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EFFECT OF BIOFUEL FROM COOKING OIL ON ENERGY CHARACTERISTICS OF DIESEL ENGINES

Summary

The aim of this study was to determine the influence of biodiesel from waste cooking oil on the energy characteristics of diesel engines. The object of the research was the production of biofuels by low-temperature transesterification process and use it to powered diesel engine in tractor URSUS 1224. Diesel fuel in accordance with the European standard EN 590 and waste cooking oil methyl esters were used for comparative tests. The energy characteristics of diesel engine were determined using a mobile break of engine PT 301 MES and a fuel gauge AMX 212F. To In order to produce biodiesel, waste cooking oil, methyl alcohol in a molar ratio of 1:6 (oil:methanol) and an alkaline catalyst, potassium hydroxide, in the amount of 1.7% (m/m) were used. The results of the test showed that engines using biodiesel from waste cooking oil produces 7% less power relative to engines powered by normalized diesel fuel. The general consumption of fuel increased to 8% relative to diesel fuel. The thermal efficiency of the test engine was 30%, independent of the kind of fuel.
***Key words**: cooking oil, biofuel, biodiese, diesel engine, esterification*

WPŁYW BIOPALIW Z OLEJU POSMAŻALNICZEGO NA PARAMETRY ENERGETYCZNE SILNIKA WYSOKOPRĘŻNEGO

Streszczenie

Celem badań było określenie wpływu biopaliw z oleju posmażalniczego (OP) na parametry energetyczne silnika ZS. Przedmiotem badań było wytworzenie biopaliw metodą estryfikacji niskotemperaturowej i zasilanie nim silnika ZS napędzającego ciągnik rolniczy URSUS 1224. Badania o charakterze porównawczym były prowadzone na znormalizowanym oleju napędowym, zgodnym z normą jakości EN590 i otrzymanym na potrzeby badań paliwem. Badania parametrów energetycznych silnika były realizowane używając mobilną hamownię silnikową PT 301 MES i paliwomierz AMX 212F. Do wytworzenia estrów metylowych (EMOP) użyto olej posmażalniczy, alkohol metylowy w proporcji molowej 1:6 (olej:metanol) i katalizator alkaliczny, wodorotlenek potasu, w ilości 1,7% (m/m). Na podstawie przeprowadzonych badań stwierdzono, że moc silnika zasilonego biopaliwami z oleju posmażalniczego była mniejsza o 7% względem uzyskanej mocy silnika zasilonego znormalizowanym olejem napędowym. Zaobserwowano 8% wzrost ogólnego zużycia biopaliw względem oleju napędowego. Sprawność cieplna badanego silnika, niezależnie od stosowanego paliwa, wyniosła 30%.
***Słowa kluczowe**: olej posmażalniczy, biopaliwa, biodiesel, silnik wysokoprężny, estryfikacja*

1. Introduction

The results of a study into first generation biofuel, conducted over the course of many years, have contributed to the development and implementation of many solutions, one of which is the possibility of using rapeseed oil as a alternative fuel for diesel engines. Hemmerlein and others [1] were the first to conduct a study into the possibility of using raw rapeseed oil as an alternative fuel for diesel engines. The result of this study was that using rapeseed oil for diesel engines influences the formation of ashes in the combustion chambers of the engine, which results in lasting damage being done to engines. Both Rathbauer et al. [2] and Slavinskas Labeckas [3, also Pasyniuk and Golimowski [4] proved that effective solutions exist for enabling the adaptation of engines to use rapeseed oil as a fuel are available. The essence of using vegetable oils as a fuels is reducing their viscosity by raising its temperature [5, 6]. The esterification reaction is another solution for reducing the viscosity of vegetable oil [7, 8].

Existing research findings confirm that the majority of vegetable oils are good materials for biodiesel production [9, 10]. Mekhilef et al. proved that palm oil is a good material for biofuel production [11]. Georgogianni et al. proved that biofuel can be produced from sunflower oil [12], whose properties are similar to those of rapeseed oil, which is widely used in the industrial production of biofuel in Europe. Less common oils (rice and peanut) can be used for biodiesel production [13, 14], also a mixture of oils such as rapeseed oil and soybean oil [15].

