# $2^{nd}$ VegOil

# Demonstration of $2^{nd}$ Generation Vegetable Oil Fuels in Advanced Engines

## Workpackage 5

## Engine Demonstration

## Deliverable N° 5.6:

# Test report stage 4

# Publishable Summary

Version: 1

Denkendorf, February 8, 2012

prepared by:

IBDI, VWP

Thomas Kaiser (VWP), Tino Wunderlich

regineering - Duft & Innerhofer GbR, Alemannenstr. 25,
85095 Denkendorf, Germany
Tel.: +49 (0)8466 90414-0
Fax.: +49 (0)8466 90414-29
Email: S.Innerhofer@regineering.com
Partner website : www.regineering.com
Project website : www.2ndVegOil.eu

*This publication has been produced with financial support of the European Commission in the frame of the FP7 Seventh Framework Programme under the grant agreement N° TREN/FP7EN/219004/"2ndVegOil".*

# Table of content

## List of acronyms

| | |
|---|---|
| Avg. | Average |
| DPF | Diesel particle filter |
| ECU | Engine Control Unit |
| FRCUMA | Fédération Régionale des CUMA Rhône-Alpes |
| IBMER | Instytut Budownictwa, Mechanizacji i Elektryfikacji Rolnictwa *(now ITP)* |
| IBC | Intermediate bulk container |
| IBDI | regineering, Ingenieurbüro Duft Innerhofer |
| ITP | Instytut Technologiczno-Przyrodniczy *(formerly IBMER)* |
| JDWM | John Deere Werke Mannheim |
| MFDA | Multi Functional Diesel Additive |
| OPh | Operating hours |
| PRV | Pressure Relief Valve |
| PTO | Power Take Off |
| Q.A. | Quality Assurance |
| RPM | Revolutions Per Minute |
| SCRi® | Seclective Catalytic Reduction integrated |
| Std | Standard mode |
| VWP | Vereinigte Werkstätten für Pflanzenöle |
| WP | Work package |
| 2G-PVO-RS | 2nd Generation – Pure Vegetable Oil – based on Rape Seed oil |

# 1 Summary

- Focus on complex Stage 4 exhaust after treatment system
- Focus on DPF baseline test with diesel
- Switch to 2G-PVO-RS
- Successfully tested in field operation (Milestone 5.8)

# 2 Test parameters

## 2.1 Testing environment

For testing the converted vegetable oil capable tractors, a stationary dynamometer in a fully instrumented test cell was used, as well as a mobile PTO dynamometer.
The stationary dynamometer (Schorch DQ7319X) can brake up to 3100 Nm at speeds from 132 to 2667 rpm, with a maximum power of 480 kW. In the test cell, all relevant engine parameters are recorded via John Deere internal monitoring software. Tested tractors are also instrumented with additional sensors which are monitored by the test cell control and information system.
The mobile PTO dynamometer (PPC 2000 by Technical Training Equipment) was used due to capacity constraints. It runs up to 3500 rpm with a maximum torque of 2300 Nm at 1000 rpm. Its maximum power is 340 kW.

## 2.2 Documentation

For documentation of the tractor field testing activities, the JD internal documentation system was used. All activities, fuel consumption, failure codes (DTC) et cetera were documented by the tractor operators on a daily basis. Workshop activities are also listed in these logbooks. The logbook entries are filed to a database daily and can be retrieved for various reports afterwards.

## 2.3 Test tractor ID-17

To establish a prototype stage 4 tractor, the stage 3B prototype (see 2nd VegOil deliverable No 5.4) was equipped with an SCR system, which represents the current JD path towards EU stage 4. The schematic layout of the added SCR system is displayed in Figure 1.

