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INFLUENCE OF RAPESEED OIL FUEL TEMPERATURE ON ENERGETIC PARAMETERS OF AN ENGINE

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Summary. The paper deals with the study upon the influence of different temperatures of rapeseed oil on energetic parameters of an engine. The study was performed using S-4003 type engine installed on a dynamometric stand. Results revealed the increase of a moment of force by about 3% and the power by about 4%.

Key words. biofuels, vegetable oil, engine fuels

INTRODUCTION

Plant oils - due to the fact that they are renewable - are very interesting alternative fuel because of a closed carbon dioxide circulation in the atmosphere, which can reduce the greenhouse effect. There is a possibility to use fuels made of plant-origin oils in diesel engines: rapeseed, sunflower, palm, etc. In Poland - due to good climatic and soil conditions - rapeseed oil is produced in great quantities, and there is hope for a further increase of the rape plantation area [Bocheński, Bocheńska 2008, Roszkowski 2006].

The diesel engine has recently become a general propulsion source in heavy transport, machines, tractors, sea-ships, track vehicles, as well as part of delivery and passenger vehicles. Such advantages of these engines as high general efficiency, great durability, operational reliability, and reduced emissions of toxic substances have resulted in the steady growth of the number of vehicles equipped with this type of driving unit. In consequence, that development has led to the situation of the growing demand for diesel oil [Kozak, Merkisz 2007].

In Poland, the rapeseed oil for diesel engines may be used in four variants [Podkówka 2004, Uzdowski 2008]:

1. pure rapeseed oil,
2. mixture of rapeseed oil with diesel oil,
3. rapeseed oil methyl esters,
4. mixture of rapeseed oil methyl esters with diesel oil.

Worse working properties as compared to diesel oil, danger of bringing the compressing elements to a halt due to the drying out of the oil and producing excessive sediments in the combustion chamber are the reasons why rapeseed oil is not recommended as a separate fuel for diesel engine supply [Kruczyński, Ambrozik, Danilczyk 2006]. Applying the rapeseed oil as diesel engine propulsion source may be realized in [Wcisło 2003]:

- specially designed engines for plant-origin oils combustion,
- engines equipped with adapting system making possible to heat the oil to an appropriate temperature.

Any interference into an engine - which aims at adapting it to be supplied with plant-origin oil - is expensive and makes it impossible to re-use the diesel oil in the same engine.

Modification consisting in applying the bi-fuel system is a much easier solution. The plant-origin oil supply system facilitates its warming up to 80-100°C. That solution allows for decreasing the oil viscosity, hence fuel can be better sprayed. Plant oils are of higher viscosity than diesel oil, namely at lower temperatures. Great difference in both viscosities causes that the engine cannot be started at 5°C and it makes a proper work of fuel injection devices at higher ambient temperatures impossible.

In systems that adapt rapeseed oil, it can be warmed in three different ways [Wcisło 2003]:

a) with the heat emitted by cooling system,

b) using electrical heater,

c) in both the above-mentioned ways at the same time.

The first mentioned solution allows for starting the engine using common diesel oil. When the cooling medium reaches about 80°C, the engine switches over the rapeseed oil supply that is warmed in a specialized heat exchanger connected to the cooling system. The exchanger structure has to heat the plant oil up to about 70°C .

Using an electrical heater is the simplest method: the heating device should be just mounted on a fuel line and connected with wires. In practice, because of large power demand (the device must work all the time), such solution seriously overloads the electrical installation, namely alternator.

The third solution consists in two-stage oil heating:

- preliminary,
- during the engine work.

Electricity is used for preliminary heating of the oil. It aims at facilitating the flow of the oil through the fuel system and enabling the start of the cold engine. When the engine is ignited, the heat carried by the medium that cools the engine is used to secure the proper temperature.

In all these variants, engine should be switched onto the diesel oil before it is turned off. The operation would cause the re-start much easier and allow for keeping the engine interior and fuel supply system clean. The plant oil itself could leave too much of hazardous sediments and cause the corrosion of injection devices [Piekarski; Dzieniszewski 2006].

PURPOSE AND METHODS

The present study aims at an evaluation of the influence of various temperatures of heated rapeseed oil on energetic parameters of the engine fed with this type of fuel. Changes of parameters recorded at supplying with rapeseed oil were compared to those for engine fed with common diesel oil.

