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Influence of the SME run Perkins 1104D-44TA engine on the power and torque as well as unitary and hourly fuel consumption

P. Łagowski[1], D. Kurczyński[1], G. Wcisło[2,3], B. Pracuch[3], A. Leśniak[4], V. Tomyuk[5]

[1] Kielce University of Technology
Department of Automotive Vehicles and Transportation, Poland; phone: 0048 41 3424332;
e-mail: kdarek@tu.kielce.pl
[2] Faculty of Production Engineering and Power Technologies. University of Agriculture
in Krakow, Poland; Phone. 0048 513-157-977, e-mail: grzegorz.wcislo@ur.krakow.pl
[3] Malopolskie Centre for Renewable Energy Sources "BioEnergia", Poland;
e-mail: gwcislo@bioenergia.com.pl
[4] Cracow University of Economics. Faculty of Commodity Science
[5] Lviv National Agrarian University; Department of Automobilesand Tractors; e-mail: vtomyuk@ukr.net,

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Abstract. The article presents the results of tests determining the impact of using sunflower oil methyl esters on power and torque as well as unitary and hourly fuel consumption of the Perkins 1104D-44TA engine. Biofuels were produced in the Fuel and Energy Laboratory belonging to the Maopolskie Centrum Energii Odnawialnej (Małopolskie Center for Renewable Energy Sources), while analyzes of the selected fuel parameters were performed both in the above-mentioned laboratory and in the Liquid Biofuels Laboratory at the University of Agriculture in Krakow. Engine tests were carried out on the engine test stand at the Kielce University of Technology. During the tests, the engine worked according to the external speed characteristic. The results of the tests have shown that the engine supplied with the SME achieves slightly lower values of both power and torque than in the case of commercial fuel oil type Ekodiesel Ultra from the ORLEN S.A company. There was also an increase, especially in the case of higher unitary fuel consumption. Hourly fuel consumption was higher when supplied with SME in relation to the diesel fuel supply, although not as much as unitary consumption. The increase in SME consumption at the engine supply can be explained by the lower fuel value of SME, which contains oxygen in its structure.

Keywords: combustion engine, biofuels, methyl esters of sunflower oil, external speed characteristics

INTRODUCTION

Fuel crises, armed conflicts, increase in energy prices, limited access to its sources and pollution of the environment have resulted in increased interest in renewable energy sources. According to Directive 2001/77/EC [15], renewable energy sources are renewable, non-fossil energy sources. This is intended to bring environmental, economic and social benefits in the future. The most important is the reduction of greenhouse gases emissions and thus preventing climate change, gaining independence from the supply of energy raw materials from outside the Union, and the development of technology and the economy [9].

A well-recognized biofuel intended for supplying compression piston internal combustion engines are esters of fatty acids of vegetable oils [4, 9, 10, 12]. At present, the most commonly used for their production are vegetable oils such as: rapeseed oil, sunflower oil, soybean oil, palm oil, cotton oil, linseed oil, peanut oil, corn oil, castor oil as well as rice bran oil, coconut oil , sesame oil and jatropha [1, 3, 7, 13]. Esters can also be obtained from animal fats constituting the most common production waste [2, 8].

In the paper [7], biodiesel is defined as a mixture of long-chain fatty acid esters derived from renewable lipid raw materials, such as vegetable oils or animal fats, mainly consisting of triglycerides. Esters included in the biodiesel are obtained in the transesterification process in which glycerol is removed from the oil [11, 16–20]. It consists in the chemical reaction of triglycerides contained in the oils with low molecular weight alcohol, methyl or ethyl in the presence of catalysts [5, 14]. During the reaction, the alkoxy group of the triglycerol molecule changes to alcohol resulting in esters of higher fatty acids and glycerol [6, 17]. The obtained esters are used to supply compression ignition engines in pure form or as an additive to diesel oil. The article presents selected results of the tests on Perkins 1104D-44TA engine powered with pure methyl esters of sunflower oil.

