RESEARCH ON ENGINE POWERED WITH A MIXTURE OF DIESEL OIL AND BIOCOMPONENT AT CHANGE OF FUEL INJECTION SETTINGS

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Abstract
The basic fuel for powering engines with self-ignition is the diesel oil, the basic components of which are the products of crude oil's processing. The energy situation prevailing in the world (increase of prices and the decreasing natural resources) resulted in the return to the renewable fuels' concept. The design solutions of the drive units allow for their powering with diesel oil and biocomponent's mixture, due to the similar physio-chemical properties. In the work there are presented studies of the drive unit powered with the mixture of 70% of diesel oil and 30% of fatty acid methyl esters. In the subject matter of the studies, modifications were made in the settings of the fuel injection controller in order to fin dan optimum setting which would make it possible to obtain high effectiveness of the drive unit in case of the mixture's change.

Key words: *transport; environment protection; engine with self-ignition; biofuels; effectiveness of an engine; means of transport; working machines.*

INTRODUCTION

Protection of the natural environment and of fossil planet's resources, is one of the most important problem taken up by authorities and society. Additives of fatty acids methyl esters to the diesel oil accepted by the European Union, make it possible to reduce consumption of the fossil energy resources. The European Union planned normalization of energy consumption by 2020 within the frames of the ecological commitments *(Ministry of Economy, 2009)*.

The forecasts of the European Union point at the increased share of diesel oil in the transport section and keeping up of the constant consumption as the engine fuel. Release of the market from the supplies of the petroleum-derived fuels is the argument for resuming the idea of plant fuels. Plant oils are the ones which have the broadest application as far as production of biofuels is concerned. Among the renewable fuels of plant origin, there may be singled out the following ones: rape oil, soybean oil, sunflower oil, arachis oil and animal fats *(Bajor K. & Biernat K., 2011)*. The listed fuels of plant origin, commonly called biofuels, have to be exposed to chemical processes in order to obtain physio-chemical properties similar to the ones of the diesel oil. Because of technical, economical, design and technological reasons, the most often used oil is the rape oil, which is exposed to the process of chemical treatment in order to adopt it for self-ignition engines' powering *(Uzdowski M., 2006; Uzdowski M., 2008)*. Reliability of the means of transport and agricultural machines, to a big extend depends on the properties of fuels they are powered with *(Markiewicz-Patalon M., Muślewski M. & Kaszkowiak K., 2018; Markiewicz-Patalon M., et al., 2018)*. Application of transesterified plant oil as an additive to the diesel oil, makes it possible to improve the lubricating properties of fuel and extends the engine's life *(Dzieniszewski G., 2015)*. Additive of biocomponent in the volume provided for in the Directive of the European Union, has the physio-chemical properties similar to the diesel oil. Only the increase of the share of biocomponent in the diesel oil by 30%, shall result in visible differences in the fuel's structure *(Markiewicz-Patalon M. & Kaszkowiak K., 2017; Markiewicz-Patalon M., et al., 2017)*.

On the efficient and ecological engine's operation, apart from the fuel there also has an impact its design that is the systems co-operating with each other. The process of combustion in engines with self-ignition, depends on the correctly prepared air-fuel mixture, characterised by even concentration of fuel in the whole space of the combustion chamber and fuel's fragmentation into drops of the diameter as small as possible *(Luft S., 2011)*. On the fuel combustion's process, there also have the design and performance factors of the drive unit, such as *(Włodarski J., 1982)*: material of a piston, compression degree, the engine's supercharging, design of a combustion chamber, fuel injection's parameters, the angle of the injection advance, composition of a combustible mixture, the engine's loading and the engine's

rotational speed. The systems of the self-ignition engine's powering may be divided into the systems controlled electronically and mechanically. Electronic controlling in these engines is used mainly because of the possibilities of interference in the course of the fuel's injection and its precise control *(Lotko W., 1995)*. Change of the injection's course allows to increase the engine's efficiency.
The aim of the study was to analyze the operational parameters of the self-ignition engine powered by a blend of diesel and fatty acid methyl esters.

