

THE APPLICATION OF NON-CONVERTED VEGETABLE OILS IN CONTEMPORARY SELF-IGNITION ENGINES

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Abstract

The paper presents a test of a self-ignition engine equipped with high-pressure fuel-dosing system based on injection units with electronic control system. The engine was fuelled with conventional fuel and few kinds of non-converted vegetable oil.

The analysis of the experiment results correlated with knowledge of their properties shows the important conclusions about possibilities, disadvantages and perspectives of the fuels usage in contemporary engines equipped with electronic control fuel-dosing system.

The vegetable oils have a special place in history of automotive industry. In 1900 a great event on Word Trades in Paris was compression-ignition engine fuelled by groundnuts oil – a masterpiece of no one else like Rudolf Diesel. R. Diesel, aware of conventional fuels limitation, patented in 1892 a vegetable oil as a fuel. The NO_x concentration in exhaust was measured for maximum engine speed (1900 rpm). The lowest emission of measured compounds was observed in case of sunflower oil and rape oil "Biedronka" (65% and 75% of emission during engine work fuelled by conventional diesel oil). The highest values were detected for post frying palm oil and rape oil "Aldi" (120% of emission during engine work fuelled by conventional diesel oil).

Keywords: combustion engines, vegetable oils, diesel engine, alternative fuels

1. Introduction

The vegetable oils have been used by humans as a fuel from the beginning of the civilization. Oil lamps, which thanks to energy discharging delivered light and heat what cause a increase of human life comfort, was used as far back as in second millennium BC. The vegetable oils have a special place in history of automotive industry. In 1900 a great event on Word Trades in Paris was compression-ignition engine fuelled by groundnuts oil – a masterpiece of no one else like Rudolf Diesel. R. Diesel, aware of conventional fuels limitation, patented in 1892 a vegetable oil as a fuel. The researcher wrote:

"Although vegetable oil using as a fuel is insignificant issue these days, but it is possible that in future this kinds of fuels will be as far important source of energy as conventional oil and coal fuels nowadays".

It seems that now, in time of fuel crisis, increasing prices of crude oil which supplies are running out and green-house effect once again we should consider the Rudolf Diesel idea [3].

A consequence of conventional fuel crisis in automotive industry two main directions for fuel saving had been shown: using of small, high-effectiveness engines, often equipped with turbo-charging systems and hybrid-systems or researches on alternative fuels development.

But is it possible to use a vegetable oil for modern, technological complicated and sensible for fuel quality diesel engines?

To find an answer for foregoing question the researches on engine testing-bed was conducted. The aim of the researches was determination of engine external characteristics, fuel consumption and emissions. The researches included engine fuelling by differential vegetable oils. The results of the experiment was compare to the results acquire during engine work on classic diesel oil.

The oils used during the experiment, was put into several physical-chemical tests in Institute of Chemistry and Technology of Crude Oil and Coal on Wroclaw University of Technology.

2. Experiment: engine testing-bed

The aim of the researches was verification and valuation of effects of the edible, vegetable oils for diesel engine fuelling in correlation with gained technical parameters.

During the researches an optimal temperature of engine and fuels was hold. The engine fuelling system was equipped into two-reservoir conception: when engine starts and ends of its work the conventional, diesel fuel is used and destination fuel is used during standard engine work. The second reservoir (with vegetable oil) is used after special, controlling cut-out opening.

The reservoir with alternative oil was equipped with an extra heat exchanger which aim is temperature uprising. The oils preheat caused upraise of their application parameters: decrease of its viscosity what causes flow, pressure and injection improving [2].

The engine type choosing

The diesel engine, cubature 1896 cm³ was employed as the research engine. The engine was an assortment of Volkswagen commercial named 1.9 TDI. The research engine characterized of follow operations parameters [1]:

- engine type: AHF,
- cylinder diameter: 79.5 mm,
- piston stroke: 95.5 mm,
- compression ratio: 19.5,
- maximum power: 115 horsepower (85 kW) at 4000 rpm,
- maximum torque 285 Nm at 1900 rpm.

Measured parameters of engine work

The researches aim was estimation of movement and operation parameters especially accented on determination of impact of fuel type on variation of engine work external characteristic, exhaust emission and fuel consumption.

The measurement applied to:

- engine power,
- torque,
- CO, NO concentration in exhaust and exhaust smokiness,
- fuel consumption,
- fuel temperature before entrance to cylinder head,
- exhaust temperature.