TEST SUBJECT

The test subject was a Perkins 1104D-44TA four-cylinder compression engine. It is used to drive a wide range of commercial vehicles for off-road applications. In terms of exhaust emissions, the engine meets the Stage IIIA and EPA Tier 3 standards. The engine is equipped with a sixteen valve type OHV valvetrain with one camshaft located in the engine block. It is driven from the crankshaft of the engine using toothed gears. The engine fuel system uses the Delphi DP310 rotary injection pump and an electric pre-pump, which supplies fuel to the high-pressure pump at 6 bars. The engine inlet system uses a turbocharger controlled by a bleed valve connected to a high boost pressure. The fixing element when the bleeder valve opens is the spring in the valve. The basic technical specifications of the Perkins 1104D-44TA engine are shown in Table 1.

TEST STAND

Experimental tests were carried out on an engine test stand which comprised an Perkins 1104D-44TA engine (test subject), brake, control and measurement cabinet, used to control the stand and obtain readings of the measured engine operation and brake parameters.

The tests were carried out on a test stand located in the Thermal Engine Laboratory of the Kielce University of Technology (Figure 1). The stand includes a Perkins 1104D-44TA engine and an eddy-current type AMX-200/6000 Elektromex Centrum brake with 200 kW, maximum torque of 700 Nm and a maximum speed of 6000 rpm. The work of the stand is controlled and supervised via a desktop computer with Automex software. In addition, this software enables the visualization and archiving of indicators and parameters of the engine and other components of the stand measured during the tests. The engine's fuel consumption is measured using the Automex gravimetric fuel meter. The fuel dose control in the Perkins 1104D-44TA engine is done by means of a cable connecting the high pressure pump with the servo. The servo is connected to the engine control cabinet. The air consumption measurement was carried out using ABB's thermal mass air flow sensor.

Table 1. Perkins 1104D-44TA compression-ignition engine specification

Parameter	Unit	Value
Cylinder system	–	inline
Number of cylinders	–	4
Type of injection	–	direct
Fuel system	–	Delphi DP310 rotary fuel injection pump
Maximum power	kW	75
Rated speed	rpm	2200
Maximum torque	Nm	416.0
Maximum torque rotational speed	rpm	1400
Displacement	m^3	$4.4 \cdot 10^{-3}$
Compression	–	18.2
Air inlet system	–	turbocharged, aftercooled

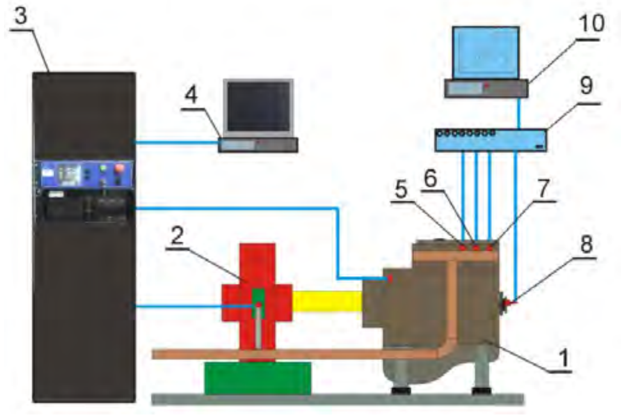

Fig. 1. A diagram of the test stand, where:
1 – Perkins 1104D-44TA engine; 2 – eddy current brake;
3 – measurement cabinet with test stand control system;
4 – computer used to control test facility parameters and to archive test results; 5 – engine cylinder pressure sensor;
6 – injector needle travel sensor; 7 – pressure sensor in the injection hose; 8 – engine crankshaft rotation angle encoder;
9 – module for measuring rapidly changing values;
10 – computer used to archive rapidly changing value readings

FUELS SELECTED FOR TESTING

The tests were carried out on the Perkins 1104D-44TA engine supplied with sunflower oil methyl esters produced in the Malopolska Center for Renewable Energy Sources "BioEnergia". They were obtained in the transesterification process of sunflower oil with methyl alcohol CH_3OH in the presence of a catalyst in the form of alkaline potassium hydroxide KOH. A GW-200 reactor designed by Grzegorz Wcisło [16] was used for this purpose. The view of the GW 200 reactor is shown in Figure 2. It enables the production of esters from various types of vegetable oils and animal fats.