Rapeseed oil samples were obtained from Fat Manufacturers in Bodaczów Sp z o.o., while diesel oil Ekodiesel was purchased on the market. Both types of fuel were divided into three groups:

OR 1 – cold-extruded rapeseed oil, non-purified +80°C,

OR 2 – cold-extruded rapeseed oil, non-purified +20°C,

ON – diesel oil +20°C.

Tests of energetic parameters were carried out in a stand on the test bench (Department of Power and Vehicles Engineering, University of Life Sciences in Lublin). The testing stand was equipped with diesel engine of S–4003 type, electric break of K1-136 B-E type that played the role of a starter, a kit for measuring the fuel utilization consisting of: dosimeter PG-200 and electronic scales TP-30B, as well as engine status measuring kit: exhausted gases temperature, temperature of cooling medium, oil pressure presented in Figure 1.

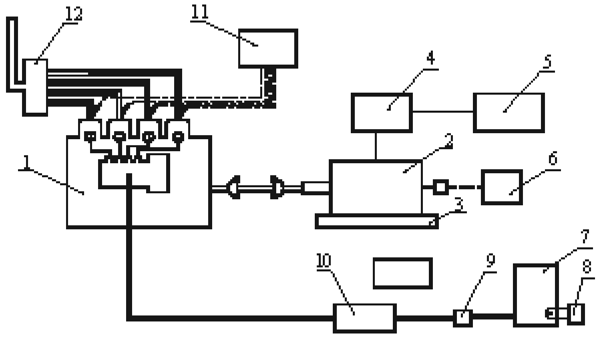

Fig. 1. The diagram of the test stand: 1 – test engine, 2 – electric brake, 3 – force counter, 4 – liquid resistor, 5 – brake switchboard, 6 – rotation counter, 7 – fuel tank, 8 – thermostatic system with temperature control, 9 – fuel filter, 10 – balance, 11 – fume temperature measures, 12 – joint fume collector

The S-4003 type engine was: four-stroke with self-ignition and direct injection to a chamber in a piston, equipped with rowed injection pump P24T8-3a with regulator R8V20-120/74D, as well as injection devices WJ1S78.7A with five-hole sprayers DSL 150.A2.

Prior to the study, necessary checks and appropriate regulations were made according to requirements of a trial card.

Tests of the engine energetic parameters consisted in performing measurements in accordance to PN for each of the studied fuel types, which made it possible to collect data necessary for plotting the outer velocity characteristics within the range from minimum to nominal rotational speed of the engine.

The following parameters were taken into account during measurements:

– rotational speed n,
– time for utilizing the fuel measuring dose τ,
– fuel density ρ,
– temperature of exhaust gases at the collector outlet t_{sp},
– power at the break P.

Electric heater was used to warm up the rapeseed oil to temperatures of 20°C and 80°C. In order to minimize the heat losses of the rapeseed fuel, the fuel reservoir was thermally isolated. Dosimeter PG–200 with electronic scales TP–30B was used to measure the fuel utilization. Fuel measuring dose for making the characteristics amounted to 25g.

Exhaust gases temperature was measured in exhausting pipes of particular cylinders, while mean value was taken into account for result analysis. The distance of the temperature probes from the outlet valves was about 30 mm. Values of exhaust gases temperatures were read from the measuring instruments installed in the measurement cabin.

The following items were calculated on the basis of the measured parameters:

1. Moment of force Mo,
2. Effective power Ne,

3. Hourly fuel utilization *Gp*,
4. Unit fuel utilization *ge*.

Such physicochemical properties of rapeseed oil as density and viscosity were also determined. Theses data are presented in Table 1.

Table 1. Physicochemical parameters of the used fuels

Research fuel	Viscosity [mm2/s]	Density [kg/m3]
OR 1	8	862
OR 2	78	920
ON	2,75	820

Statistical processing of the achieved study results included energetic parameters variability assessment, analysis of significance of differences between these parameters values and the determination - based on curvilinear regression analysis method – of the functional dependencies. The influence analysis of a bio-component addition on energetic parameters was carried out by means of one-way variance analysis (ANOVA), while the assessment of significance of differences between the tested fuels vs. diesel oil was performed applying the Tukey's least square differences test (LSD) at significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The influence of rapeseed oil supplying engine on its energetic parameters was evaluated on the basis of outer characteristics. Changes were compared to those made for the engine fed with the diesel oil. Study results are presented in Figure 2.