The research description based on physical-chemical analysis

For 1.9 TDI engine fuelling four kinds of vegetable oils was applied and standard fuel: conventional diesel oil. The fuels which were used during the engine test are edible oils which are available in popular supermarkets nets. For better differentiate of the oils in the researches the oils was named of supermarket names.

In the researches post frying oil was also used (from chosen gastronomy point). It was palm oil contains additional esters of fatty acids and many others organic substances absorbed during thermal conversion of food. For the post frying palm oil conditioning for the researches aim multistage filtration process was applied. The aim of the process was elimination of hazardous for injection system pollution and particle matter.

The scheme of the engine fuel was as follow:

- sunflower refinement oil "Lidl",
- rape refinement oil "Wyborny-Biedronka",

- rape refinement oil "Aldi",
- post frying palm oil, multiused in gastronomy, after conditioning, filtration process.

The physical-chemical researches were conducted in Institute of Chemistry of Wroclaw University of Technology. During the researches variable density of fuels was determinate in several temperatures: 15, 20, 80, 90, 100°C, kinematical viscosity in 20, 40, 80, 90, 100°C, temperature of ignition (method of close melting pot), amount of solid matter and water, fraction composition (in distillation process), iodine number, temperature of filter blocking.

The analysis of the results allows evaluating and estimating the effects of the oils using as an engine fuels. The results are shown on Fig. 1.

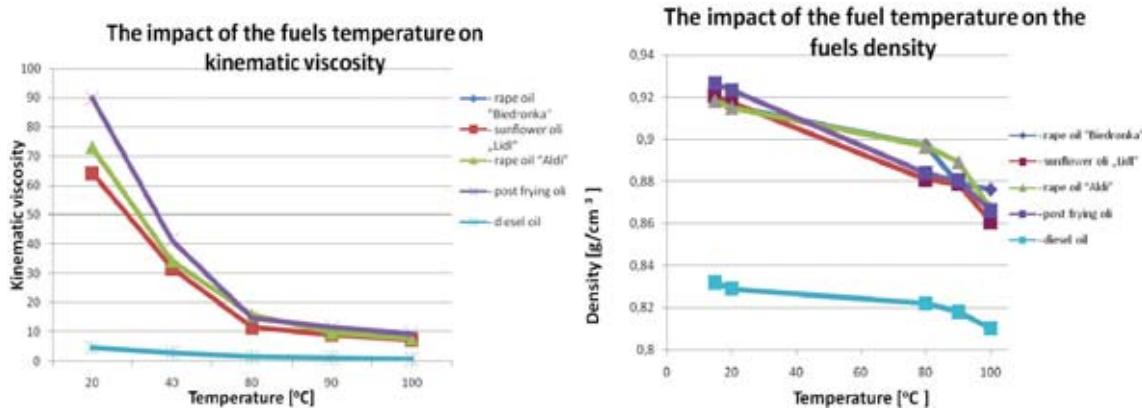


Fig. 1. The impact of the fuels temperature on kinematic viscosity and on the fuels density

It is possible to conclude that kinematic viscosity of tested during the researches vegetable oils is even several fold higher than conventional diesel oil. In case of post frying palm oil this value is over 17 fold higher (in 20°C). Comparing these values to operation parameters of engine it is evident that the fact impact negatively on fuelling system, especially: dose value, needle movement, pressure, injection time and fuel spraying in combustion chamber. In result is aggravation of fuel-air mixture composition process and its combustion. Relative high value of kinematic viscosity does not possible of engine start in temperature below 15°C. The engine should be equipped in doubled fuelling system where vegetable oil fuelling system should be preheated (to gained oil temperature on level 90°C) before high-pressure part of the system.

The density value of vegetable oils (Fig. 1) is approximately 10% higher than conventional crude oil and it is sustained in that correlation in whole range of temperatures. Higher density impact on fuel flow in injection system decreases its pulsation. Higher values of density and viscosity of vegetable oils have significant effects on time of fuel injection into combustion chamber. This problem causes consequences in exhaust toxicity and residuals (i.e. soot).

Significant differences in fuels parameters are shown in ignition temperature range (temperature of ignition is four fold higher than conventional diesel fuel). This parameter impacts strongly on ignition delay period. It is also shown in lower cetin number (CN) of vegetable oils: CN = 37 ~ 45, when diesel oil CN is over 51. When CN is very low (below 40), soot is generated on fuel spring system elements. Also negative effects on particle matter emission and exhaust smokiness is shown [5].