Heated animal fats have also been used as a fuel for diesel engines. The results of this study are similar to those of rapeseed oil as a fuel, and show that reduced power is caused by lower induced pressure in the combustion chamber [16]. Due to the high solidification temperature of animal fats, it is not possible to use them as fuel for vehicles. A study of the possibilities to lower the solidification temperature by emulsifying did not bring the expected results as these emulsions were not stable substances and were prone to gravitation stratification in a short time [17]. The methyl esters from animals fat are characterized by lower solidification temperatures relative to the input material. However, depending on the type of fat, the temperature ranges from 5-15°C [18-21]. Methods for reducing the solidification temperate of methyl esters from animal fat are known, for example, by adding a depresator [22] or by using winterization processes [23].

Currently, II generation biofuels obtained from non-food materials are the object of research all around the world. Jatropha oil is one such material being analysed [24]. The results many studies in the world, carried out on the basis of laboratory tests and technical scale tests, have proved that used cooking oil is a good material for biodiesel production [25-27]. Various technologies for biodiesel production have been developed, [28] but not all are guarantee biofuels whose performance will meet European standards (EN 14214) for methyl ester as a biodiesel introduced onto the market [29].

When using cooking oil for biofuel production the problems are collecting it and the varied quality of the cooking oil. Production of biodiesel may be good solution for farmers producing this kind of fuel for their own needs. It is estimated that about 350 thousand tons of waste fat are produced in Poland each year [30], of which the majority are used cooking fats. However, there is a lack of information on how this type of fuel affects the energy performance of engines in the older tractors used in the Polish farming sector. Hence, the aim of this study was to determine the effect of methyl esters from cooking oil on diesel engine parameters.

2. Materials and methods

2.1. Fuel preparation

Used cooking oil (OP) and diesel fuel accordance with the European standards EN590 and with a calorific value of 45,439 $MJ\cdot kg^{-1}$ were analysed in to the study. The cooking oil's physical parameters were: acid value (2.6 mg $KOH\cdot g^{-1}$), density at 20°C (912 kg.m-3), kinematic viscosity at 40°C 53.99 $mm^2\cdot s^{-1}$, flash point 242°C, calorific value 38.868 $MJ\cdot kg^{-1}$ and the articulation of fatty acids by gas chromatography: 5,45% (16:0), 0,27% (16:1), 2,19% (18:0), 64,91% (18:1), 16,46% (18:2), 5,15% (18:3), 0,65% (22:1), 2,3% Other acids.

The esterification reaction was carried out in reactors with a mechanical stirrer made for this type of test process [31]. Three processes on the same reaction parameters were conducted using samples obtained in these conditions. The reaction was carried out at 35°C, stirring for 30 min, after which a free gravitational stratification process was conducted for 24 hours. The reaction used methyl alcohol catalysts of a 1:6 (fat:alcohol) ratio with 1,7% wt% KOH (potassium hydroxide) dissolved therein. For each test the efficiency of the reaction was determined, and the physicochemical parameters of all biofuel samples obtained (EMOP).

2.2. Determined of energy properties parameters

This study took part agricultural tractors URSUS 1224 with Z-8701-1 engines (Table 1). The tractor was connected by PTO to a PT 301 MES mobile engine brake. An AMX 212F fuel gauge was installed where the main tank of tractor would normally be.

Table 1. Specification of engine

Type	Z-8701.1
General details	4 stroke, compression ignition, natural aspirated, 6 cylinder
Compression ration	17:1
Bore and stroke	110 mm x 120 mm
Rated power output	77 kW at 2200 rpm
Displacement volume	6842 cc
Injection system	Direct injection

Measurement points were registered manuall every 100 rpm of the engine. Torque (Mo) and Power (Ne) of the engine were registered using a PC connected to the engine brake. The overall fuel consumption (G) was determined once the measuring vessel had been filled with fuel. The procedure for measurement was performed as follows: the engine was heated to a temperature of 85°C ±2°C, accelerator speed set to the maximum speed position, the first measuring point was recorded at 2300 rpm, the next measuring points were recorded at 100rpm ± 10 rpm to 1400 rpm, then the brake was disabled. For each fuel three tests were conducted.