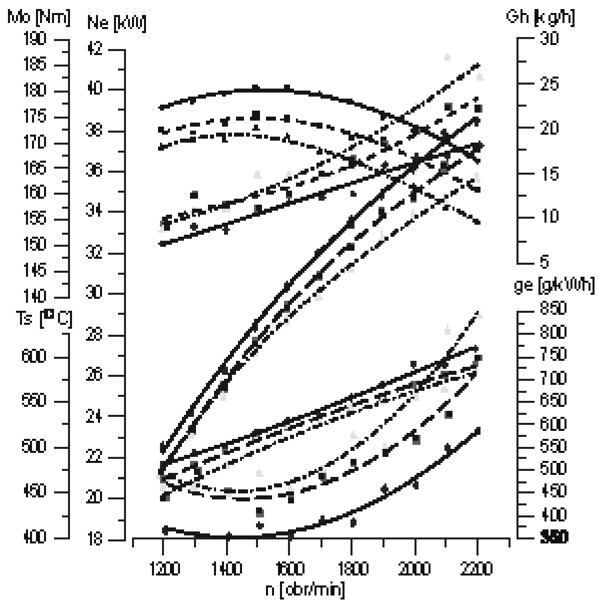

Fig. 2. Outer characteristics of S–4003 type engine fed with the tested fuels

The analysis of the moment of force curves revealed that the rapeseed oil applied at various temperatures did not cause any significant changes in the curves trends wherease the decrease of the moment values for particular plant oils is apparent. The largest drops of the moment values within the whole range of rotational speed were recorded for rapeseed oil at 20°C, which amounted to 6%. A lower decrease of the moment of force for plant oil was observed at elevated temperatures - only about 3%. Maximum moment of force achieved by the engine fed with the tested fuels reached the following values: OR1 – 175.9 Nm, OR2 – 173.1 Nm, and OR3 – 170.7 Nm. The relative decrease of the moment compared to the diesel oil (Figure 3) was 4.4% for "cold" oil and 2.78% for "warmed" oil.

The analysis of plant fuel power curves indicated that their course character did not considerably differ from those for diesel oil. Application of the tested rapeseed fuels caused the decrease of engine power that was most apparent at higher rotational speed values. However, these drops reached different values for particular fuel types. The largest power decrease was found for rapeseed oil at 20°C (OR2), heating the vegetable oil resulted in lower drop in engine power. Heating up the rapeseed oil contributed to the decrease of engine power drop, which was within the range of 2.8-5.5%.

The maximum power reached by the engine when fed with tested plant fuels was as follows: for OR1 – 37 kW, while for OR2 – 35.6 kW. Relative change of maximum power was 3.45% for OR1 and 7.08% for OR2 fuel.

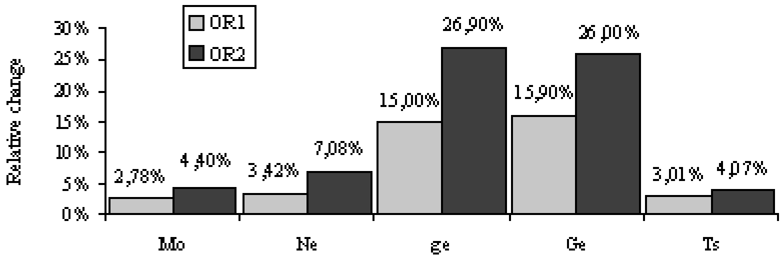

Fig. 3. Relative change of energetic parameters for S-4003 type engine supplied with the tested fuels and compared to diesel oil

Curves illustrating the unit fuel utilization revealed that their character for rapeseed oil at 20°C differed from those for diesel oil. It was particularly seen at higher rotational speed values of the engine; above 1600 rpm, the unit rapeseed fuels utilization increased more suddenly than for diesel oil: for diesel oil from about 1600 to 2200 rpm, the increase of unit fuel utilization was 322 g/kWh, whereas for OR3, the increase was up to 423 g /kWh. It is worth noticing, that unit fuel utilization curve characteristics for rapeseed oil was of similar shape as that for diesel oil; however all the values were higher.

Minimum unit fuel utilization for the tested plant oils was the following: OR1 – 407.2 g / kWh and OR2 – 449.3 g /kWh. R The relative changes in minimum unit fuel utilization values were: 26.9% for OR2 and 15% for OR1.

Curves of hourly fuel utilization for the tested fuels were of similar character as for diesel oil; only their slight shift towards higher values, namely at higher rotational speeds, could be seen. Application of rapeseed oils for supplying the engine resulted in the increase of average fuel utilization. Mean fuel utilization for the tested fuels was OR1 – 14.9 kg /h and OR2 – 16.2 kg /h.