Important in operating point of view is temperature of cold filter blocking which determine flow abilities of fuel in low temperatures of external environment. Determination of cold filter temperature for vegetable oils wasn't possible – the filter had been blocked before the test started. The fact could be caused because of glycerine crystallization and water content in the fuels. The crystals can block the filtration area of the filtration net. Additionally, high resistant of vegetable oil flow is also parameter escalate the phenomena [5].

The iodine number is a determination of the amount of unsaturation contained in fatty acids and is very significant parameter of oil in storage and combustion aspects. The highest number of

saturated combinations (lowest iodine number) gives the more problems with fuel combustion. Based on own analysis of physical-chemical properties of the tested oils even 8 fold higher iodine number is observed in case of vegetable oil in comparison with conventional diesel oil. This information is compatible with cetin number and confirms the fact that vegetable oils are worse engine fuel in self-ignition aspect [4].

The criteria of fuel valuation

As criteria of fuel valuation – a factor which contribute a base for optimal engine vegetable fuel choosing – the parameters of engine work on that fuel were used. The valuation is a comparison analysis of achieved parameters with parameters of engine fuelled of standard, classic diesel oil, but complex analysis of the research engine work should be extended as follow:

- impact of the fuel on injection system usage,
- changes of physical-chemical properties of lubrication oil and level of slide bearings,
- soot accumulation in combustion chamber,
- condition of sealing piston annuluses.

Description of the research work stand

The researches were conducted in Department of Vehicles and Combustion Engines at the Wroclaw University of Technology. The engine test bed was equipped in special analytic and controlling systems for engine work monitoring.

3. Results and discussion

The torque

Follow figure (Fig. 2) torque characteristic of the engine fuelled by tested oils in correlation to the engine speed is presented. The average decrease of torque value in whole range of engine rotation, in correlation to standard diesel oil, is 20.5 %. The torque decrease was significantly seeable in case of rape oil "Biedronka" and sunflower oil "Lidl". Rape oil "Aldi" characterized the closest values of torque in comparison to diesel oil (torque decrease was 9 %).

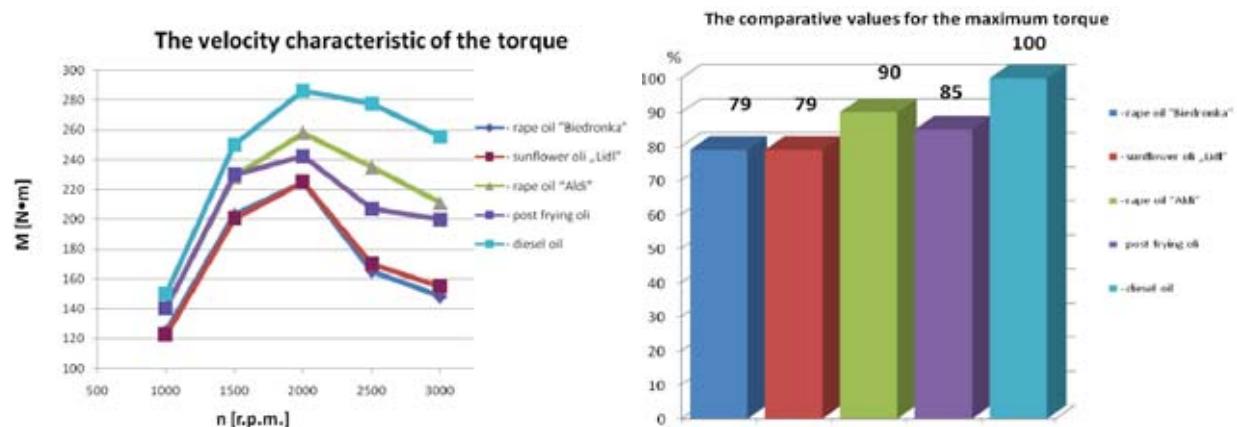


Fig. 2. The velocity characteristic of the torque and the comparative values for the maximum torque

The maximum torque value for the research engine was observed in case 2000 rpm of engine speed. For that engine speed a comparison diagram was made (Fig. 2). On the diagram maximum values of the torque is shown. As a standard value maximum torque for diesel oil was assumed: 286 Nm. On the Fig. 4 it is possible to observe that the lowest aberration is 10% (28.5 Nm) from nominal value was achieved for "Aldi" oil.

The engine power

The engine power was significant lower when engine was fuelled by vegetable oils. The average decrease of the engine power in tested range of the engine speed is 28%. The highest reductions of measurement value were observed for sunflower oil "Lidl" and rape oil "Aldi" (Fig. 3). In case of

vegetable oils a significant tendency of rapid engine power decrease after maximum torque achieving was also observed.

