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CHARACTERISTICS OF BIOFUEL INJECTION IN DIESEL ENGINES

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SUMMARY

The paper presents the results of research into the influence of different types of biodiesel-type biofuels on some parameters of the injection system in diesel engines with direct injection. For experimental studies of the mentioned impact, standard diesel fuel was used as a reference fuel and pure methyl esters (100%) of biodiesel produced from rapeseed, soybean and palm oil in the B100 designation.

The analysis was performed in terms of comparing the pressure values in front of the injector as well as the stroke of the needle of the injector with the use of appropriate pressure sensors and needle lift sensors. It was found that injectors with a slightly increased diameter of the nozzle channel were used on the particular engine, which leads to poorer fuel dispersion, a more compact jet and greater fuel deposition on the wall of the combustion chamber. All this can lead to difficult formation of the fuel-air mixture when working with biodiesel.

Key words: diesel engine, injection processes, injection pressure, needle lift

INTRODUCTION

Using biofuel produced on one's own farm is a very interesting option for farmers, of small, medium , as well as large farms. This enables a certain reduction in fuel costs for manufacturers, which has a direct economic interest for them. On the other hand, there is the question whether the use of such fuels, either pure or mixed with diesel fuel, significantly affects the injection system of diesel engines of agricultural machinery, i.e. whether the elements of the injection system on the engine may be damaged as a result. This issue is particularly important for the safety and reliability of the engine during long-term exploitation of machinery on the farm.

In this country, detailed research was carried out within the project of the Ministry of Science and Technological Development TR35042 and was presented in the paper [1]. Similar researches were also carried out in the world, which can be seen in papers [2], [3], [4], [5] and [6]. Potential problems that may arise on the injection system when using biofuels based on

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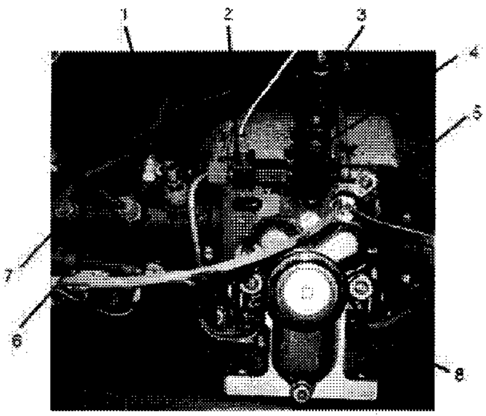
vegetable oil are presented in [7]. In all the mentioned papers, along with the measurement of other relevant parameters, the lift of the injector needle and the fuel injection pressure were also monitored. In this paper, the impact of biofuels of different raw material compositions on the change of the specified parameters will be shown in comparison with standard diesel fuel.

TEST PROCEDURE

Research on the influence of different biofuels of the biodiesel type on the change in injection pressure and the injector needle lift was carried out on a diesel engine with direct injection. The pressure in front of the injector and the injector needle lift were measured with the help of a suitable measuring system. Individual components of this installation are described in more detail in [1]. The entire experimental procedure of this research was carried out on a mono-cylinder direct injection diesel engine, LDA450 of the engine factory (FMM) May 21, Rakovica - Belgrade. Originally, the engine was intended to drive smaller agricultural machinery, smaller boats, irrigation pumps and electric generators. In Figure 1, the basic positions necessary for understanding the position of individual measurement sensors used during the research are given. Data collection was performed with the ADS2000 measurement-acquisition system with subsequent processing of the collected data.



Positions in the picture:
1. Current intake pressure sensor
2. Injection pressure sensor
3. Injector needle lift sensor
4. Nozzle
5. Cylinder pressure sensor
6. Medium intake pressure sensor
7. Intake air temperature sensor
8. Engine head temperature sensor

Figure 1. Position of measuring points on the engine

For the research, a LDA 450 diesel engine of the domestic production was used, which is very widespread and widely used in Serbian agriculture, both for driving single-axle tractors, lawnmowers, irrigation pumps, and as an aggregate engine for power generators and air compressors. Technical specifications of this engines 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. Pure (100%) fuels were used for the research, and the common label of all fuels is B100.
The injector nozzle used in the research is shown in Figure 2, and the technical characteristics of the injection system are given in Table 2.