On the basis of findings the external characteristics of the engine were set and representing results the average measuring points of the three tests. By changing the type of fuel, one fuel was removed from the engine's injecting system and another took its place. The measuring procedure was performed once the engine had been working without load for 30 minutes (to allow the total replacement of the fuel in the system). Control measurements were performed using a standard diesel fuel to which the results of engine operation on the fuel being tested were compared. In view of the comparative nature of the study, such factors as the efficiency of transmission (η=1 was adopted) and climatic condition (tests were carried out in the same climatic conditions) and engine use were omitted.

3. Results of study

The average efficiency of the esterification reaction was 96,2% ± 0,3%.The biofuel obtained was subject to MEOP analysis. Selected parameters are presented in table 2.

Table 2. Performance of biofuel used in the study

Property	Units	EMOP	Tolerance	Norm EN 14214
Density at 20°C	$kg\cdot m^{-3}$	879	± 0,04%	-
Kinematic viscosity at 40°C	$mm^2\cdot s^{-1}$	4,63	± 0,06%	3,5-5,0
Flash point	°C	109	± 0,03%	>101
CFPP	°C	-5	± 0,00%	-
Calorific value	$MJ\cdot kg^{-1}$	39,432	± 0,01%	-
Monoglyceride	% (m/m)	0,22	± 4,54%	0,8
Diglyceride	% (m/m)	0,05	± 6,36%	0,2
Triglyceride	% (m/m)	0,22	± 11,66%	0,2
Free glycerin	% (m/m)	0,2	± 3,70%	0,02

The quality of EMOP was not consistent with the current European biodiesel standard EN 14214. Used the technology for production of biofuel from OP presented in this study, which is used by Frąckowiak to obtain agricultural fuel from rapeseed oil [32], does not guarantee biofuel of a high standard. Fuel whose parameters are similar to the standard can only be used as fuel for their own use in older tractor engines, as these are more resistant to low-quality fuel. However, such biofuels can not be a commercial fuel. Furthermore, using these fuels in Central Europe in the winter, spring and autumn could by troublesome, because of their high cold filter plugging point. The methyl esters obtained were characterized by an increased glycerol content . Inaccurate delamination of post-reaction products is the reason for such a large amount of free glycerol. EMOP production requires additional purification by means of silica gel, 5% phosphoric acid H_3PO_4 or hot water [33]. The high level of free glycerol can affect the life and durability of the engine, but insignificantly affected the energy parameters of the engine during the tests.

As a result of comparative research of engines running on different fuels, the maximum engine power at a speed of 2100 min-1 kW was determined. The power generated by engine was 70,1 kW ± 0,4% for the engine using diesel fuel and 65,4 kW ± 0,4% for the engine using EMOP. This difference was due to a 4% lower torque. The maximum torque for diesel fuel was 384,2 Nm ± 0,3% with a turnover of 1400 min-1, and for EMOP it was 371,4 Nm ± 0,3%. Figure 1 shows the characteristics of torque and power in relation to engine speed.

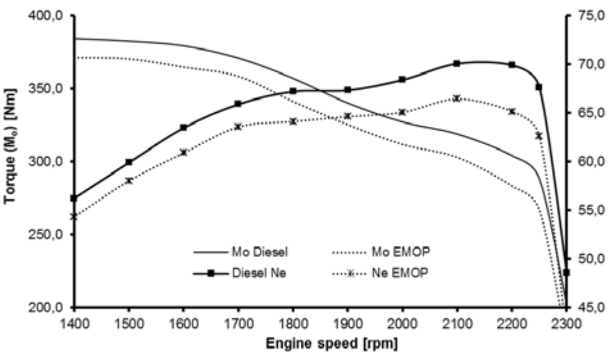

Fig. 1. Characteristics of Power (Ne) and torque (Mo) test engine

On this basis, it can be assumed that the dynamics of heat release during the combustion of EMOP were lower than in the case of diesel fuel. The main reasons for this phenomenon are rheological and energy differences of the fuels, which was confirmed by the results of the test of overall fuel consumption.
(Fig. 2).

