

Analysis of efficiency of the vehicle transport facilities powered with diesel oil with additive of biocomponent

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Abstract. The prospect of renewable energy sources development to be used in transport originated from the tendency to limit the use of fossil fuels which leaves no choice but look for other possibilities to provide combustion engines with power supply. Use of fuel from renewable sources has also a positive influence on the environment and economy. The research object of the study was a power unit of a car transport means with a direct injection diesel engine, equipped with a common rail supply system. The tests were performed by the method of a laboratory experiment during which the experimental factor was controlled so that the experiment would be thoroughly scheduled. The method involved performing tests on a chassis dynamometer and measuring the power and torque depending on the engine rotary speed. Measurement of the power and the torque, in dependence on the crankshaft rotation speed of the engine, was performed for standard settings of the fuel injection controller. At the same time the impact of adding biocomponent to a fuel on its consumption values has been analysed. The tests also included an analysis of the exhaust fumes content: carbon monoxide, hydrocarbons, solid particulates and nitrogen oxide. The obtained results were analyzed and presented in the form of generalized conclusions concerning the impact of using various biocomponent additives in diesel engines including the impact on selected operational parameters of the vehicle, level of harmful substance emission and specific fuel consumption.

1. Introduction

Protection of the planet's natural environment and the mining resources is one of the most important problems taken up by the authorities and the society. Implemented and exacted by the European Union application of additives in the form of the fatty acids methyl esters to the diesel fuel, allows to decrease consumption of the mining power sources. The European Union, within the ecological commitments, is planning normalization of power consumption by 2020, what is to result in the increase of the share of renewable energy sources up to 20% of the total power consumption in EU, including the increase of the renewable energy sources' use in transport up to 10% [8].

Apart from the diesel oil, alternative fuels are used to power motors with self-ignition. The oils of plant origin like: arachis, rape, corn, linseed, ricinus, palm, soya oils, are included in this group [3]. In Poland, rape is the most popular plant for alternative oils' production, because of the cultivation conditions. The mixture of the diesel oil and the transesterificated diesel oil, that is biodiesel [4], is most often used to power motors with self-ignition. Biodiesel is considered to be the alternative fuel for motors with self-ignition. As opposed to the diesel oil, biocomponent is the biodegradable and nontoxic



fuel, and its use results in a considerable reduction of hazardous substances' emission to the atmosphere, it is used everywhere, where the diesel oil is [2]. Additionally, the mixture of the diesel oil and the fatty acids methyl esters, has much better lubrication properties than the traditional diesel oil and it significantly extends a motor's life [3]. The use of alternative fuels also reduces the emission of noise generated during engine operation [6]. There are also many pro-ecological arguments in favour of biodiesel's application, such as: no environment pollution with sulphur compounds and reduction of the CO₂ volumes introduced to the atmosphere. However, the use of biodiesel results in forming of for more than 20% of nitrogen oxide introduced to the atmosphere. There also occur complications connected with biodiesel use, such as: reaching the required cetane number, solubility of plastics under the influence of biodiesel, change of physical properties, viscosity under the influence of temperature, requirements of the use of additional motor's cooling sources, change of mechanical properties at negative temperatures, so-called gelling [10]. Transesterificated plant oil is characterized by much better parameters for compression-ignition motors than the raw plant oils. It has the properties close to the diesel oil. In the table 1, there are presented the basic parameters characterizing the biodiesel and the diesel oil.

Table 1. Basic parameters characterizing biodiesel and the diesel oil (own study based on ASTM 2007)

Parameter	Biodiesel	Diesel oil
Viscosity [$\text{mm}^2 \cdot \text{s}^{-1}$]	3.5-5.0	2.0-4.5
Content of sulphur [$\text{mg} \cdot \text{kg}^{-1}$]	≤ 10	≤ 350
Mass density [$\text{g} \cdot \text{cm}^{-3}$]	0.86-0.90	0.82-0.845
Cetane number	≥ 47	≥ 51
Contents of particulate solids [$\text{mg} \cdot \text{kg}^{-1}$]	≤ 24	≤ 24
Contents of water [$\text{mg} \cdot \text{kg}^{-1}$]	≤ 500	≤ 200
Coal residues [%]	≤ 0.3	≤ 0.3
Fire point [$^{\circ}\text{C}$]	≥ 101	≥ 55