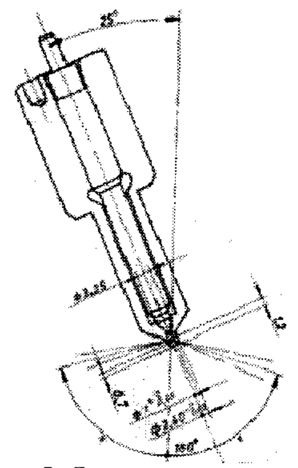


Figure 2. Construction of the IPM injector nozzle for the LDA 450 engine

Table 1. Technical data of the injector IPM

Type of injector	IPM	YPFR170YS6459
Number and diameter of nozzle holes	n	4 x 0,28 mm
The angle of the jets in the vertical plane	angle	160°
Needle lift	h	0,2 - 0,22 mm
Nozzle hole length	lg	0,7 mm
Nozzle chamber diameter and length	/	1 x 1,5 mm
Needle dimensions	/	6 x3,25 mm
The angle of the jets in the plane perpendicular to the axis of the nozzle	angle	90°

EXPERIMENTAL RESULTS

Injection pressure flows and injector needle lift

As mentioned earlier, in this research, the influence of certain fuels on the flow of injection pressure and stroke of the injector needle was investigated. A comparison of three biodiesel type fuels was made with the reference diesel fuel D100 in pure - 100% state, labelled B100. Palm oil methyl ester PME100, soybean oil methyl ester SME100, rapeseed oil methyl ester RME100. Pressure change and stroke of the injector needle when working with these types of fuel are shown in Figure 3. The engine operating mode was n=1600 rpm and 100% engine load.
On the test diesel engine in question, for the purpose of determining the injection start moment as well as the duration of the injection, measurement data from the injector needle travel sensor and the injection pressure sensor installed in front of the engine injector were used. Figure 3 shows the injection pressure and injector needle stroke for B100 biofuel, as well as well as for the reference diesel fuel D100, while Figure 4 shows enlarged details of the injection pressure change of the tested fuels. These diagrams make it possible to observe the differences in some parameters of the injection system for different biofuels and to compare them with the same parameters for diesel fuel.

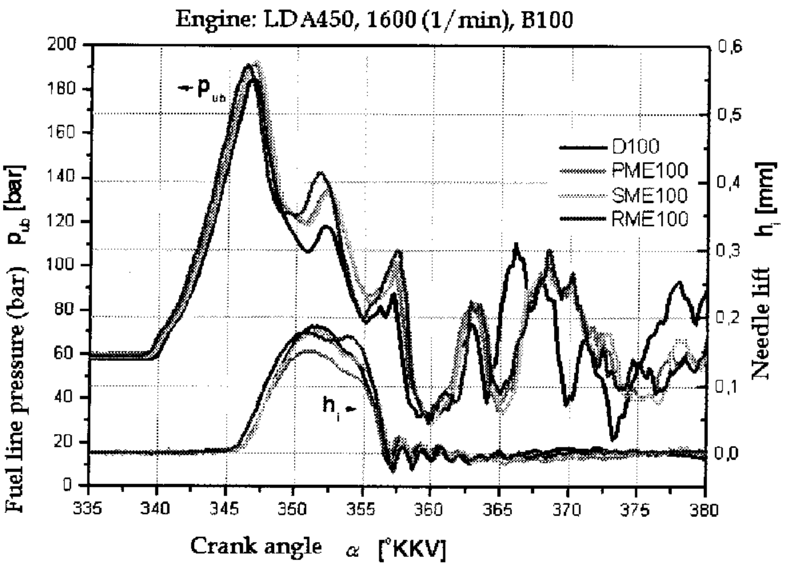


Figure 3. Diagrams of injector needle stroke and injection pressure with diesel fuel and pure biodiesels - 100% (B100)

The injector needle lift pressure was set at 185 bar for diesel fuel which corresponds to the factory specification for the LDA450 engine. From the diagram it can be seen that the maximum injector opening pressures are slightly higher for B100 fuel than for diesel fuel, Figure 4. Specifically, RME100 – 190 bar, PME100 – 191 bar and SME100 -193 bar. As is known, biodiesel has a higher density and viscosity than diesel fuel, which affects a slightly higher residual pressure, as well as a slightly higher nozzle opening pressure in the high-pressure pipe, which can be seen in the diagram.

Analysis of the characteristic parts of the diagram

If you look more closely at the diagram, Figure 4, of the change of the injection pressure, it can be noticed that the pressure of the needle lift of the injector is also the maximum injection pressure. The next peak after the start of injection is significantly lower than the first. This indicates a very large pressure drop in the nozzle chamber, i.e. the injector, which is a consequence of the excessive diameter of the nozzle channel of 0.28 mm. Broadly speaking, the excessive diameter of the nozzle channel consequently leads to poorer atomization, a larger diameter of the fuel droplet in the jet, a more compact jet, a greater range of the jet and a greater deposition of fuel on the wall of the combustion chamber.