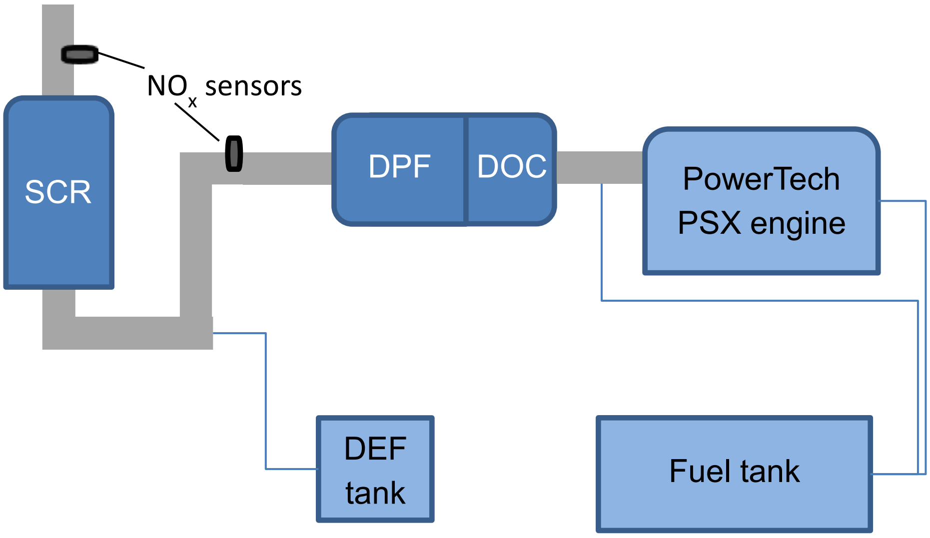


**Figure 1** **Schematic layout of L06210RT9P620601 engine and exhaust aftertreatment**

After the exhaust gas is leaving the DPF, diesel exhaust fluid (DEF, AdBlue®) is injected into the exhaust gas where it is hydrolysed into ammonia ($NH_3$) and water[1]. Within the SCR, NO and $NO_2$ is reduced into $N_2$. The required amount of DEF is calculated by the ECU software, based on the outputs of two $NO_x$ sensors before and after the SCR catalyst.

To convert the stage 3B tractor into a stage 4 tractor, various tractor components had to be replaced and other complete new components were added. The replaced components were primarily those of the electrical and electronic system such as the ECU and the main engine wiring harness and five engine sub-harnesses. In terms of hardware most of the parts were completely new, including the DEF tank and DEF supply module (see supply module mounted on supply tank), the heated DEF lines, the SCR catalyst including its brackets, the mixing pipe, sensors and the DEF injector.


[1] For further details regarding SCR principles, see **Fehler! Verweisquelle konnte nicht gefunden werden.**, **Fehler! Verweisquelle konnte nicht gefunden werden.**.

**Figure 2 Left hand side of stage 4 prototype**


**Figure 3 Right hand side of stage 4 prototype**

## 2.4 Test planning

The tractor was converted from stage 3B to stage 4 in August and September 2011.
After the complete SCR system was installed, functional tests including the first operation of the DEF system and DEF injection into the exhaust flow had to be performed.
The full load curve was measured with diesel fuel as a reference, followed by measurements with 2G-PVO-RS and a test phase to adjust the software for the same power output as with diesel fuel.
Finally the emissions were measured in mode 1 and mode 5 of the NRSC utilising the SCR system's $NO_X$ sensors.
Task 5.6 was finished with a short field testing phase of two days on a JD testing field.

# 3 Test results

## 3.1 Statistics

Table: field test data ID-17 (December 2011)

| | |
|---|---|
| Tractor: | JD 6210R, ID-17, L06210RT9P620601 |
| Partner, operator: | ETIC, JDWM |
| OPh in field test: | 10 h |
| Documentation of OP modes: | 10 h (100%) |
| Avg. load level: | 45 % (in percentage of mode 1-15 OP hours) |

| | |
|---|---|
| Balancing of load: | 0% Low load<br>92.5% Mid load<br>0% High load<br>7.5% mode 16 (in percentage of total documented OP hours in field test) |
| Lubricant level: | ok |
| Lubricant samples: | Analysis reports and other samples not reported yet, see reports of WP4 |
| Tested fuels: | RS: 400 L (including PTO dyno performance testing)<br>DK: 100 L (PTO dyno performance testing) |
| Fuel consumption: | 13.9 L/OPh |
| Tested fuel additive: | JD Biodiesel Protect 100 |
| Tested engine lubricant: | E9 |
| PTO measurements/ tested fuels: | 11. Oct 2011 and 2. Nov 2011 (diesel)<br>6. Dec 2011 (2G-PVO-RS) |

**In**

Figure 4 the load profile of the tractor during the two days of field testing is displayed. The tractor was run on a JD internal testing field near the JDWM. On the field the tractor was used with a cultivator (width 2.60 m, working depth appr. 25 cm).