It is the rape oil that is the most often used raw-material for production of fatty acids ethyl esters. Last years, a significant increase of rape production has been recorded in the Western European countries (Germany, France, Italy), and in the Eastern European countries (Belarus, Ukraine). Production of rape in Poland concentrates within the regions of Zulawy, Western Pomerania, Kuyavia, Lublin, Opole, Wrocław, Olsztyn. For the power purposes, there are produced the varieties of dual improved rape of low contents of erucic acid and glucosinolates. Due to high coefficient of substance's viscosity, the use of the rape oil in its pure form is not possible in diesel engines. In order to use the rape oils for the combustion engines, they have to be modified by reducing of the viscosity parameters by [5]: diluting of the plant oil with diesel fuel of naphtha origin, microemulsification with micromolecular alcohols for ex. methanol in the presence of ionic or non-ionic emulsifying agent, thermal decomposition or cracking and then releasing of an appropriate fraction by way of distillation, ester exchange with micromolecular alcohols (methanol, ethanol and butanol).

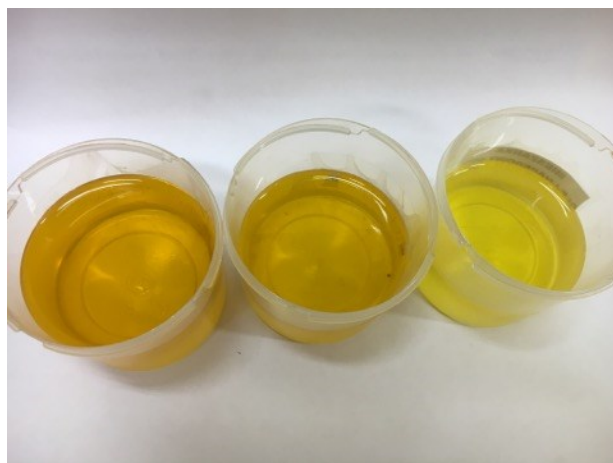
2. Methodology, materials

The material used for the tests were the mixtures of fatty acids methyl esters and the diesel oil, the proportions of which are presented in table 2.

Table 2. Proportions of mixtures used for the tests (own study)

No.	Composition of the mixture	Mixture's marking
1	Diesel oil	mixture I
2	90% diesel oil 10% methyl esters of fatty acids	mixture II
3	70% diesel oil 30% methyl esters of fatty acids	mixture III
4	50% diesel oil 50% methyl esters of fatty acids	mixture IV

The ester exchange process means the exchange of the chemically bonded glycerol in a triacylglycerol molecule into the methyl alcohol added in the presence of a basic or acid catalyst, which are commonly called biocomponents [9]. In figure 1, the view of the diesel oil and the fatty acids methyl esters of mixtures in proportions 10%, 30% and 50%, used in tests. The analysis of properties of the discussed diesel oil and biocomponent blends was discussed by the authors in previous studies [7].

**Figure 1.** Exemplary mixtures used for tests (own study)

The object of the tests was the combustion motor with self-ignition of the power of 80 kW, with turbocharger and with direct common rail injection and with the applied electro-magnetic injectors, which is presented in figure 2. The tested drive unit is used in vehicles of the allowable total weight not exceeding 3.5t. A vehicle powered with the above-mentioned motor, has been singled out for the tests due to the following features: universality of its use as the means of transport and possibility of the injection parameters' modification, resistance to possible disadvantageous consequences resulting from the use of the fuel mixture. In the tested object there was conducted adaptation of the feed system, allowing for non-invasive change of fuel powering the motor. An additional fuel tank was installed. During the tests, the computer software controlling the motor was changed. The performed modifications did not directly interfere in the power unit's construction, they concerned only the motor's fixtures and its software. The fuel powering system was connected from the additional tank directly to the power unit. There were also performed modifications of the exhaust system allowing for placement of the exhaust gases analyser's probe and the measuring instrument of the volume of particulate solids ahead of the catalyser and the exhaust system (the vehicle is not factory-equipped with the particulate solids' filter).



