can also signal any anomalies in the suction circuit. In this study, the AVL 4010 dimer was used, Figure 2 b), which has a measuring range of 0-10 Bosch exhaust units. The exhaust fumes of diesel engines originate from the presence of soot particles in the exhaust gas, and based on the methods of measuring the smoke, the instrument makes gas leakage through special filter paper and a relative comparison of the degree of blackness of the filter paper from level 0- completely white paper to level-10 completely black paper. The measurement gas sample was taken from the expansion vessel, position 7 of Figure 1, in the prescribed quantity to be measured by the measuring device. After reading the degree of blackness by the measuring head of the device, the smoke number in the Bosch units is read on the device display.

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EXPERIMENTAL RESULTS

Figure 3 (left), shows the smoke emission in Bosch units for all biofuels and reference diesel. It can be seen that in all engine operating modes shown, the smoke emissions for biofuels are lower than for diesel. At the highest load level, the exhaust fumes are significantly lower with biofuels than with diesel. The lowest smoke is achieved with RME100, 51.3% lower compared to diesel emissions, smoke emission with SME100 is lower by 45.9% and PME100 by 43.2%. As for the difference in smoke emissions between different biofuels, this difference is much smaller and amounts to about 14.2% at the highest load level, up to 17.6% at the lowest level. These inter-differences in smoke emission between biofuels are most likely due to inter-differences in the physicochemical characteristics of these biofuels.

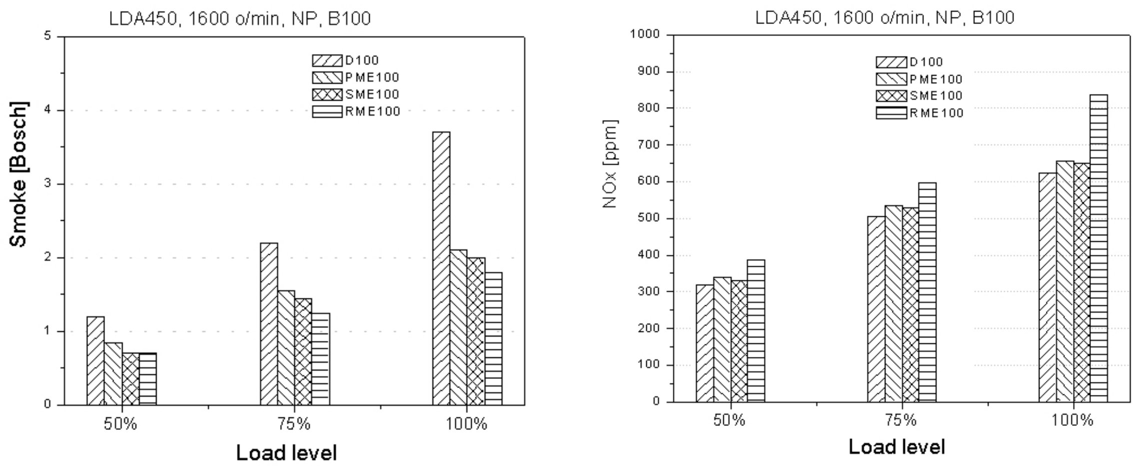

Figure 3. Smoke emission and NOx tested from pure biofuels under various engine loads

Figure 3 (right) shows the differences in the level of nitrogen oxides - NOx emission in the three operating modes. All biofuels give higher NOx component emissions compared to diesel fuel. The differences in the NOx emission of individual biofuels are due to differences in the characteristics of the biofuels themselves as well as to the difference in the composition of the mixture for these different biofuels due to the different oxygen content of the fuel molecule. The main cause of NOx formation during the combustion process is the temperature in the cylinder of the engine, the availability of oxygen for combustion, especially the amount of oxygen present in the fuel molecules, and the duration of the cooldown period.

Of particular importance is the influence of oxygen existing in the structure of the fuel and its rapid availability to form a stoichiometric ratio of fuel to air, especially in the periphery of the jet. In this zone, favorable conditions for the formation of the NOx component are created at the high temperatures prevailing during the combustion process, especially during the unregulated combustion period. The lower amounts of heat developed during the unregulated combustion period have the effect of lowering the mean cycle temperature, which should contribute to the reduction of NOx emissions. However, if zones in the hot jet with a very high temperature occur locally. NOx formation will occur faster, the formation reaction will take longer and aided by the presence of oxygen in the fuel molecule, a larger amount of NOx component will appear in the exhaust, which is the case here. The diagram shows that the RME100 fuel produces the highest NOx emissions, up to about 34% higher emissions than in the case of diesel fuel at the highest load level. The other two fuels also produce higher NOx emissions compared to diesel fuel, but to a lesser extent. Regarding the differences in NOx emissions between different biofuels, it can be said that this difference ranges from 17.5% at load 50% to 28% at the highest load level.