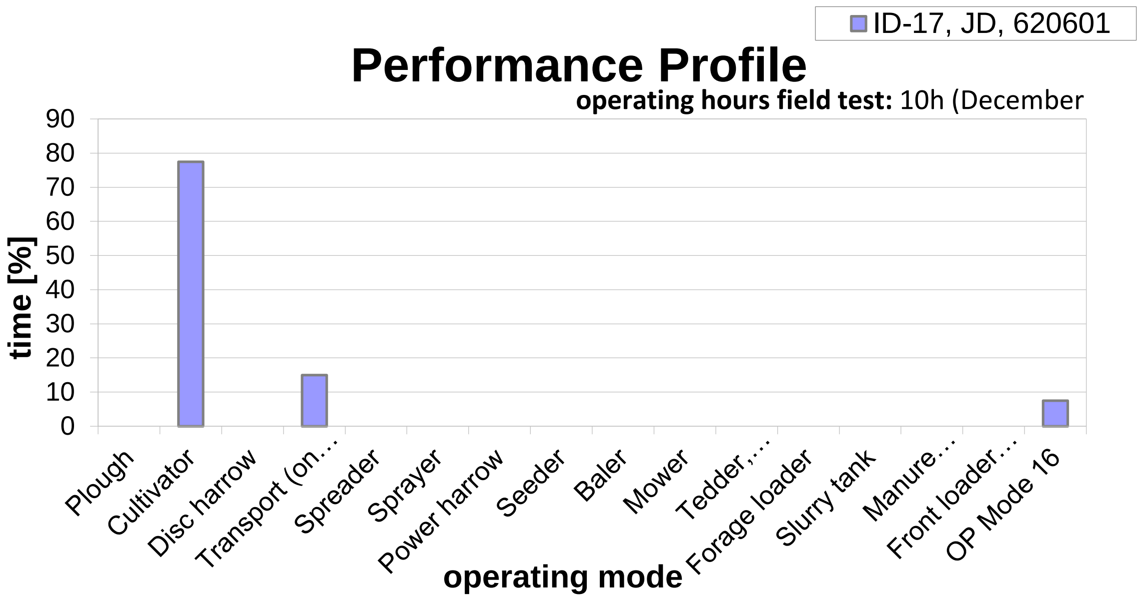


**Figure 4** **Performance profile of tractor L06210RT9P620601**

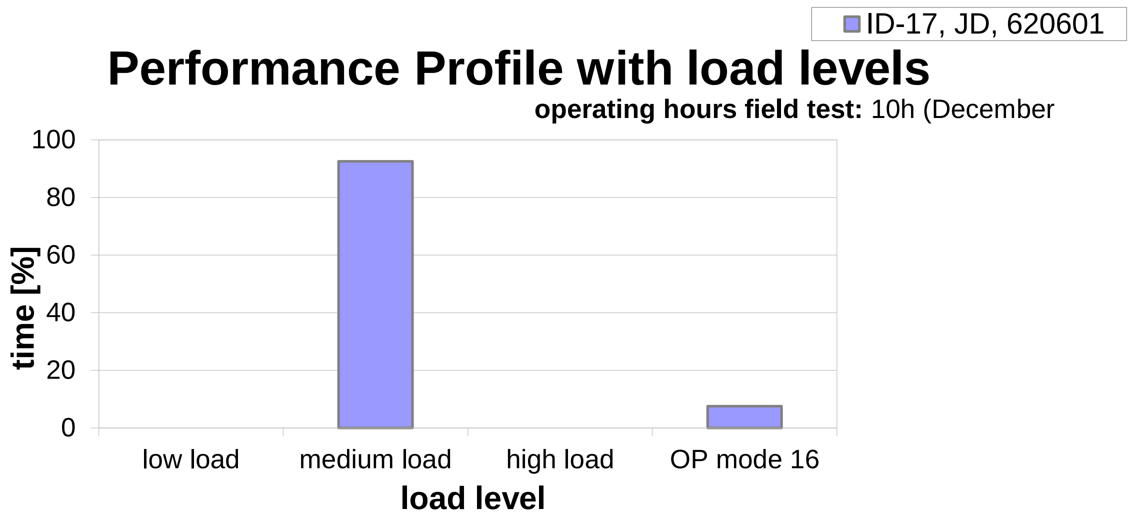


**Figure 5** **Load levels of tractor L06210RT9P620601**

## 3.2 PTO results

The PTO full load performance was measured with diesel fuel as a reference and with 2nd generation rapeseed oil. The diesel reference full load showed less torque compared to the IT4 tractor configuration. As the engine was not designed for the additional SCR catalyst this torque loss is likely caused by the increased back pressure. An increase of the desired fuel command increased the torque, but not up to the level expected from the IT4 configuration. The average of three diesel measurements was used as a reference for vegetable oil fuel. The ECU software was adjusted to reach the diesel reference power, which could not fully be achieved. There is still a difference of about 5% between the diesel and the rapeseed oil curve, which is less than the difference of the heating value of the fuels. The prototype injection system is probably at its limit for the required fuel amount.