Figure 2. The tested drive unit (own study)

The tests were conducted on the chassis test house, on which the road conditions may be simulated. The vehicle put on the test house's rollers, was strapped with belts to the foundation. Each time during a test, it was under the load up to the speed of 140 km/h. The appliance, considering the information on the diameter, mass and the rollers' inertia, measures acceleration with which the vehicle's wheels set the rollers in motion. On that basis, the power and the turning moment of the means of transport's power unit and the unit fuel consumption are calculated. During the operating tests of the vehicle means of transport, the measurements of the following were conducted: course of the power changes and the turning moment depending on the motor's rotational speed, exhaust gases' composition, the volume of particulate solids in exhaust gases. Each of the listed measurements was conducted in repetitions for individual fuel mixtures. The measurement of the fuel combustion products in the motor with self-ignition, was conducted with the use of the fuel analyser, type MGT-5. The device allows for measurement of such components like: carbon oxide, carbon dioxide, hydrocarbons and oxygen. The analysis of the volume of particulate solids in exhaust gases, was conducted with the use of an instrument measuring the particulate solids mass concentration in the exhaust gasses of MPM-4 motors.

3. Tests' results

The obtained results of the measurements were subject to the statistical analysis and are presented in the table 3 and in the figures 3 and 4.

Table 3. Results of the power and the turning moment's measurements

No.	Type of a mixture	Power	Turning moment
1	ON	100.95	238.88
2	10% BIO 90% ON	101.49	246.87
3	30% BIO 70% ON	100.15	233.60
4	50% BIO 50% ON	100.99	239.50

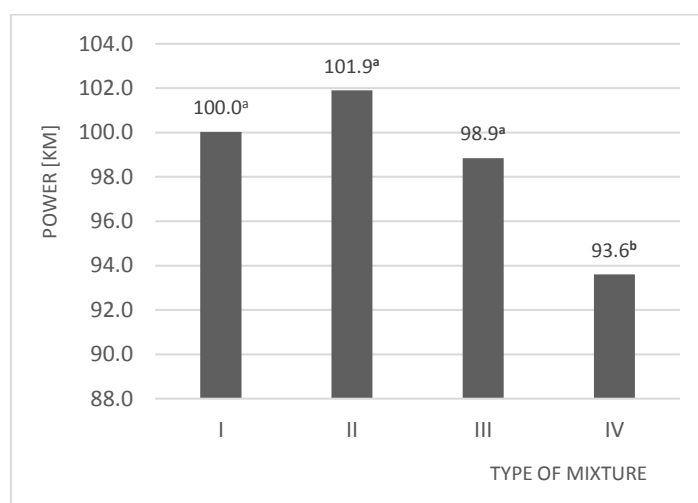


Figure 3. Measurement results of the engine's power supplied with different mixtures

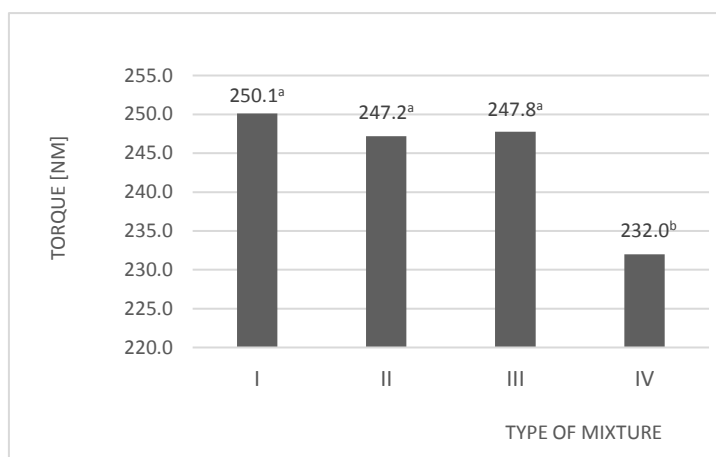


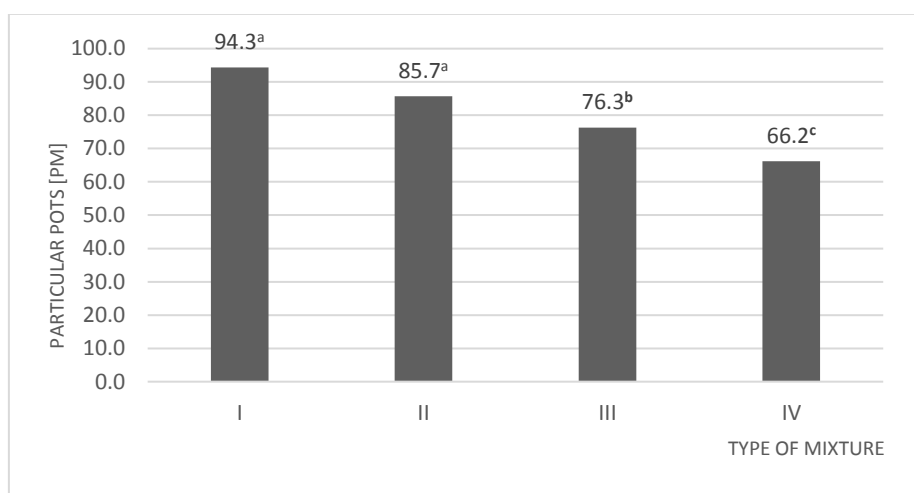
Figure 4. Results of the turning moment of a motor supplied with different mixtures

