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# WORK INDICATORS TEST FOR PROTOTYPE JOHN DEERE 6830 AGRICULTURAL TRACTOR FUELED WITH PURE VEGETABLE OIL

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K e y w o r d s: diesel fuel, pure plant oil fuel, tractor engine power, fuel consumption.

A b s t r a c t

The paper summarizes results of tests of John Deere agricultural tractor type 6830 fueled with pure raps oil. The measurements were performed using an electro-magnetic brake connected to the tractor with a power transfer shaft (WOM). Specification of the engine fueled with pure raps oil was drawn up during the tests and it was compared with the engine fueled with diesel. The main conclusions include identification of a power drop of the engine fueled with the raps oil by an average of 10% in comparison with the same engine fueled with diesel and increase of fuel consumption per kWh by 15%. The identified drop of power had no impact of work efficiency including power consuming agricultural works.

## BADANIA WSKAŹNIKÓW PRACY PROTOTYPOWEGO SILNIKA CIĄGNIKA ROLNICZEGO JOHN DEER 6830 ZASILANEGO NIEPRZETWORZONYM OLEJEM ROŚLINNYM

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S ł o w a k l u c z o w e: olej napędowy, czysty olej roślinny, moc ciągnika, zużycie paliwa.

A b s t r a k t

W artykule podsumowano wynik badań ciągnika rolniczego marki John Deer typu 6830 zasilanego czystym olejem rzepakowym. Pomiar prowadzono z wykorzystaniem hamulca elektromagnetycznego podłączonego do ciągnika przez wałek odbioru mocy (WOM). W trakcie badań sporządzono zewnętrzną charakterystykę silnika zasilanego czystym olejem roślinnym i w celu porównania – olejem napędowym. Zauważono spadek mocy silnika zasilanego olejem roślinnym średnio o 10% w stosunku do tego samego silnika zasilanego olejem napędowym oraz zwiększone o 15% jednostkowe zużycie paliwa w przeliczeniu na kWh. Zarejestrowany spadek mocy nie miał wpływu na efektywność wykonywanej pracy także podczas wykonywania energochłonnych prac polowych.

**List of units**

$M_o$ – torque [Nm]
$N_e$ – effective power [kW]
$G$ – fuel consumption [kg $h^{-1}$]
$g_e$ – fuel consumption per unit [g $kWh^{-1}$]

## Introduction

In the twentieth century crude oil has become a strategic resource for the whole global economy. The first diesel engine was developed in line 1890s. It revolutionized the world and diminished importance of steam engines. Initially it was fueled with raps oil. Fast development of crude oil extraction and its processing resulted in replacement of raps oil with diesel produced from crude oil. The first major energy crisis took place in 1970s. It caused increase of prices of diesel and undermined fuel supply. The crisis triggered research for alternative fuel for common use in internal combustion diesel engines. The idea of use of raps oil as an alternative source of fuel for diesel engines was reconsidered. Characteristics of raps oil, however, significantly differs from parameters of diesel. Therefore simple replacement of crude-oil derivative fuel with raps oil in commonly used engines is impossible, mainly due to the significantly higher viscosity of this liquid. Tests of six different diesel engines indicated that engines with direct fuel injection cannot be fueled with raps oil due to high growth of deposits in a combustion chamber (HEMMERLEIN et. al. 1991). Similar results were presented by VELLGUTH (1983) who observed residues in injector nozzles which stopped engines after just 50 working hours.ąIn 1964 Klaus Elsbett developed an engine with hearth combustion chamber adjusted to combustion of raps oil (BOCHEŃSKI 2003). The solution, however, cannot be applied to ready engines since the adjustment of a finished engine would require significant structural changes.

Rape oil, in comparison with diesel, is characterized by high viscosity with an impact on distribution of an oil spray in a combustion chamber. Fuel and air mix is not fully combusted in a cylinder chamber and produces residues. Viscosity of raps oil drops rapidly with increase of temperature and at 70oC it is similar to viscosity of diesel oil. This property of raps oil was used to test an agricultural tractor equipped with a double tank installation (BOCHEŃSKI 2008). Results of operating tests indicated that it was a good solution.