Analysis of exhaust gases temperature changes indicated that the dependence course for plant oils was similar to that for diesel oil; only their shift towards lower values was apparent. The maximum exhaust gases temperature when the engine was fed with rapeseed oil reached 590°C for OR1 and 584°C for OR2. Relative exhausted gases temperature changes amounted from 3% for OR1 to 3.01% for OR2 fuel.

Statistical analysis of the results related to the influence of rapeseed oil temperature as a fuel on engine moment of force revealed that the changes in the latter ran with various dynamics in relation to diesel oil, i.e. determined regression curves were not parallel (an appropriate statistical test rejected the parallelism hypothesis). It was also found that power changes for the tested fuels statistically differed from those for diesel oil at the significance level of 0.05. Changes in unit and hourly fuel utilization also significantly differed from those for diesel oil at the significance level of 0.05. On the other hand, changes of the exhausted gases temperature did not significantly differ from those for diesel oil at the significance level of 0.05.

The regression models for moment of force, unit and hourly fuel utilization, as well as for exhausted gases temperature for the tested fuels were described with equations presented in Table 2, where also determination coefficients R^2 were given.

Table 2. Regression equations for variables calculated on the basis of test results

Dependent variable y	Fuels	Regression equations	Coefficient of determination R^2
Mo [Nm]	ON	$y = -3 \cdot 10^{-5} \cdot n^2 + 0{,}08 \cdot n + 114{,}57$	0,973323
	OR1	$y = -3 \cdot 10^{-5} \cdot n^2 + 0{,}0854 \cdot n + 110{,}71$	0,961842
	OR2	$y = -3 \cdot 10^{-5} \cdot n^2 + 0{,}0949 \cdot n + 107{,}7$	0,971745
Ne [kW]	ON	$y = -6 \cdot 10^{-6} \cdot n^2 + 0{,}0382 \cdot n - 14{,}482$	0,999401
	OR1	$y = -6 \cdot 10^{-6} \cdot n^2 + 0{,}0362 \cdot n - 13{,}205$	0,999032
	OR2	$y = -6 \cdot 10^{-6} \cdot n^2 + 0{,}0382 \cdot n - 12{,}826$	0,999124
ge [g /kWh]	ON	$y = 1 \cdot 10^{-7} \cdot n^3 - 0{,}0003 \cdot n^2 + 0{,}0259\, n + 527{,}49$	0,967711
	OR1	$y = 4 \cdot 10^{-7} \cdot n^3 - 0{,}0013 \cdot n^2 + 1{,}4705\, n + 73{,}302$	0,931001
	OR2	$y = 2 \cdot 10^{-7} \cdot n^3 - 0{,}0006 \cdot n^2 + 0{,}1165\, n + 730{,}74$	0,969144
Gp [kg /h]	ON	$y = 0{,}0111 \cdot n - 5{,}9895$	0,966321
	OR1	$y = 0{,}0131 \cdot n - 6{,}6491$	0,927419
	OR2	$y = 0{,}0177 \cdot n - 12{,}957$	0,918102
Ts [°C]	ON	$y = 2 \cdot 10^{-5} \cdot n^2 + 0{,}0802 \cdot n + 358{,}53$	0,983914
	OR1	$y = -6 \cdot 10^{-5} \cdot n^2 + 0{,}3288\, n + 133{,}2$	0,953012
	OR2	$y = -2 \cdot 10^{-5} \cdot n^2 + 0{,}1803 \cdot n + 271{,}58$	0,966451

CONCLUSIONS

Issues related to bio-fuels, including rapeseed oil, utilization for engine supplying should be considered taking into account the technical, ecological, economical, and social aspects. The present work focused only on one selected technical aspect of rapeseed application as a bio-fuel. It resulted from economical and social reasons. For farmers, rapeseed oil is a fuel whose production is completed after the oil extrusion and filtration; it does not require any additional devices and chemicals, contrary to FAME production.

The high viscosity value of rapeseed oil is an important factor limiting its use as a fuel [Baczewski, Kałdoński 2004, Szlachta 2002, Tys et al. 2003], because at 20°C it is about 12 times higher for rapeseed oil than for diesel oil [Piekarski, Dzieniszewski 2006]. Viscosity is a parameter having a significant influence on the work of injection devices and injection process. Higher viscosity contributes to the spraying level decrease, thus large drops are formed and their range increases. Non-optimum combustion conditions cause an increase of exhaust gases production and penetration of the not-combusted rapeseed oil to the lubricating oil [Cisek, Szlachta 1996, Lotko 1994]. Lowering the viscosity of rapeseed oil supplied to an engine, hence an improvement of injection parameters, can be achieved by its heating.