Based on the conducted analyses it was found, that no statistically significant change of power occurs for the content of biocomponent up to 30% in the fuel. The power obtained for the motor powered with mixture I, II and III, did not statistically significantly differ among themselves. The power obtained during operation of the motor powered with the mixture IV (of the biocomponent's content amounting to 50%) differed statistically significantly from the remaining cases and was for about 8.2% lower than for the power obtained at the motor's supplying with fuels of the lower biocomponent's content or with the diesel oil without biocomponent's additive. Similarly, like in case of power, the obtained moment, in case of the motor's supplying with fuels of the content up to 30% did not statistically significantly differ among themselves. It was only for 50% of biocomponent's additive in the diesel oil when the statistically significant drop in the turning moment was measured, and it was for approximately 7.2% lower than for the remaining cases.

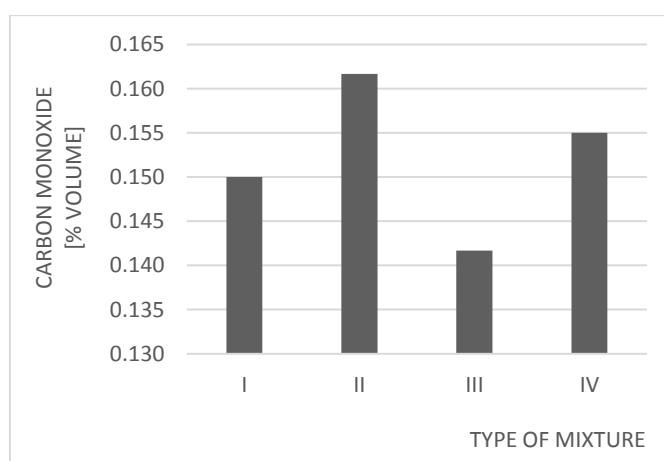
The measurement of combustion gases and particulate solids was conducted for the purposes of determining the volume of toxic components for the power unit of self-ignition supplied with the mixture of the diesel oil and biocomponent. The tests were conducted at the time of power and the turning moment's measurements on the chassis test house.

Table 4. Composition of exhaust gases and the number of particulate solids in exhaust gases

	ON	10% BIO 90% ON	30% BIO 70% ON	50% BIO 50% ON
carbon oxide	0.1307	0.1563	0.0683	0.057
carbon dioxide	11.96	11.99	11.89	12.00
hydrocarbons	51.47	22.10	9.03	65.00
carbon dioxide	17.269	15.782	10.249	7.887
nitrogen oxides	227.23	237.17	237.77	280.4
particulate solids	94	85.73	75.03	66.4

**Figure 5.** Contents of particulate solids

The contents of particulate solids in exhaust gases for the fuel I and II did not significantly statistically differ. At the increase of the fatty acids methyl esters' contents in the diesel oil, the number of particulate solids decreased, and for the fuel of the contents of 50% of biocomponent's additive it was for almost 30% lower than in the case of motor's fuelling with diesel oil without the biocomponent's additive.

