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ANALYSIS OF THE BIOFUEL COMBUSTION PROCESS IN A SMALL AGRICULTURAL DIESEL ENGINE

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ABSTRACT

The paper presents the results of research into the possibility of using a mixture of various types of biodiesel fuel with standard diesel fuel of mineral origin in a mixture ratio of 50:50, labelled B50, on a diesel engine with direct injection intended for small agricultural machinery driving. The analysis was performed in terms of comparing the pressure flow in the cylinder and the dynamics of the combustion process over the heat release flow in the engine cylinder. It was found that with the specified fuel mixture ratio in the mixture there were no major changes in the pressure flow in the cylinder and the heat release process, which indicates that the given fuel mixture ratio can be used without problems to power this class of engine in long-term operation, without fear of possible harmful consequences for the engine.

Key words: diesel engine, combustion processes, pressure flow in the cylinder, heat release flow

INTRODUCTION

Fuel production "from the field" is very interesting for farmers, both for small and medium or large farms. This enables a certain reduction in fuel costs for manufacturers, which implies a direct economic interest for them. On the other hand, there is the question whether the use of such fuels, both pure or mixed with diesel fuel, significantly affects the dynamics of the combustion process and the pressure flows of the working gas in the engine cylinder, i.e. whether the engine elements can be damaged as a result. This issue is particularly important for the safety and reliability of the engine during long-term exploitation of the engine on the farm.
In our country, a detailed research was carried out within the project of the Ministry of Science and Technological Development TR35042 and was presented in paper [1]. Similar research was also carried out in the world, which can be seen in papers [2], [3], [4]. and [5]. Potential problems with the use of pure vegetable oil in the engine are shown in [6] and [7]. In all the mentioned papers, the dynamics of the combustion process of the selected biofuels were analyzed with the aim of studying the influence of different biofuels on the flow of the work process and the output parameters of the engine. In this paper, the impact of a mixture of 50% biofuel with different raw material compositions and standard diesel fuel will be presented. The influence on the pressure flow and the combustion process, as well as the specified mixture of pure sunflower oil without further processing and the diesel fuel were also studied.
To determine the flow of heat release, the working space of the engine was observed as an open thermodynamic system. The calculation model is given by the equation below:

$$dQ_f = mdu + p_z dV_z + udm_f + (h-u)dm_{pr} + dQ_w \qquad (1)$$

or as a function of the crankshaft angle:

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$$\frac{dQ_f}{d\alpha} = m\frac{du}{d\alpha} + p_z\frac{dV_z}{d\alpha} + u\frac{dm_f}{d\alpha} + (h-u)\frac{dm_{pr}}{d\alpha} + p_z\frac{dQ_w}{d\alpha} \quad (2)$$

are in the equation:

dQ_f – the amount of heat developed in the cylinder

mdu – gas mass and internal energy change

$p_z dV_z$ – current pressure and volume

udm_f – elemental mass of injected fuel

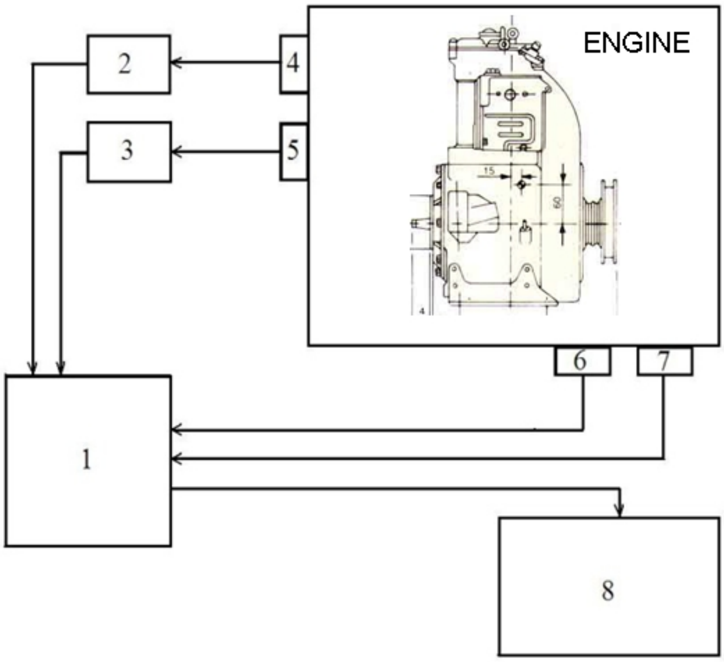
$(h-u)dm_{pr}$ – gas loss from the working space through gaps in assemblies

dQ_w – heat that is lost by cooling through the walls of the work space

This model, in a somewhat simplified version, was used during the calculation of the heat release flow, and is presented in detail in the papers [1], [8] and [9].