When it comes to CO and CH components, their concentrations can be seen in Figure 4. Carbon monoxide

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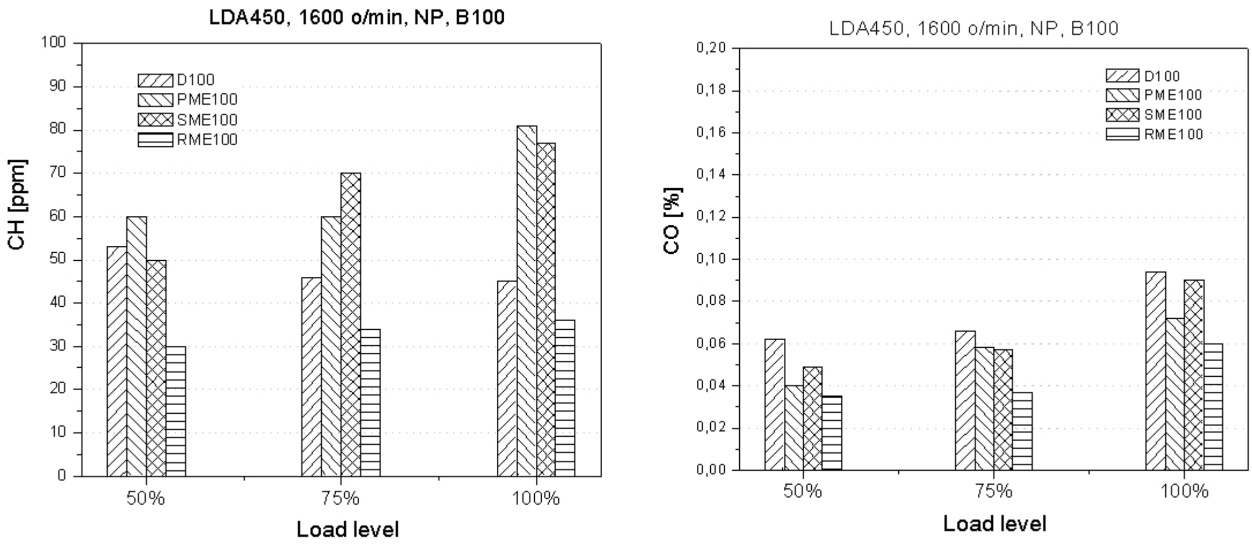
emissions are always lower when working with biofuels than when working with diesel. In particular, the lower COE emission of fuel is RME100 in all operating modes. It can be seen that the RME100 fuel emission is even the lowest in all operating modes. For all fuels, including the reference diesel, the CO component emission increases slightly with load levels.

When it comes to the emission of unburnt CH hydrocarbons for different biofuels, it can be seen that the emission of this component has a rather unpredictable character depending on the operating mode, which is probably due to the inaccurate measurement of this component and its condensation in the lines from the sampling point to the measuring device. However, a certain increase of this component for two biofuels and one can be noted as decreased RME 100.



Figue 4. Emissions of CO tested by pure biofuels under various engine load

Along with measuring the emission of toxic components, carbon dioxide emissions were measured, as shown in Figure 5. There is a slight increase in CO2 emissions when working with RME100, PME100 and SME100 biofuels over that of diesel. This increase is very small except at the highest load level where variation is slightly more noticeable.

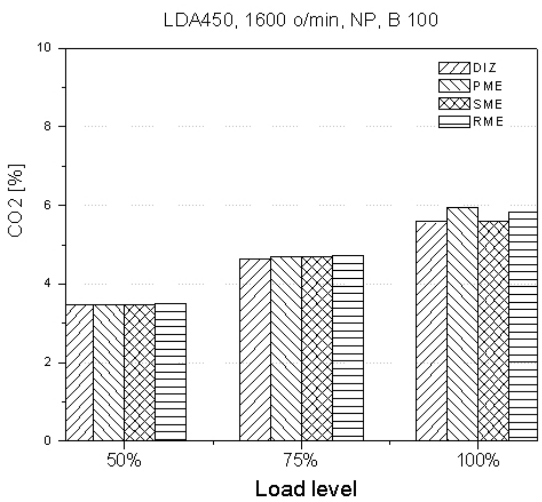


Figure 5. Emission of CO_2 tested pure biodiesel under different engine loads

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CONCLUSION

The research presented in this paper indicates that the content of toxic components in the exhaust gases of a research engine is variable in character with respect to the case of diesel fuel operation. Smoke emissions are always lower when working with biofuels. NOx emission is slightly higher when working with biofuels, while CO and CH emissions are such that CO is always lower while the CH component emissions are higher except for RME100. RME100 biodiesel is considered to be the most favorable in terms of exhaust emissions.

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