2nd VegOil

Demonstration of 2nd Generation Vegetable Oil Fuels in Advanced Engines

Workpackage 5

Engine Demonstration

Deliverable N° 5.2:

Stage 3A vehicle field testing

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List of acronyms

BCU	Basic Control Unit
DK	Dieselkraftstoff / Diesel
DPF	Diesel particle filter
ECU	Engine Control Unit
EPC	Electronic Engine Power Control
FLRS	Full Load Rated Speed
FRCUMA	Fédération Régionale des CUMA Rhône-Alpes
IBMER	Instytut Budownictwa, Mechanizacji i Elektryfikacji Rolnictwa
IBC	Intermediate bulk container
IBDI	regineering, Ingenieurbüro Duft & Innerhofer
JDWM	John Deere Werke Mannheim
MFDA	Multi Functional Diesel Additive
OPh	Operating hours
PRV	Pressure Regulating Valve
PTO	Power Take Off
Q.A.	Quality Assurance
RPM	Revolutions Per Minute
resp.	Respectively
SAPS	Sulfate Ashes, Phosphor, Sulphur
std	standard
TCU	Torque Control Unit
TFZ	Technologie- und Förderzentrum
TAN	Total Acid Number
TBN	Total Base Number
VWP	Vereinigte Werkstätten für Pflanzenöle
WP	Work Package

Blend	Mixture of 2G-PVO-RS and 2G-PVO-CS
CS	2nd Generation – Pure Vegetable Oil – based on Camelina Sativa oil
2G-PVO-CS	2nd Generation – Pure Vegetable Oil – based on Camelina Sativa oil
JA	2nd Generation – Pure Vegetable Oil – based on Jatropha oil
2G-PVO-JA	2nd Generation – Pure Vegetable Oil – based on Jatropha oil
MG	2nd Generation – Pure Vegetable Oil – based on Maize Germ oil
2G-PVO-MG	2nd Generation – Pure Vegetable Oil – based on Maize Germ oil
RO	2nd Generation – Pure Vegetable Oil – based on Rape Seed oil
RS	2nd Generation – Pure Vegetable Oil – based on Rape Seed oil
2G-PVO-RS	2nd Generation – Pure Vegetable Oil – based on Rape Seed oil
SF	2nd Generation – Pure Vegetable Oil – based on Sun Flower oil
2G-PVO-SF	2nd Generation – Pure Vegetable Oil – based on Sun Flower oil

1 Summary

This interim test report is concerned with stage 3A vehicles field testing. Four tractors were tested at different places and were monitored by John Deere (JDWM). The main focus had to be put on power, durability and engine lubricant when using 100% of 2nd generation pure vegetable oils (2G-PVO). A final test report D5.2 will follow in month 36.

At first all tractors were submitted to inhouse baseline tests before the field tests. These reference measurements of power take off (PTO) were done with diesel fuels. After the tractors' mechanical conversion, the tests were repeated with 2nd generation rape seed oil (2G-PVO-RS) to record engine performance prior field testing. Two tractors are based at the TFZ with the possibility to conduct not only field testing but also test bench testing with different engine software status and different fuels.

After 500 to 580 operating hours of field testing the tractors PTO measurements were repeated. At this point it can be seen that the tractors satisfied in terms of power and durability.

The 2G-PVO-RS that was developed in WP3 showed constant quality throughout the test period so far. First of all, there has been no engine damage during all the time when the tractors were fuelled with different 2G-PVOs, including oils that had been considered to be entirely unsuitable as engine fuels until now.

Concerning the engine lubricant it can be seen that E7 as well as E9 achieved a good performance. As a first positive result, the oil change interval could be increased up to 500 hours depending on the results of analysis for two tractors.

At this stage, a final statement about the used fuel additives "JD Protect 100" and "Lubrizol" can not yet been made. Both seem to work correctly in terms of fitting with the engine performance and long-term functionality.

For the forthcoming field testing period, all 4 tractors are planned to be retrofitted with a diesel particle filters (DPF). During construction work, JD technicians decided to test different aftertreatment systems.

All results will be a finally reported at the end of the project in deliverables D5.2 and D5.9 according to the workpackages the tractors belong to. For the remaining test period there will be operations using 2nd generation pure vegetable oils based on sunflower (2G-PVO-SF), 2nd generation rape seed oil (2G-PVO-RS), 2nd generation jatropha oil and maize germ oil (2G-PVO-JA and 2G-PVO-MG) as well.