It, however, has some significant disadvantages. Firstly, the vehicle is equipped with two independent fuel tanks. Secondly, diesel has to be used to start up the engine and operate it until coolant is heated to a high temperature (DZIENISZEWSKI 2006). Comparison of parameters of raps oil and diesel oil clearly indicates that a raps oil engine would have less power. Research performed by Polish scientists indicated that application of raps oil resulted in a power drop of approximately 10–20% combined with an increase of fuel consumption per unit by approximately 15–25%. (ZBŁOCKI 1990, LOTKO 1995, SZLACHTA 2002).

The company John Deere, a global manufacturer of agricultural machines, produced a prototype agricultural tractor adjusted for combustion of pure raps oil based on structural changes developed by a team of engineers of the company Vereinigte Wekstätten Pflanzenötechnologie GbR (VWP), Germany. Changes related only to the engine accessories and presented them in Figure 1.

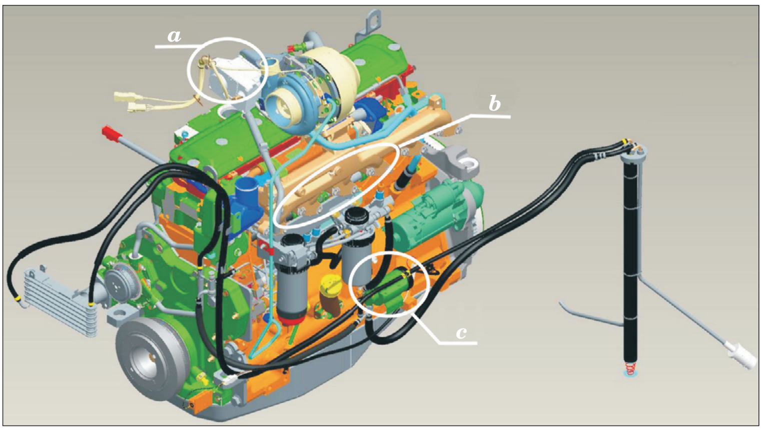


Fig. 1. Major changes in the gear motor. Software engine control computer (*a*) has been change, was used fuel heater combined with the injectors (*b*) and increased power of the fuel pump (*c*)

Sixteen tractors were prepared for tests. They are operated in farms in Austria, France, Germany and Poland. Tests are co-funded by the European Union under the project TREN/FP7/219004/2ndVegOil.

## Test Object and Description of the Test Site

The tests were designed to compare parameters of an engine fueled with raps oil and diesel. The test tractor was one time fueled with diesel to compare its power distribution and fuel consumption.

The tests were conducted on John Deere 6830 agricultural tractor equipped with six cylinder engine with turbocharger generating power of 102 kW (140 KM). Introduced changes allowed the tractor to be fully fueled with raps oil even when it was started in low temperature. Prior to the tests the tractor worked for 300 mth. Technical specification of the engine was based on operating manual presented in Table 1.

Table 1

Basic parameters of the tested engine

| | |
|---|---|
| Engine type | 6068HL481 |
| Max. engine power in accordance with 97/68/EC | 103 kW |
| Intelligent power management (momentary power) | 121 kW |
| Max. torque | 620 Nm at 1 400 rpm |
| Number of cylinders | 6 |
| Cylinder diameter / piston travel | 106.5 mm/127 mm |
| Displacement | 6790 $cm^3$ |
| Nominal revolution | 2100 rpm |
| Range of operating revolutions | 1300–2100 rpm |
| Size and type of injection system | PowerTech, 4 Valves |
| Air intake system | Turbocharger with active air cooling system |
| Fuel injection system | High-pressure “CommonRail” |
| Combustion chamber | Swirl chamber |

The tests were conducted in the Institute’s branch in Poznań in Autumn 2009 in good weather and the average ambient temperature of 18°C. The tractor was prepared one day prior to the actual tests. Fuel meter was connected to a fuel installation at the main fuel tank. The fuel meter consisted of a strain scales connected to the control system. Scales measurement cylinder with the capacity of approximately 1.2 $dm^3$ was fueled through a solenoid valve from a tank with the capacity of 10 $dm^3$ located above the scales. In addition, a return fuel line from the engine was connected to the scales.