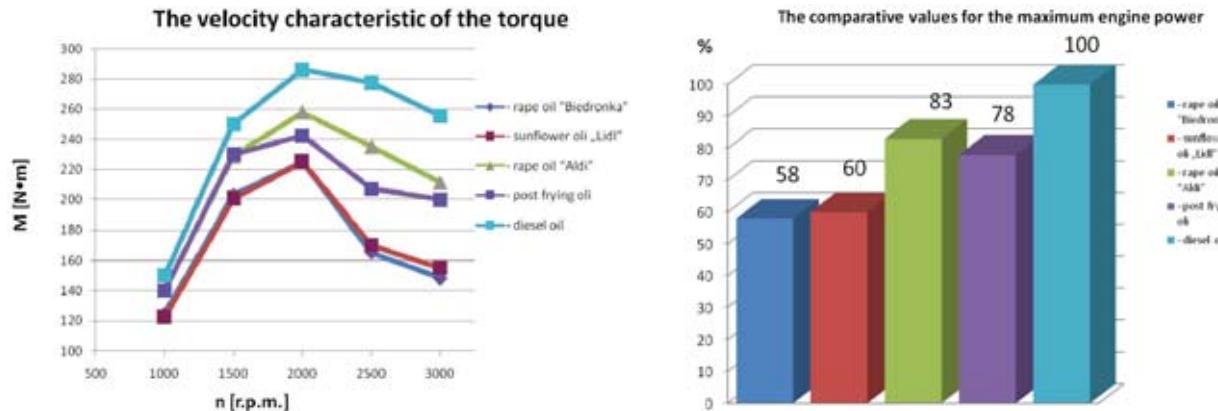


Fig. 3. The velocity characteristic of the engine Power and the comparative values for the maximum engine power

On Fig. 3 maximum power values for vegetable oils in correlation to standard value for diesel oil (80 kW, 3000 rpm) are shown. The highest, almost 40%, decrease is observed for "Biedronka" oil. Achieved values of engine power are strongly correlated with the results of the torque measurements.

Aggravation of the torque and the engine power can be reasoned mainly by lower energy which vegetable oils consist. Also the highest kinematic viscosity of vegetable oils and correlated with this a specific way of injection system operating, have a significant impact on oil dose to the combustion chamber.

Fuel consumption

During the researches of using vegetable oils as a diesel fuel higher value of the fuel consumption was observed in comparison to conventional curled oil (Fig. 4). The average difference of fuel consumption was 10% in case post frying palm oil to even 18% in case of rape oil from "Biedronka".

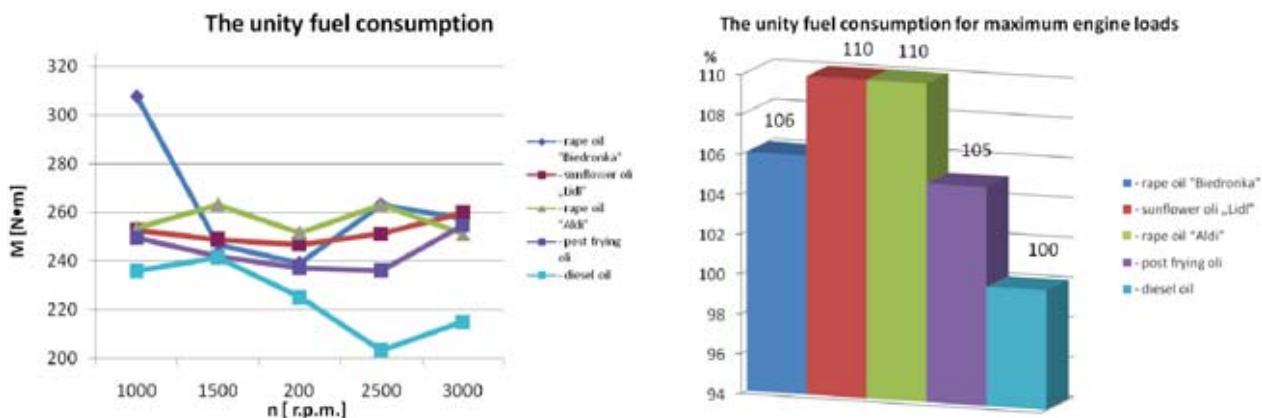


Fig. 4. The unity fuel consumption for the full characteristic and for maximum engine loads

For the fuel consumption measured Turing the maximum torque (Fig. 4) the highest value was observed for sunflower oil from "Lidl" and rape oil "Aldi" (110% value of conventional diesel fuel).