2 Field testing parameters

2.1 Design of experiment task T5.2 – Tractor Masterplan

The task T5.2 is concerned with stage 3A vehicles field testing of installed engines with after-treatment components. Due to the direct monitoring by JDWM additionally various combinations of engine software, engine lubricant and fuel additives can be tested more detailed. All tractors of the task T5.2 shall be tested with the main focus on power, durability and engine lubricant when using different 2G-PVOs.

At the 1st periodic meeting in Oct.2009 the project members decided to widen the testing of 2G-PVOs different than 2G-PVO-RS. That was why the amounts of other 2G-PVO-fuels were extended in the work package WP5. The higher amounts of 2G-PVOs were put on other tractors than of task T5.2 too. So you will find more information about testing 2G-PVOs other than 2G-PVO-RS in tasks T5.7 and T5.9 and its reports in month 36 deliverable D5.7 and D5.9.

As in task T5.9 the major aspect of the task T5.2 experiments is to obtain data from running converted tractors with pure 2nd Generation Vegetable Oil. Throughout the testing period, the testing participants have to report all relevant experiences to the project by use of logbooks, fault reports and any feedbacks. Additionally there are results from running tractors on a PTO test bench and exhaust emission measurements by John Deere and the TFZ.

The **tractor masterplan** describes the planned use and further conversions of the vehicles during the 2nd VegOil project period. It is the main document to organize and update the 2ndVegOil project field test. It is build up as a life cycle overview. Due to the experiences and progress with field testing the scheduled masterplan changed in terms of timing the use of 2G-PVOs and conversion status.

2.2 Local testing environment

2.2.1 JDWM

After the tractors were adapted for vegetable oil fuel, all were evaluated at the different JDWM test rigs. The tractors were tested either with mobile PTO dynamometers, or on the stationary engine and PTO dynamometer. The data serve as a reference for further performance measurements during and after the field test demonstration. 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. Also, the tractors are

instrumented with additional sensors which are monitored by the test cell control and information system. The fuel consumption is measured with an AVL Continuous Fuel Balance, which is not capable for vegetable oil fuel. Thus, for a few tractors the vegetable oil fuel consumption was measured with a specially modified measurement unit at full load rated speed (FLRS).

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.

Before testing the tractor it is important to adjust and maintain some basic operating conditions, otherwise the tractor performance is suboptimal and the results are not comparable. Therefore the ambient temperature should be around 25 °C, the transmission oil temperature has to be in the range from 55 to 60 °C, and the fuel temperature has to be conditioned to 40 °C if fed from an external source. These prerequisites have to be fulfilled at all tractor testing locations during the project otherwise the results can not be compared.

2.2.2 TFZ

The Technology and Support Centre (Technologie- und Förderzentrum, TFZ) is an institution of the Bavarian Ministry of Food, Agriculture and Forestry. It is doing basic research in the field of energetic use of biomass. The main goals of the TFZ is the support of the agricultural production, the processing and utilization of renewable resources by applied research, the development and testing of products and methods, and the transfer of technology by demonstration and education. The TFZ supports the 2ndVegOil project with measurements of power take off and exhaust gases.

The test rig is designed to measure PTO torque as well as limited gaseous and particulate (PM) emissions following 2000/25/EG and 97/68/EG as close as possible. The test rig layout is displayed in Figure 1. The engine power is measured via a PTO dynamometer (EGGERS PT 301 MES, max. 340 kW, resolution 0.1 kW). Losses between engine and PTO due to the transmission and auxiliary drives, which are not installed on the bare engine, are added basing on the manufacturer's specifications to calculate the engine power. Fuel consumption is measured gravimetrically with a scale (Mettler-Toledo KB60.2, max. 60 kg). A more detailed description of the test rig can be found in [1], also see figure no.1.

The gaseous emissions CO_2, H_2O, CO, NO, and NO_x are measured with a FT-IR Gasmet 4000 by Ansyco. O_2 is analyzed with the PMA 100-L (by M&C Products), hydrocarbons (HC) are measured by the Thermo-FID (Mess- und Analysetechnik GmbH. PM are measured according to VDI 2066 and ISO 8178, resp. 97/68/EC.

In another research project (not yet published) the complete measurement principle was applied on three different test rigs (TFZ Straubing/ Germany, BRT Wieselburg/ Austria and ART

Tänikon/ Switzerland) with the same tractor. Regarding the comparability of those measurements the results were unexpectedly good, showing for example a maximum deviation of 3% of the average for PTO power and fuel consumption. This is a good prove of the reliability of the performance measurements at mobile dynamometers, as long as the defined preconditions are fulfilled.