MATERIALS AND METHODS

The subject matter of the studies was the engine with self-ignition, which has been widely used in the motor transport and working machines. The technical data of a drive unit used in the studies, are presented in the table 1.

Tab. 1 Technical data of a drive unit

swept capacity [cm^3]	1560
motor capacity [KM]	110
maximum turning moment [Nm]	240
number of cylinders	4
type of injection	direct, Common Rail
injectors	electromagnetic
supercharging	Turbo-compressor

The tested engine is presented in the drawing 1. The driving unit mates with dual-mass flywheel and a turbo-compressor of variable blades' geometry, what has an impact on the increase of the generated engine's performance.

Fig. 1 The driving unit used in the tests

The material under investigation was the mixture of 70% of diesel oil and 30% of fatty acid methyl esters. The fatty acid methyl esters are the plant oils put through to the transesterification process that is the exchange of the chemically bounded glycerin in triacylglycerol's particle into added methyl alcohol in the presence of basic or acid catalysts, which commonly are called biocomponents.
Modification of the engine's electronic system were conducted during the tests, by modification of the computer's driving unit factory software. The purpose of the introduction of the changes in the injection controller's settings was to find out if and how the values of the vehicle's performance parameters change. Because of the specificity of a vehicle's electronic system, disassembly of a dive computer and introduction of changes in the software on a special stand, was required each time. Prior to introduction of the changes in computer software, a diagnostic measurement was conducted in order to establish the possibility and rationality of the engine parameters' increase. Modifications in the vehicle's software consisted in the increase of the fuel dope by 2% and air supercharging by 50 hPa. Also the factory's settings were tested in order to relate the results obtained at the time of conducted modifications. The

injection maps which came into being after the conducted modifications of the fuel injection controller's settings, are presented in the drawings 3 and 4.

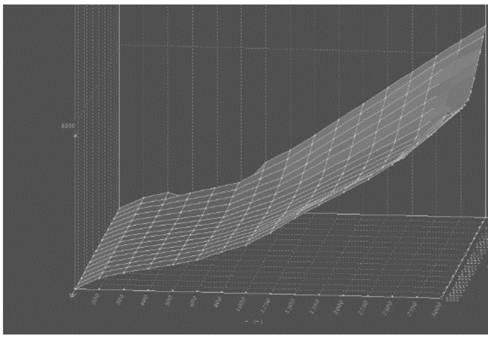

Fig. 3 Injection map for a fuel dope of 2%

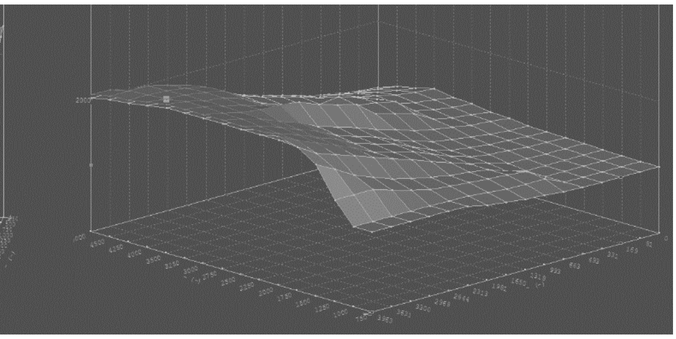

Fig. 4 Injection map for air supercharging 50 hPa

The conducted studies concerned the values of the performance parameters of a driving unit powered with a mixture of diesel oil and the fatty acid methyl esters, at variable settings of the fuel injection's controller. The measurement also covered such parameters as: power, turning moment, emission of noise generated by the engine and the volume of solid particles in exhaust gas.