Fig. 2. Reactor GW 200 for production of Biodiesel FAME (SME)

TEST CONDITIONS

Perkins 1104D-44TA engine tests were carried out according to its external speed characteristics. The measurements were carried out in the range of rotational speeds of the crankshaft from 1,000 to 2,200 rpm. The engine torque and effective power, hourly fuel consumption as well as the concentration of the basic exhaust components and the excess air coefficient were measured in the set engine operating conditions. Measurements for powering the engine with esters and diesel fuel were carried out under the same fixed operating conditions. Figure 3 shows the comparison of M_o, torque, effective power N_e, hourly fuel consumption G_h, and unitary fuel consumption g_e of the Perkins 1104D-44TA engine powered with sunflower oil methyl esters and diesel fuel. At each measurement point, lower values of torque and effective power were obtained when the engine was supplied with methyl esters of sunflower oil compared to its supply with diesel fuel. At the same time, when the engine was powered with esters, an increase in hourly fuel consumption and a clear increase in the unitary fuel consumption were obtained.

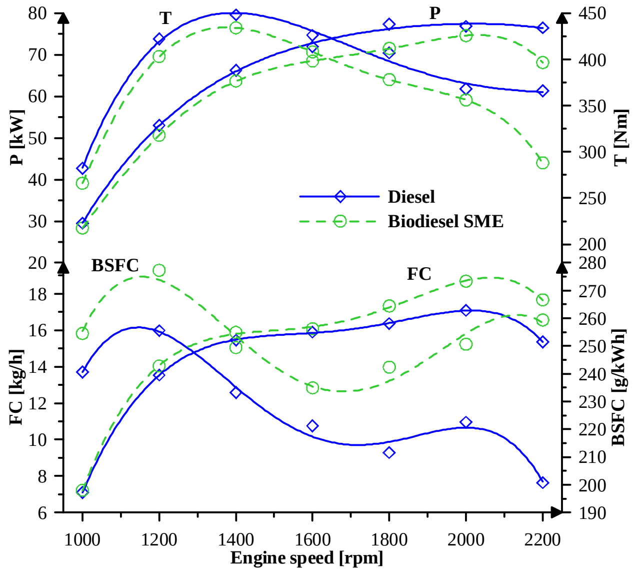

Fig. 3. External speed characteristics of Perkins 1104D-44TA engine powered with sunflower oil methyl esters and pure diesel fuel B0

CONCLUSIONS

Qualitative research on the manufactured SME biofuels, i.e. esters of sunflower oil, showed that biofuel in general is characterized by slightly inferior properties. The net calorific value of SME is lower by 6.2 MJ/kg, or about 16 % [m/m]. However, due to the fact that the density at 20 ºC is characterized by higher properties because it is: for SME 878 [g/dm^3] and diesel fuel 831 [g/dm^3] respectively, and because the fuel dose is worked out in the injection equipment volumetrically, not massively, therefore the value of energy of the injected SME fuel is lower not by 16 %, but by about 10 %. Biodiesel B100 SME is characterized by slightly higher values of kinematic and dynamic viscosity. The differences, however, are small and when fuel is supplied to the engine at temperatures above -10 ºC, no negative impact should be observed. Also, when analyzing the fractional composition, we can see that the SME begins to evaporate much later, which has a negative effect from the point of view of engine run-on and the beginning of combustion. The temperatures of the distillation end are similar and do not exceed 360°C, and therefore meet the requirements of quality standards EN590: 2014 and for SME EN 14214: 2014, respectively

The analysis of the obtained engine test results showed a significant effect of the use of methyl esters of sunflower oil on the concentrations of the basic components of the Perkins 1104D-44TA engine exhaust. Esters and diesel fuel are two fuels that differ in their origin and physicochemical properties. By supplying the engine with sunflower oil esters, its operation according to the external speed characteristics showed a decrease in the obtained torque and effective power values as well as an increase in hourly and unitary fuel consumption in comparison to the engine fuelled with conventional fuel. However, it is worth noting that the differences were minimal. At lower speeds, namely 1000, 1200 and 1400 rpm, the difference was smaller, while in the remaining range it was slightly bigger. This is mainly the effect of lower fuel value of vegetable fuel.

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