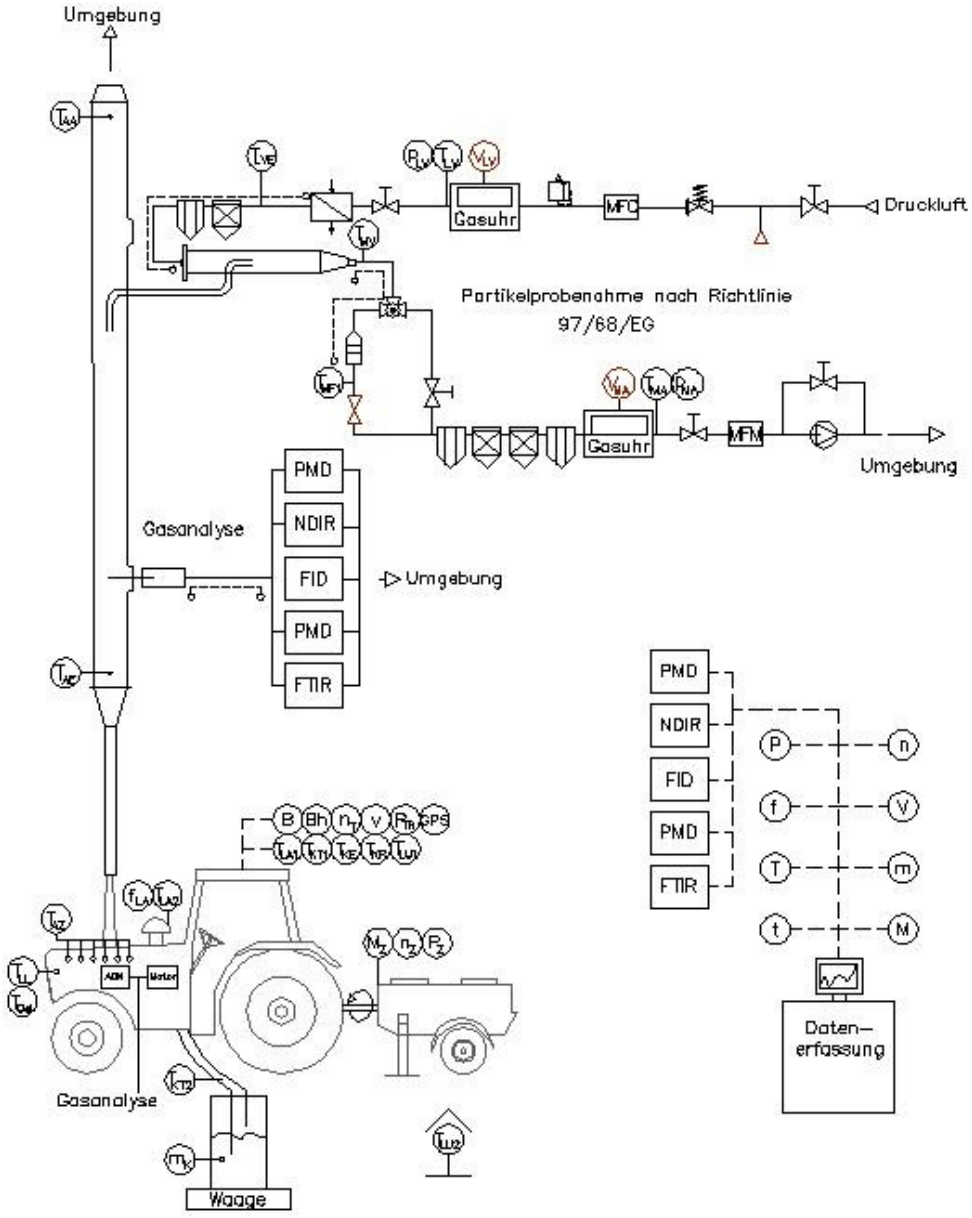

Figure 1: Test rig layout at the TFZ Straubing [1]

2.3 Tested oil types (fuel)

As in deliverable D5.9 already reported 2nd generation pure vegetable oils based on rape seed, camelina sative, jatropha, maize germ and sunflower will be tested. Among others these 2G-PVOs have a higher quality standard with less minerals compared to 1st generation

pure vegetable oils. The basic fuel is 2G-PVO-RS. All tractors in task T5.2 used only 2G-PVO-RS fuels produced by the partner Waldland up to date. One tractor will be fuelled with 2G-PVO-SF, another tractor will be fuelled with 2G-PVO-JA and 2G-PVO-MG in the future. They will be finally reported in the deliverables D5.2 and D5.9 in month 36.