The smokiness level

The results show almost 70% decrease of exhaust smokiness during the vegetable oils combustion in the diesel engine (in comparison to conventional fuel). The measurement was conducted during the maximum engine load. The best results were achieved when engine was worked fuelled by post frying palm oil (80% decrease of exhaust smokiness) (Fig. 5).

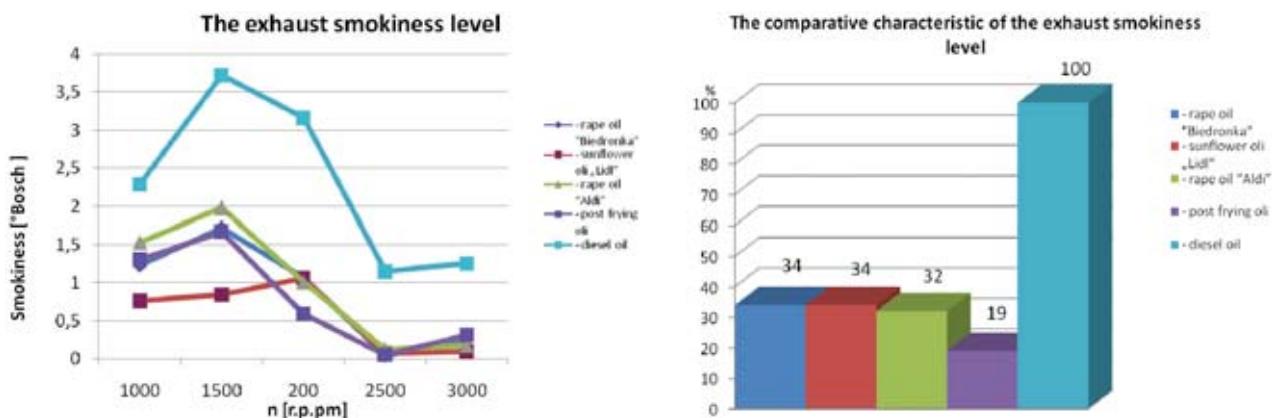


Fig. 5. The exhaust smokiness level and the comparative characteristic for maximum engine loads

The NO_x emission

The NO_x concentration in exhaust was measured for maximum engine speed (1900 rpm). The lowest emission of measured compounds was observed in case of sunflower oil and rape oil "Biedronka" (65% and 75% of emission during engine work fuelled by conventional diesel oil). The highest values were detected for post frying palm oil and rape oil "Aldi" (120% of emission during engine work fuelled by conventional diesel oil).

4. Conclusions

1. The researches proofs that it is possible to use raw vegetable oils for diesel engine fuelling. The necessary requirement is oil preheated to 80-100°C.
2. The important factor is also fuel consumption which is significantly higher for vegetable oil (from 10%, in case post frying palm oil, to even 18% for rape oil "Biedronka") in comparison to the conventional diesel oil.
3. In case of vegetable oil using as the engine fuel, decrease of the engine power was observed in whole range of engine speed (from approx. 30% for "Biedronka" rape oil and sunflower "Lidl" oil, to 12% for rape oil "Aldi") in comparison to the conventional fuel.
4. The important phenomena are exhaust smokiness level decrease when engine was fuelled by vegetable oils in whole range of engine speed. The average value of smokiness reduction was 70% in comparison to the diesel oil (the highest, 81%, for post frying palm oil).
5. The NO_x emission was the highest for post frying palm oil and rape oil "Aldi" (approx. 20% increase in comparison to conventional diesel fuel), the lowest emission was detected for "Lidl" sunflower oil (approx. 35% decrease in comparison to conventional diesel fuel).
6. In aspect of the engine combustion effectiveness the conclusion is that the process is the most effective for rape oil "Aldi" and post frying oil. The researches show NO_x concentration increase (about 20%) and CO significant decrease. Those values suggested increase of the combustion temperature what cause in increase of engine combustion effectiveness. The proofs for those phenomena are values of engine power and torque for these fuels which are similar for conventional fuel values.
7. The researches effect is a conclusion that modern engines parameters which are fuelling by vegetable oils are similar to tendencies showed in the results of the researches which had been conducted in past. The highest temperature of fuel combustion is responsible for NO_x concentration increase and CO concentration decrease.
8. The technical, ecological and economical aspects of vegetable oils, according to this study results, suggest that it is very important to continue the researches especially in aspect of an optimization of an engine injection system, durability and viability of the engine.

9. A new idea is using post frying oil for engine fuelling which often is a residual. That kind of alternative fuel may be a chip, profitable energy source for combustion, diesel engine.

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