TEST PROCEDURE

Investigating the impact of a mixture of different biofuels of the biodiesel type with standard diesel fuel on the combustion process of a diesel engine with direct injection for driving small agricultural machinery. The pressure in the engine cylinder was indicated with the help of the measuring system shown schematically in Figure 1. The schematic diagram of the installation shows the basic positions necessary for understanding the functioning of the measurement system described, as well as the position and the type of appropriate sensors of measurement quantities. Individual components of this installation are described in more detail in [1].



Positions in the picture:

1. Acquisition system ADS2000
2. Charge amplifier for the pressure in the cylinder sensor
3. Charge amplifier for the injection pressure sensor
4. Cylinder pressure sensor
5. Injection pressure sensor
6. TDC marker
7. Crankshaft angle sensor (CA)
8. Computer

Figure 1. Simplified sketch of the measuring system for engine indication

For the research, a domestically produced LDA 450 diesel engine from the DMB Rakovica factory was used, which is widespread and widely used in Serbian agriculture, both for driving single-axle tractors, lawnmowers, irrigation pumps, and, as an aggregate engine, for driving electric generators and air compressors.

The technical specifications of this 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)

The experimental fuels used in this research were produced from suitable vegetable oils by the esterification process in accordance with the standard EN14214: 2010. In this way, this fuel, by its physicochemical characteristics, approaches the diesel fuel produced according to the standard SRPS EN 519: 2010, which is important especially in terms of viscosity. Biodiesel - diesel mixture ratios of 50:50 were used for the research, and the label B50 was used for this fuel mixture.

EXPERIMENTAL RESULTS

Cylinder pressure values for B50 fuel mixture

As mentioned earlier, in this research, mixtures of the following fuels with the reference diesel fuel in a ratio of 50:50, labelled B50D100 were investigated: palm oil methyl ester PME50, soybean oil methyl ester SME50 and rapeseed oil methyl ester RME50. Pure sunflower refined edible oil mixed with diesel fuel in a ratio of 50:50, labelled SRF50 fuel, was also included in the research. The pressure flows in the engine cylinder when working with these types of fuel are shown in Figure 2. The engine operating mode was n=1600 rpm and 50% engine load.

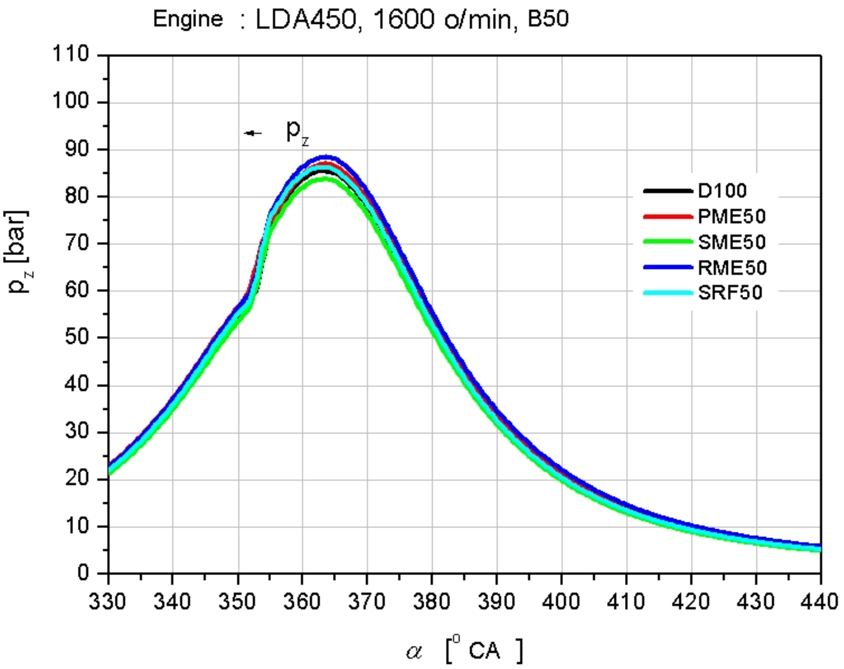


Figure 2. Pressure in the engine cylinder for all biofuel mixtures and diesel fuel at 50% load

It can be noted that the max. the pressure of the alternative fuel cycle is slightly higher and that it generally appears, a little earlier than when working with D100. This applies to all blends except SME, where the cycle pressure for this fuel is slightly lower than when operating with D100 diesel fuel. This can be interpreted by the fact that biodiesel fuels have a slightly higher cetane number – CN, and a shorter ignition delay period, so that the maximum pressure values are reached closer to TDC than in the case of operation with diesel fuel. However, it should be noted that the differences are not too big.