The studies were conducted with the use of load chassis dynamometer with an eddy current brake. The chassis dynamometer made it possible to obtain the data necessary to determine the characteristics of the driving unit's performances just as power and turning moment *(Kolator B., & Janulin M., 2014; Kołodziej E., & Skrzyniowski A., 2012)*. The device measured the turning moment turned over to the crankshaft and calculated the engine's power based on the value of the turning moment and the rotational speed of the crankshaft *(Michalski R., Gonera J., & Janulin M., 2012)*. The air humidity, changes in the atmospheric pressure and the air temperature had an impact on that measurements. The purpose of conducting the tests on the load chassis dynamometer there were the following: checking of the parameters reached by the driving unit assembled in a vehicle, measurement of the engine's parameters following the changes in the settings of the fuel injection controller, checking of the values of the noise emission's values and solid particles with the use of additional analysers. The chassis dynamometer used in the tests, is presented in the draving 5. The measurement of the solid particles occurred with an optical method, with the use of a solid particles' analysed MPM-4, presented in figure 6. That method consisted in checking of the intensity of the light beam going through the stream of exhaust gas *(Peterson C., et al., 2000)*. The solid particles coming into being at the time of fuel's combustion in self-ignition engines, are the coal particles and smaller particles absorbed by it that is carbon black *(Pelkmans L., & Debal P., 2006)*. The analyser, took the samples of exhaust gas with the use of an instrument stalk, which was exposed to the laser action. Then, with the use of a dispersed light's detector, the measurement of the volume and concentration of solid particles was conducted.

Fig. 5 Chassis dynamometer

Fig. 6 Solid particles' analyser

The experiment was conducted in order to determine the engine's performance parameters for three settings of the fuel injection's controller. The examinations were conducted in the laboratory's environment, with the use of a load chassis dynamometer, which simulated the road conditions. Preparation of the object of the studies for the experiment, consisted in fastening of the vehicle on the dynamometers with belts, heating up of the driving unit and connection of all the necessary instrument stalks. Before staring of the measurements, the engine was heated up to the temperature of 85°C for cooling liquid. Each measurement of the performance parameters of the examined driving unit was conducted 30 times in the conditions of the maximum engine's loading.

RESULTS AND DISCUSSION

Based on the conducted literature's analysis, the performance parameters of a driving unit powered with the mixture of a diesel oil and fatty acid methyl esters, the values of which were analysed. The analysis concerned also such parameters as: power, turning moment, noise and solid particles. The analysis concerned 30 measurements of the selected values of the driving unit powered with the mixture of 70% of diesel oil and 30% of fatty acid methyl esters, at variable settings of the fuel injection's controller. The values of the basic statistics for the analysed performance parameters of a driving unit and the standard engine's settings, are presented in the table 2.

Tab. 2 Statistical analysis of the performance parameters for the setting I

Performance parameters	power [KM]	turning moment [Nm]	noise [dB]	Solid particles [ppm]
Medium value	100.15	233.59	120.8	75.033
Median	100.30	234.35	121.1	75.50
Standard deviation	0.833	2.905	0.764	4.468
Coefficient of variation	0.008	0.012	0.006	0.060
Minimum	96.3	228.3	119.5	68.0
Maximum	100.8	237.6	122.6	85.0

In the table 3 there is presented a statistical analysis of the performance parameters of a driving unit powered with the mixture of 70% diesel oil and 30% of fatty acid methyl esters and the II setting of the fuel injection controller (fuel's dose increased by 2% and air supercharging increased by 50 hPa).

Tab. 3 Statistical analysis of the performance parameters for the setting II

Performance parameters	power [KM]	turning moment [Nm]	noise [dB]	Solid particles [ppm]
Medium value	104.79	241.49	120.52	93.233
Median	104.85	253.90	120.5	92.50
Standard deviation	0.367	0.264	0.344	3.029
Coefficient of variation	0.003	0.001	0.003	0.032
minimum	104.2	241.0	119.9	88.0
maximum	105.5	242.0	121.0	99.0

Measurement of the selected performance parameters was conducted in order to check, how a change of the fuel injection controller's setting influences the driving unit, which is powered with a mixture of 70% of diesel oil and 30% of fatty acid methyl esters. The data from the above table (medium value and median) are presented graphically in figures 7-10.