2.4 Developed engine lubricants

All tractors of work package WP5 do use engine lubricants developed by the project partner Lubrizol. Two lubricants are field tested, the Lubrizol E7 and E9. The E9 is a “low SAPS oil” with low percentage of Sulphate Ashes, Phosphor and Sulphur (SAPS). This will be needed when using exhaust filter systems as DPF e.g. In task T5.2 the oils shall be used and monitored as well. The evaluation of the lubricants will be done in the deliverables of work package WP4.

2.5 Tested fuel additives

According to the aims of WP3 fuel development, additives developed and produced by John Deere and Lubrizol are admixed to the 2ndVegOil fuels. The additives are so called Multi functional Diesel Additive (MFDA). They optimize combustion and secure the injection system from combustion residuals.

It is proofed by other research projects, that the use of additives is necessary for engines with a common rail system. State of the art engine injection systems can be very sensitive to only smallest residuals in terms of durability of the engine. These residuals can be caused either by incomplete combustion (coking of the injection nozzle) or ingredients of the fuel as magnesium, phosphor or potassium.

Normally these additives are used only for diesel fuels. Additives shall optimize the combustion and contain detergents to clean up the residuals.

In the field test there are 2 additives of different manufacturers admixed to the fuel. Both are multi functional diesel additives (MFDAs). The main objective of the field test is to see if the different additives also have different effects.

For more information see reports of the work package, WP3.

3 Evaluation sources

3.1 Tractor logbooks

The project partners VWP and IBDI published logbooks that shall record the status of each tractor and the effected jobs. It has to be filled by the operator every day if the tractor has been used. The documents will be used for analysing each vehicle compared to the fleet. Additionally, damages shall be prevented by checking the correct intervals and reading the trends e.g. history of consumption and oil levels. All partners are forced to check the continuous keeping of the logs. Especially IBDI asks for missing results monthly as well as to improve the form if new knowledge requires so during the field test period.

The recorded data are:

- operation hours
- fuelled amount of fuels specified by type (2G-PVO-RS, -CS, -SF, -JA; Blends; DK)
- engine oil level
- amount of replaced or refilled engine oil
- effected job
- maintenance/ repair work/ ECU failure codes/ remarks

All logbooks were more detailed in terms of work load compared to the logbooks of task T5.9. Two tractors also used logbook forms by John Deere as day reports and service protocols.

3.2 Fault reports

Each tractor is by default equipped with a command centre that shows the most important operation parameters. Among others, the failure codes which are saved can be read out here. Failure codes specify unusual status of the tractor as engine failures as well as general failures. Only the engine specific failure codes (ECU failure codes) shall be reported in the logbooks.

Note that ECU failures have to be interpreted if they are of sporadic or systematic nature. It is important to know, if the failure is caused by the use of 2G-PVOs. All the same attention is to be given to damages of engine parts, being influenced by the use of 2G-PVOs.

3.3 Others

Concerning engine exhaust gases there were several measurements at the TU Kaiserslautern test bench under task T2.3. At this test bench only a separated engine is tested to get reproducible results. Measuring the engine installed in a vehicle would cause failures due to not having same surrounding conditions. Concerning 2G-PVO-JA there will be more measurements at the TFZ test rig.

4 Conclusions

In task T5.2 four tractors have been field tested. All are owned by JDWM. Two of them were tested by the TFZ, the other two were part of the JDWM test fleet. In total the tractors run 2.445 hours.

In terms of power and durability the tractors satisfied.

The PTO measurements showed variable results that could be identified as measurement failures mainly. All other differences are in the expected range. The failures can be caused by different environmental influences as temperature, air pressure, humidity or different test rigs too.

Due to the still less operating hours in field test there can be expected more result at the end of the field test (also see deliverable D5.9 in month 36).

The same can be said concerning the effect of fuel additives to engine performance.

Concerning engine lubricant both engine oils satisfied. For more information see reports of the work package WP4.

Finally the stage 3A vehicles field testing satisfied in terms of power, durability and engine lubricant when using the 2nd generation pure vegetable oils (2G-PVO) for this first testing period. A final test report D5.2 will follow in month 36.

5 References

[1] Wichmann, V.: Rapsölbefeuerte Traktoren mit abgaszertifizierten Motoren nach Euro Stufe 3. Abschlußbericht zu FNR - Förderprojekt FKZ 22014905, Rostock, 2008

[2] Thuneke, K., T. Gassner, P. Emberger und E. Remmele: Untersuchungen zum Einsatz rapsölbetriebener Traktoren beim Lehr-, Versuchs- und Fachzentrum für Ökologischen Landbau und Tierhaltung Kringell. Berichte aus dem TFZ Nr. 17, Straubing, August 2009. ISSN 1614-1008