On the basis of the performed tests and studies the following conclusions can be drawn:

1. Warming the rapeseed oil to 80°C makes its viscosity decrease to 8mm2/s and density to 862 kg/m3. Lower viscosity and density result in the improved quality of fuel spraying and a higher combustion process efficiency, which is reflected as an improvement of the engine's energetic parameters when fed with this type of fuel.
2. Studies upon energetic parameters of the engine fed with heated rapeseed oil revealed better features for plant oil warmed to 80°C: an increase of the maximum moment of force by about 3%, power increase by about 4%, decrease of unit fuel utilization by about 11%, and decrease of exhaust gases by about 1%.

Nevertheless, further research into the detailed mechanisms of the above-described changes is necessary.

REFERENCES

Baczewski K., Kałdoński T. 2004.: Paliwa do silników o zapłonie samoczynnym. WKŁ, Warszawa..

Bocheński C., Bocheńska A. 2008.: Ocena zasobów ropy naftowej i perspektywy jej substytucji biopaliwami. Motrol, t. 10, 23–30.

Cisek J., Szlachta Z. 1996.: Wpływ oleju rzepakowego i jego mieszanin z olejem napędowym na właściwości robocze, rozruchowe i eksploatacyjne silnika wysokoprężnego. Wydawnictwa Politechniki Krakowskiej. Monografia nr 210. Kraków.

Kozak M., Merkisz J. 2007.: Some Considerations on the Oxygenated Fuels for Diesel Engines. Kom. Mot. Energ. Roln. TEKA t. 7, 129–136.

Kruczyński S.W., Ambrozik A., Danilczyk W. 2006.: Assesment of Operating Characteristics of Fuels for Diesel Engines. Kom. Mot. Energ. Roln. TEKA t. 6, 46–54.

Lotko W. 1997: Zasilanie silników wysokoprężnych paliwami węglowodorowymi i roślinnymi. WNT Warszawa.

Merkisz J. 1994: Wpływ motoryzacji na skażenia środowiska naturalnego. Wydawnictwo Politechniki Poznańskiej, Poznań.

Piekarski W., Dzienszewski G.: 2006.: Wybrane problemy zasilania silników Diesla nisko przetworzonym olejem rzepakowym. Eksploatacja i Niezawodność 3.

Podkówka W. 2004.: Biopaliwa. Gliceryna. Pasza z rzepaku. Wyd. Uczel. AT-Rbydgoszcz

Polski Koncern Naftowy ORLEN S.A. 2008.: Świadectwa jakości paliw, Płock.

Roszkowski A. 2006.: Agriculture and Fuels of the Future. Kom. Mot. Energ. Roln. TEKA t. 6, 131–134.

Szlachta Z. 2002.: Zasilanie silników wysokoprężnych paliwami rzepakowymi. WKŁ, Warszawa.

Tys J., Piekarski W., Jackowska I., Kaczor A., Zając G., Starobrat P. 2003.: Technologiczne i ekonomiczne uwarunkowania produkcji biopaliwa z rzepaku. Acta Agrophysica 99. Instytut Agrofizyki PAN, Lublin.

Uzdowski M. 2008.: Problematyka wykorzystania paliw alternatywnych do zasilania silników trakcyjnych. MOTROL t. 10, 143–146.

Wcisło G. 2003.: Możliwości zasilania olejem rzepakowym silników wysokoprężnych w pojazdach rolniczych. Inżynieria Rolnicza, 10 (52),43-49.

WPŁYW TEMPERATURY PALIWA-OLEJU RZEPAKOWEGO NA PARAMETRY ENERGETYCZNE SILNIKA

Streszczenie. W artykule przedstawiono wyniki badań oraz analizę wpływu różnych temperatur oleju rzepakowego na parametry energetyczne silnika. Badania przeprowadzono na silniku typu S-4003 zainstalowanym na stanowisku dynamometrycznym. Na podstawie przeprowadzonych badań zaobserwowano wzrost wartości momentu obrotowego o około 2% oraz mocy o około 4%.

Słowa kluczowe: biopaliwa, olej roślinny, paliwa silnikowe