A mobile engine brake PT 301 MES was connected through the power transmission shaft (WOM). It is a dynamometric device mounted on a stable frame structure which can be easily disassembled and transported. It is equipped with an independent control system and PC output used to register measurement signals. A shaft (WOM) socket located at the back of the brake. It was used to connect the agricultural tractor through a telescopic shaft. The device records two parameters: torque on the shaft between the tractor and two electromagnetic brakes and the shaft rotation speed. The above data is uploaded to software which draws a curve showing relationship between torque and power, and the engine speed. Test station is presented on Figure 2.

Fig. 2. Test station

## Test Methodology

The test started with heating up of the engine to the operating temperature. During the measurements the engine coolant temperature was maintained between 79 and 83°C. At the same time data necessary for calculations was uploaded to the PC connected to the brake. Data about coupling between the engine and WOM was entered which for the tractor amounted to 2000:1000. Other information included air temperature, atmospheric pressure and WOM revolution setting at the output. The tractor was tested at the speed of 1000 rpm.

The first test was conducted using raps oil. The tractor's operator turned on the power transfer shaft and set the maximal engine speed at 2250 rpm. A potentiometer controlling the brake was used to set a point when the engine speed started to drop and then the first measurement point was recorded at 2200 rpm. Subsequent points were recorded every 50 rpm until the engine reached 1200 rpm.

The range of measured engine speed reflected the full power potential of the engine. During the second test the engine was fueled with summer diesel purchased in a gas station located in the vicinity of the test site. The measurement was conducted in accordance with the same methodology as applied to the raps oil.

## Test Results

The following table presents results measured and calculated by PC connected to the brake, as well as readings from the fuel meter.

Table 2

Parameters of the engine of the tested agricultural tractor

| Engine speed [rpm] | Diesel test | | | Raps oil test | | |
|---|---|---|---|---|---|---|
| | $M_o$ [Nm] | $N_e$ [kW] | $G$ [kg h$^{-1}$] | $M_o$ [Nm] | $N_e$ [kW] | $G$ [kg h$^{-1}$] |
| 2200 | 214 | 50.5 | 16.33 | 188 | 43.8 | 17.72 |
| 2150 | 363 | 83.2 | 21.76 | 302 | 68.9 | 21.58 |
| 2100 | 389 | 86.6 | 22.26 | 317 | 70.5 | 22.23 |
| 2050 | 413 | 90.2 | 22.54 | 337 | 73.6 | 22.14 |
| 2000 | 442 | 94.0 | 23.56 | 368 | 78.0 | 23.45 |
| 1950 | 460 | 95.7 | 23.12 | 394 | 81.6 | 23.85 |
| 1900 | 484 | 97.9 | 23.46 | 420 | 84.5 | 24.38 |
| 1850 | 504 | 99.3 | 23.80 | 438 | 86.2 | 24.34 |
| 1800 | 526 | 100.5 | 23.85 | 455 | 87.2 | 24.55 |
| 1750 | 544 | 101.4 | 23.80 | 477 | 88.8 | 25.2 |
| 1700 | 563 | 101.9 | 24.30 | 497 | 89.9 | 25.18 |
| 1650 | 579 | 101.3 | 24.32 | 505 | 90.5 | 25.47 |
| 1600 | 584 | 99.6 | 24.17 | 516 | 87.6 | 24.82 |
| 1550 | 577 | 94.6 | 22.90 | 512 | 84.6 | 23.96 |
| 1500 | 581 | 92.5 | 22.01 | 514 | 82.0 | 22.62 |
| 1450 | 582 | 89.6 | 21.39 | 514 | 79.4 | 21.64 |
| 1400 | 574 | 84.3 | 19.50 | 504 | 75.2 | 19.80 |
| 1350 | 572 | 81.7 | 18.19 | 494 | 70.7 | 19.10 |
| 1300 | 572 | 78.8 | 17.66 | 494 | 68.5 | 18.00 |
| 1250 | 566 | 74.8 | 17.07 | 492 | 65.3 | 17.30 |
| 1200 | 566 | 72.2 | 16.32 | 498 | 61.7 | 16.51 |

The speed range of 2200–1200 rpm fully reflected distribution of power and torque of the tested engine. The maximal power generated by the tested engine fueled by diesel and raps oil amounted to 101.9 kW and 90.5 kW, respectively. Obtained test results allowed us to draw a curve reflecting distribution of tested parameters and perform a comparative analysis of various types of fuel. The following drawing presents distribution of the tractor's power in relation to torque for raps oil and diesel.