Table 2. Maximum pressures in the cylinder and the position of the maximum in relation to TDC

	50% load (OP50)				
Cyl. pressure and max pressure	D100	PME50	SME50	RME50	SRF50
p_z (bar)	84.9	86.9	83.7	88.4	86.1
$\alpha_p\,(^\circ KV)$	365.2	363	362.8	363.4	362.2

Table 2 shows numerical data on the the maximum pressure values in the engine cylinder, as well as the position of that pressure in relation to TDC. It can be seen that mixtures of rapeseed and palm oil methyl esters give a slightly higher combustion pressure than diesel fuel, and this also applies to the mixture of pure sunflower oil and diesel fuel. With soy methyl ester, the situation is opposite.

Heat release rate (HRR) for the B50 fuel mixture

Regarding the heat release flow, f igure 2 shows the heat release rate for the B50 fuel blends for the specified operating mode. The maximum of the heat release rate is always lower for biodiesel blends than for a diesel fuel. The difference is only with SRF50, where the peak of heat developed is the same as for D100. This is probably due to the difficult formation of the mixture of sunflower oil and diesel fuel and larger droplet sizes in the jet, which with a relatively low thermal level of the engine in this operating mode gives a slightly longer period of ignition delay and a large accumulation of fuel in the combustion chamber during this period. That fuel later burns rapidly and leads to a slightly higher maximum value *dQ/dα.*

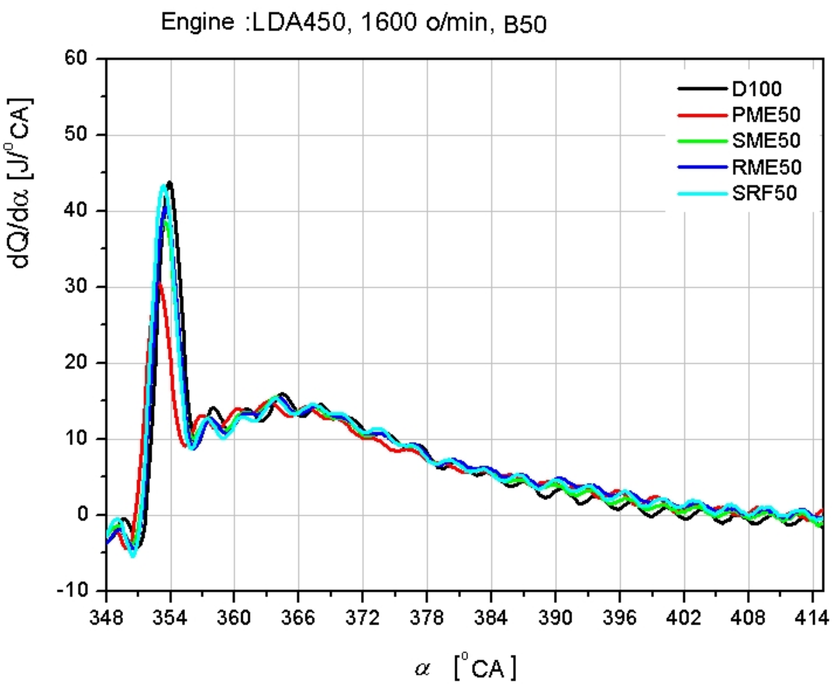


Figure 2.Heat release rate-HRR, for all biofuel mixtures and diesel fuel at 50% load

The order of peaks is distributed from the highest to the lowest as follows: SRF50, RME50, SME50 and PME50 respectively excluding diesel fuel when the peak is at the highest.

CONCLUSION

The aim of this research was to determine the influence of different types of biofuel mixed with standard diesel fuel on the basic parameters of the working process of the engine and to draw conclusions about the possibility of using such fuel mixtures for safe operation. Based on very detailed and long-term research on the impact of different biofuels on the work process and many other output parameters of this engine, it was concluded that there were no major changes neither in the pressure flow in the cylinder, nor in the maximum pressure values. As for the heat release flow, there are certain differences in the patterns and peaks of the released heat for different fuels, as well as in the position of those peaks in relation to TDC. It should be noted again that the influence of a mixture of pure refined sunflower oil and diesel fuel was investigated and it was found that from the aspect of the flow and the maximum pressure in the cylinder, as well as from the dynamics of the combustion process, this mixture gives very good results. Long-term tests of this type of fuel mixture on the level of wear of engine elements and the deposited soot amount in the combustion chamber and on the injectors have not been carried out. Nevertheless, we do not recommend long-term operation of the engine with this type of mixture due to the potential problems that could occur on the engine. For other fuel mixtures such as biodiesel and diesel, we consider them to be very suitable, safe and economical for long-term operation. We especially point out that these fuels can be produced independently and used, but under the condition that they are produced according to the EN14214: 2010 standard.

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