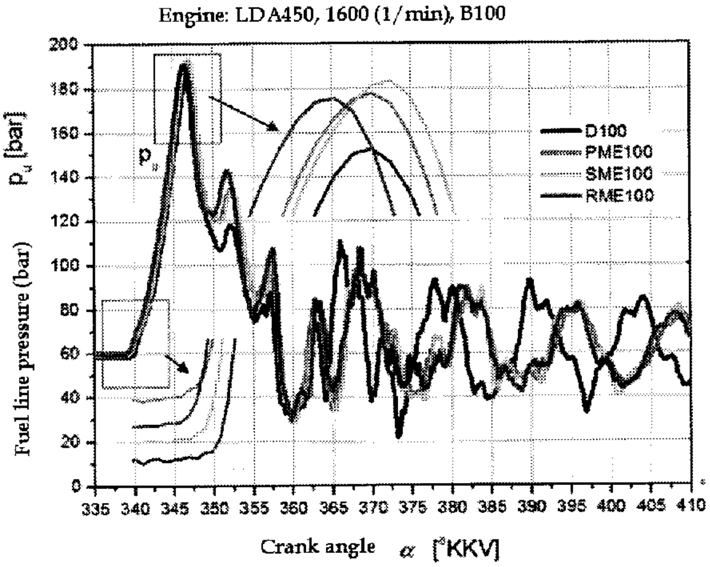


Figure 4. Enlarged part of the characteristic areas of the injection pressure flow diagram

All this together can lead to a difficult formation of the fuel-air mixture. This problem is especially complicated when injecting biodiesel or mixtures of biodiesel or vegetable oils with diesel fuel, which otherwise have a higher viscosity, density and surface tension of droplets in the jet.

The right part of the diagram indicates a fairly large pressure fluctuation in the high pressure pipe for both diesel fuel and biodiesel. A phase shift can also be observed between the pressure with diesel fuel and with biodiesels. On the other hand, the pressure fluctuation is synchronous for all investigated biofuels without significant phase shift. Generally, this appearance of the entire injection pressure diagram, from the beginning of the injection to its end, indicates the non-optimization of the injection system applied on this engine. Slow subsidence of the pressure wave in the high pressure pipe after the injection is completed, which also indicates too small relief volume in the relief valve and in some cases this can cause subsequent injection with all the negative consequences to the engine operation.

Taking into account the stroke diagram of the injector needle, it can be concluded that no subsequent injection, at least the injection in the operating modes the research was carried out on, occurs after all. Also, an earlier start of the injector needle lift can be observed when working with B100 type fuels. When it comes to the moment of the start of the injection, it is concluded that it is the moment when the needle of the injector is raised by 0.01 mm in relation to the closed position. The earliest needle lift was found for fuel RME 100 at 345.7 ^{o}CA, followed by SME100 ^{o}CA at 346.2, PME at 346.2 ^{o}CA and D100 at 346.3 ^{o}CA. It is stated in the literature that the increased viscosity of biodiesel leads to reduced loss of biofuel through gaps in the elements of the high-pressure pump. During the injection process, the pressure wave propagation from pump to the injector is faster, which all together leads to an earlier start of injection. In addition, the content of the vapor phase in biodiesel is always lower than when injecting diesel fuel, which is another reason for the earlier start of injection of basically all biodiesel compared to diesel fuel.

Also, the compressibility of biodiesel is lower compared to diesel fuel. This also affects the increase in the speed of pressure rise and the somewhat earlier start of injection. The earlier start of the injection, mainly over the duration of the ignition delay, has an impact on the entire combustion process as well as on the composition of the exhaust gases.

CONCLUSION

The goal of this research was to determine the influence of different types of biofuels on the change in the parameters of the injection system in this engine and to draw conclusions about the possibility of using such fuels in their pure form for safe operation. The parameters of the injection pressure and the needle lift of the injector were measured and it was established that there were no major changes in the value of the maximum injection pressure, nor the occurrence of subsequent injection, which would lead to a series of harmful consequences for the working process of the engine. An earlier start of injector needle lifting was observed due to the increased viscosity of all investigated biodiesel fuels. The process of propagation of the pressure wave from the pump to the injector through the pipeline is faster, which alltogether leads to an earlier start of injection compared to the reference diesel fuel. No long-term tests have been performed using biofuels of this type and their impact on the reliability of the injection system, but during relatively short-term tests, no negative effects in terms of increased wear or failure of the injection system elements were observed. Taking this into account, is possible to produce these fuels independently on an agricultural farm and use them in exploitation, but with the condition that they are produced according to the EN14214: 2010 standard.

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