The above numbers shows, that the maximal and minimal power and torque values are observed at the same crankshaft speed for both fuel type. For the tested engine the optimal speed at which torque and power curves cross, amounts to 1700 rpm. The difference between generated power is stable through the whole range of speed and amounts to approximately 10%. Tests performed by HEMMERLEIN and KORTE (1991) indicated that the power drop

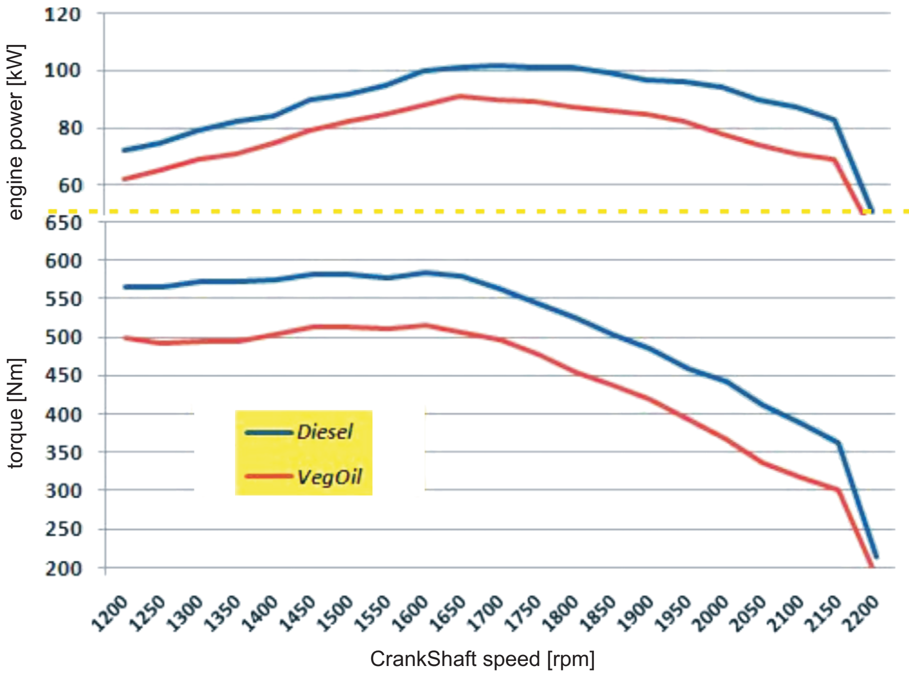


Fig. 3. Relation between torque and power of the tested engine

for the tested engine with direct injection generating power of 40 kW amounted to just 2%. It ought to be noted, however, that the tested engine was damaged after 155 hours of work. Tests performed in Lublin University of Technology on a high-speed engine with direct injection and a vortex combustion chamber confirmed the power drop of 10% (KIERSKI, STRZĘSŁY 1994). Power consumption curves for both tests were drawn based on fuel consumption and power data (Fig. 4).

The tests indicate that consumption of raps oil per hour is comparable to diesel. There was a slight difference at the engine speed of 1500–2000 rpm. Raps oil is on average 12% more dense than diesel and its calorific value is by 17% lower (MATYSCHOK 2001). Consequently, these properties have an impact on volume of consumed fuel. Raps oil consumption per kWh is on average by 15% higher than consumption of diesel. It is related to the fact that the tractor fueled by raps oil generated on average 10% less power. In addition, a slight raps oil consumption per hour also has an impact on the parameter.

Comparison of differences of power generated by the tested tractor and fuel consumption per unit with results of other Polish tests which achieved 10–20% power drop and 15–25% increase of fuel consumption leads to the conclusion