**Figure 6.** Contents of hydrogen oxides in exhaust gases

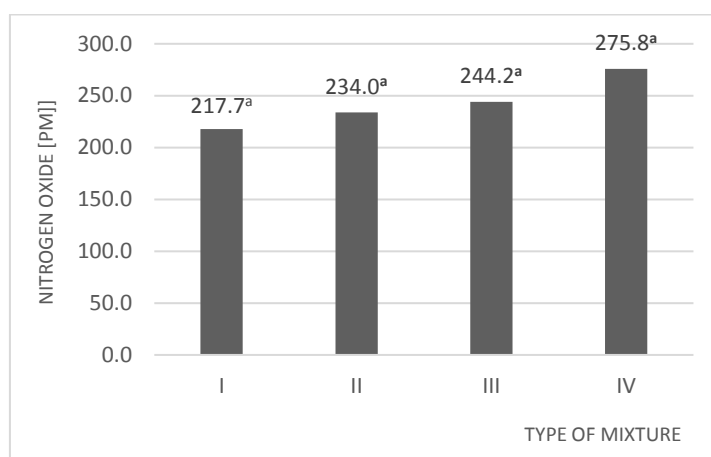


Figure 7. Contents of nitrogen oxides in exhaust gases

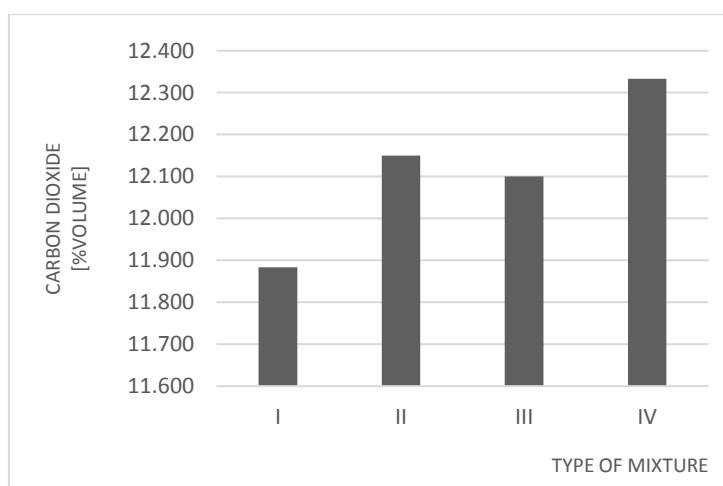


Figure 8. Contents of carbon dioxides in exhaust gases

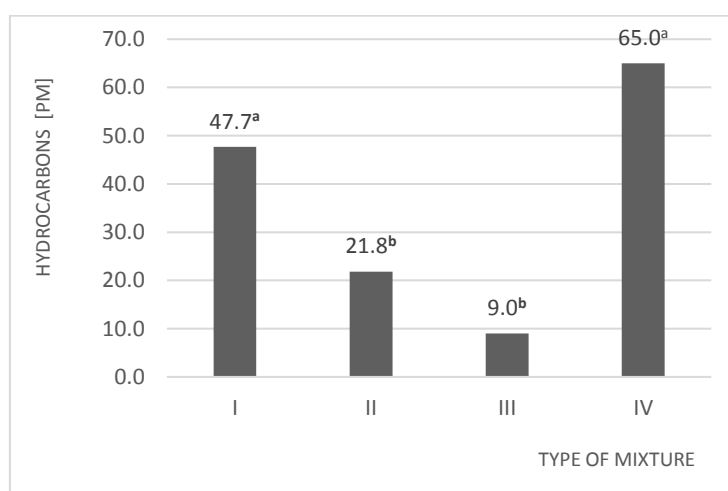


Figure 9. Contents of hydrocarbons in exhaust gases

From the statistical analysis of the obtained results of harmful substances in exhaust gases' measurements it results, that the additive of fatty acids methyl esters influences the concentration of

individual exhaust gases' components. The drop in the carbon dioxide and the carbon oxide as well as the increase of the nitrogen oxides may be noticed.

4. Summary

As a result of measurement of the toxic exhaust gasses' mass concentration and the particulate solids comprised in exhaust gases, conducted on MPM-4 and MGT-5 devices, there was obtained the distribution of the measured substances, which changed together with the quantitative change of the fatty acids' methyl esters additives to the diesel oil. Due to the content of such substances as carbon oxide and carbon dioxide in the exhaust gases, the additive of 30% of fatty acids' methyl esters to the diesel oil may be considered to be optimum. During the statistical analysis of the measurement results of the particulate solids comprised in exhaust gases', the decrease of their concentration by approximately 30% was noticed. On the basis of the obtained results it may be found, that application of the biocomponent's additive results in a slight drop of operating parameters (power and the turning moment) at simultaneous reduction of the toxic compounds' contents in exhaust gases. Based on the obtained results it may be concluded, that the use of the fatty acids methyl esters to the diesel oil is justified due to the limited environment pollution.

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