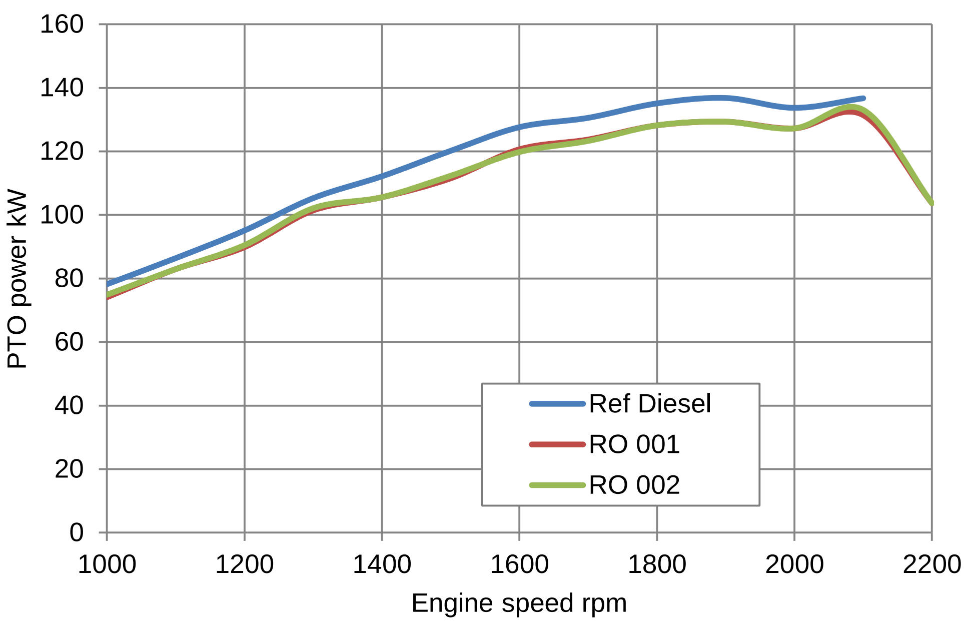


**Figure 6** **Full load curves of L06210RT9P620601 with diesel and 2G-PVO-RS (RO) fuel**

# 4 Conclusion

The conversion from a stage 3B to a stage 4 tractor prototype caused quite a few problems, not caused by the vegetable oil fuel, but mostly by the changes made to the electrical and electronic system, that could be solved to enable a tractor operation in public traffic and on a test field.

Comparing the $NO_x$ values measured with the SCR system's $NO_x$ sensors with the results on the engine test bench, it can be assumed that the stage 4 $NO_x$ emission limit can be fulfilled with adapted software and 2nd generation vegetable oil fuel.

For future projects a tractor closer to stage 4 series production will be used to improve the operation with vegetable oil fuel. There will be a closer look especially at the regeneration of the DPF, maybe even a redesign of the complete aftertreatment system based on the different properties of diesel and vegetable oil exhaust gases. Also the John Deere series solution for exhaust aftertreatment is still subject to changes which will be considered.