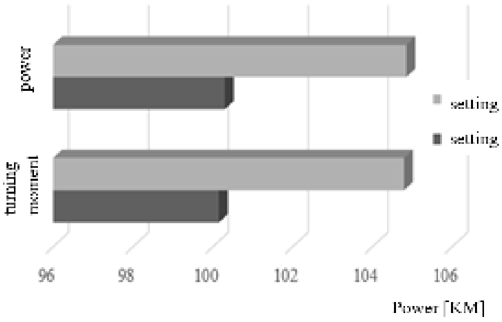

Fig. 7 Values of power for the setting I and II

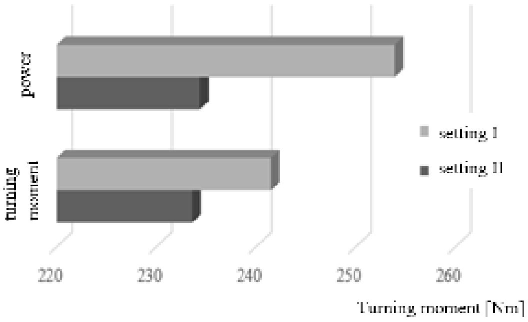

Fig. 8 Values of the turning moment for the setting I and II

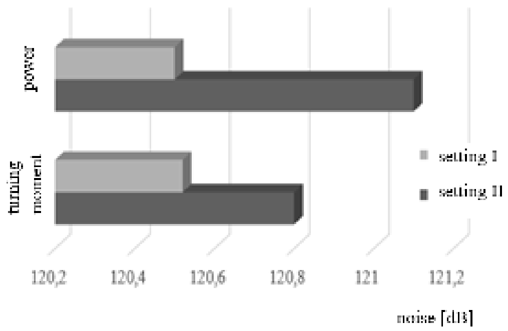

Fig. 9 Values of noise for the setting I and II

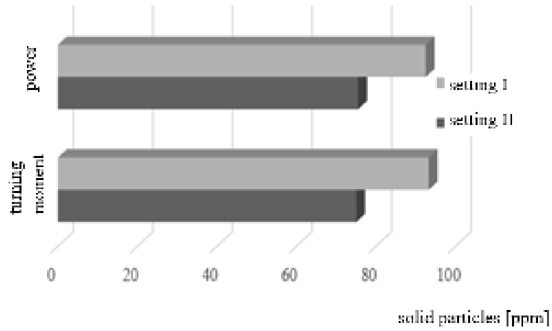

Fig. 10 Values of solid particles for the setting I and II

From the statistical analysis of the obtained results of measurements it results, that the change of the fuel injection controller's settings improves the engine's performance and lowering of the volume of solid particles in the exhaust gases. During the studies there was also observed the constant level of noise's emission generated by the driving unit powered with the mixture of 70% of diesel oil and 30% of fatty acid methyl esters.

CONCLUSIONS

Based on the anaysis of the literature and own studies, there have been determined the performance parameters such as: power, turning moment, noise generated by the engine and solid particles included in the exhaust gases *(Agarwal A., et al. 2006, Agarwal A., 2007, Ambrozik A., et al., 2012, Arapski N., et al. 2007, Banapurmath N., 2008, Szlachta Z., 2001)*. Then, the measurement of their value depending on the fuel injection controlling's settings was conducted. The obtained results of the driving unit performance parameters' testing justify the purposefulness of modification of the engine computer's software system. Analysis of the results of the studies, made it possible to determine the number of solid particles formed at the time of combustion of the mixture of 70% of diesel oil and 30% of fatty acid methyl esters at different settings of the fuel injection controller. In the study there are compared two settings: the factory one and the increase dope of fuel by 2% and the increased air supercharging by 50 hPa. It results from the conducted studies, that the change of the fuel injection controller's setting results in the decrease of the solid particles in exhaust gases by 20%. In case of power measurement, there has been noticed the increase by approx. 5%. Emission of noise generated by a driving unit remained on a comparable level. At the time of the conducted studies, there was also observed a higher turning moment for the setting of the increased dope of fuel and the air supercharging, which amounted to about 3%. These were the parameters of power and the turning moment, which proved to be the most sensitive to the change of the fuel injection controller's settings. Studies on the properties of the basic parameters of self-ignition engines fed with mixtures of transesterified vegetable oil and diesel oil were conducted in many centers *(Podolak A., et al. 1998)*. While studying at literary studies, they are not conducted due to changes in software powered by mixed diesel and ester oil. Engine parameters are available in the literature *(Agarwal A., et al. 2013, Arapaki N., et al. 2007, Armas O., et al. 2010).*

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