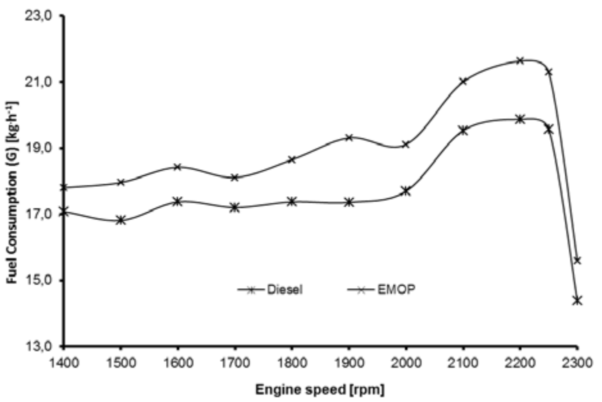

Fig. 2. Characteristic of general consumption of fuel (G)

The EMOP analyzed have a higher density than diesel fuel, whereas the fuel dose in the injection pump of the engine being tested is assumed volumetrically. In new generation engines, the fuel dose is controlled by an electronic system, determined by mass and remains constant, regardless of the type of fuel used. It must be assumed that older engines will consumed more biofuel relative to conventional fuel, and in this case the difference amounted to an average of 7%.

As shown in Figure 3, the energy differences of fuel mainly affect consumption of a specific fuel, and in the case of the EMOP tested here, this was about 12% relative to diesel oil. The parameter of specific fuel consumption is the best indication of the impact of EMOP on engine operation. It is an absolute value that can be compared to the results of other studies. The research of Rathbauer et al. shows a difference average 12% of unit fuel consumption [2]. The same results were obtained by Golimowski and Pasyniuk, who used crude vegetable oil to power the tractor [4], and Senthil et al. who tested a diesel engine using fuels from animal fats [16].

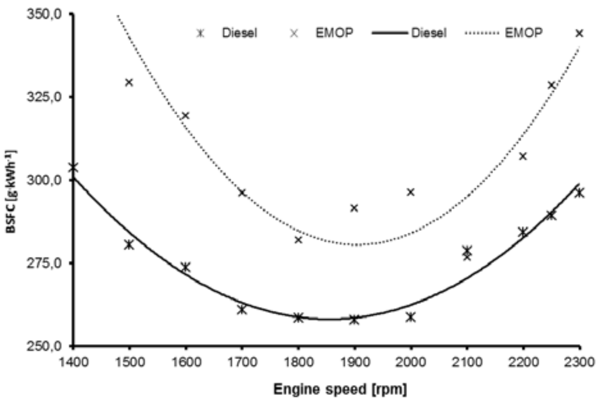

Fig. 3. Characteristic of Brake Specific Fuel Consumption (g_e)

On the basis of the results collected, the thermal efficiency of the engine was determined. In both cases, it was approximately 30%, which means that rheological parameters like kinematic viscosity have no significant impact on the engine running, regardless of the fuel used.

4. Conclusion

1. A fuel injection system in older diesel engines powered by biofuel from cooking oil will generated less power than one using standard diesel fuel. This is due to the low calorific value of biofuels from cooking oil. The difference in the power generated was 8% lower than with standard diesel fuel.
2. The difference level (7%) in unit fuel consumption between the biofuel from cooking oil and diesel fuel used to power older engines is similar to differences level in the density of both fuels tested. The Density of biofuel from cooking oil was 879 $kg \cdot m^{-3}$ but the density of diesel fuel was 7% lower. Effect of the difference level probably resulted with tape of injection system used in this study. Amount of fuel injection was dispensed volume by fuel pomp not dispensed mass like in contemporary injection system.
3. The differences between fuel parameters didn't impact on the thermal efficiency of older engines which was used to the study. Thermal efficiency of engine was the same used both fuels and amounted 30%.

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