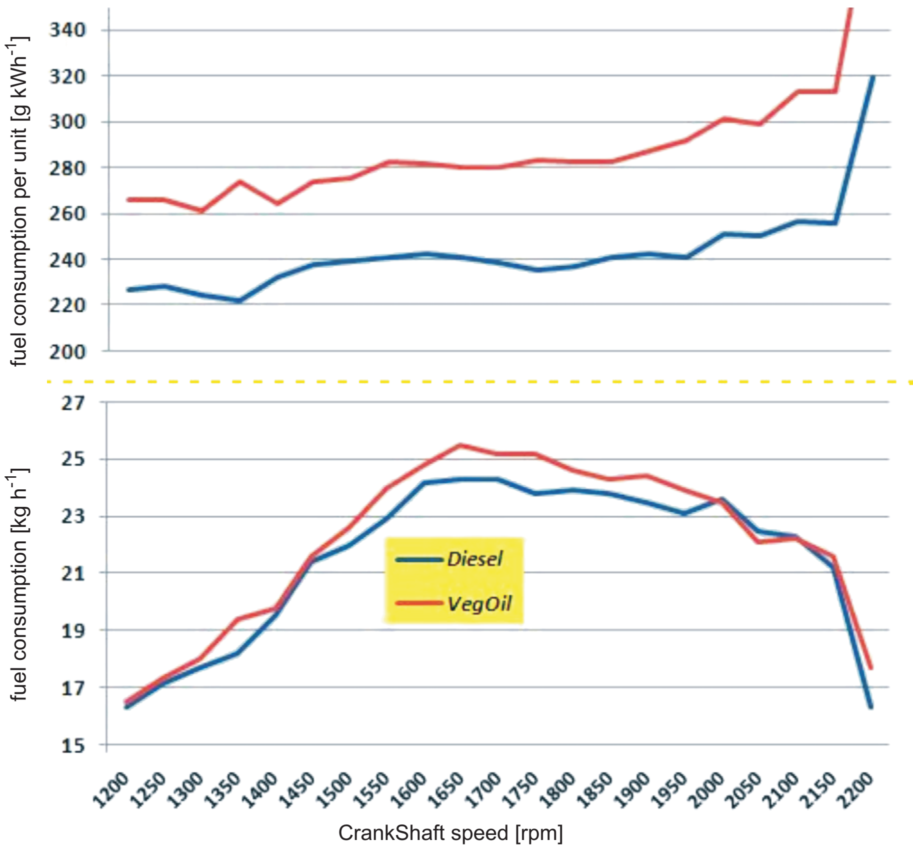


Fig. 4. Fuel consumption per hour and unit

that the tested tractor fueled with raps oil could be classified at the lowest edge of the difference brackets.

## Conclusions

1. Innovative structural solutions introduced by the company John Deere allow for use of the tractor fueled with pure raps oil. In addition, there was no problem with starting up of the tractor in low temperature.

2. Performed tests indicated power drop of 10%. In comparison with earlier tests which identified 10–20% power drops, the achieved result ought to be deemed as good.

3. Considering 10% power drop and little change of power consumption per hour, raps oil consumption per unit is by 15% higher than diesel consumption.

In theory, a tractor fueled with raps oil would consume 15% more fuel than an engine fueled with diesel.

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## References

BOCHEŃSKI C.I. 2003. *Biodiesel paliwo rolnicze*. Wydawnictwo SGGW, Warszawa.

BOCHEŃSKI C. KIRYLUK J. 2008. *Prace badawcze Pronaru*. Pronar, 4(7).

DZIENISZEWSKI G. 2006. *Analiza możliwości zasilania silnika diesla surowym olejem roślinnym*. Inżynieria Rolnicza, 12.

HEMMERLEIN N., KORTE V., RICHTER H., SCHROEDER G., 1991. *Performance, exhaust emissions and durability of modern diesel engines running on rapeseed oil*. SAE Technical Papers Series, 91 0848.

LOTKO W. 1995. *Zasilanie silników spalinowych paliwami alternatywnymi*. Wydawnictwo Instytutu Technologii Eksploatacji, Radom.

KIERSKI Z., SZCZĘSNY P. 1994. *Badania silnika wysokoprężnego S-4002 zasilanego biopaliwem na bazie oleju rzepakowego*. Journal of KONES, 94.

MATYSCHOK H. 2001. *Odnawialne, oparte na olejach roślinnych, alternatywne paliwa dla silników wysokoprężnych*. Chemik, 3.

SZLACHTA Z. 2002. *Zasilanie silników wysokoprężnych paliwami rzepakowymi*. Wydawnictwo Komunikacji i Łączności, Warszawa.

VELLGUTH G. 1983. *Performance of vegetable oils and their monoesters as fuels for diesel engines*. SAE Transactions, 83 1358.

ZABŁOCKI M. 1990. *Olej rzepakowy jako paliwo do silników wysokoprężnych*. Teka Komisji Naukowo--Problemowej PAN, Oddział w Krakowie 2.