

DETECTION OF EMISSION IN COMBUSTION ENGINES' EXHAUST

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Abstract: Emission of internal combustion engine has negative impact on environment and also on humans. Mainly, it is emission of harmful substances "greenhouse gases" which cause progressive irreversible heating of the Earth and also ruin equilibrium of nature by acid rain. It is CO (carbon monoxide), NO_x (nitrogen oxide), SO_x (sulphur oxide) and CH₄ (methane). These gases get into atmosphere by fossil fuels' combustion (diesel oil, coal and natural gas). This work is aimed at basic analysis of diesel oil and rape seed methylester and evaluation of their limited but also unlimited emission. Thereafter, the test results are compared and there is done also evaluation of emission – the greenhouse gases (CO, CO₂, NO_x, NO₂, N₂O, NO, CH₄, H₂O), dangerous exhaust gases (NH₃, SO₂, THC, AHC) and strong carcinogens (C₄H₆ – 1,3 butadiene, CH₃CHO – acetaldehyde, HCN – cyanic acid, HCHO – isocyanic acid) and their contents during combustion is detected. These measurements were realized at Department of Transport and Handling (DTH) at Slovak University of Agricultural in Nitra and at the Research Station Agroscope ART in Tänikon (AAT) in Switzerland. At DTH, there were done measurements with two internal combustion engines types Z-8002 and MD 8701.12. At AAT, there were done measurements with two tractors types Hürlimann H488 and Hürlimann XB Max 100.

Keywords: EMISSION, INTERNAL COMBUSTION ENGINE, ALTERNATIVE FUEL

1. Introduction

There exists a lot of exacting activities in agricultural which were gradually simplified by machinery. The most overextended is agricultural tractor. It is a universal machine for almost all the activities in vegetable and livestock production and it can be also use for transport of agricultural products by the help of trailers. Permanent and intensive utilization of tractors in agricultural, unfortunately, has also its own disadvantages. The primary absence is internal combustion engine as an only source of energy for agricultural tractors. The main defect of combustion engine is a product of combustion – emission. The one of possible solution is looking for the new alternative sources of energy. This give reason for it if take into account drawdown of fossil fuel which are the most important for global energetic.

Alternative fuel could replace not only classic fuel but it also has to be considerate to environment. At present, the most significant fuel for internal combustion engines is diesel oil. This is also depletable fuel so in the near future it has to be at least partially replaced by fuel on different base than crude oil. There was done a lot of work about different fuel characteristics. Scientists found out which alternative fuel could be the most appropriate to replace diesel oil. The most used tested fuels are crude vegetable oils made from rape seed, sunflower seed, soybeans, palm fruit and their esters. Generally, vegetable oils and their esters have strong potential to be used as an alternative fuel. Esther's had good results and also if were blended with Diesel oil. [Sims, 1981] But also RME can be use as fuel for DI engine without addition of different components or additives [Walter – Schäfer, 1990] By *Shober and Mittelbach*, due to the iodine value limitation the current European biodiesel specification EN 14214 discriminates several potential feedstock for biodiesel production Feedstock like soybean oil, sunflower oil, Jatropha oil, or cottonseed oil cannot be used as 100%. [Schober – Mittelbach, 2007] Another very important characteristic is oxidation stability. Oxidation stability's limit is also included in this standard and the minimum limit is 6 hours period by 110 °C. Degradation of vegetable oils and its esters over the time is natural process, more if they are influenced by temperature. Formation of organic acids and aldehyde may cause engine and injection problems. One of the solutions could be adding of antioxidants into biodiesel. At high concentrations, added antioxidants investigated showed beneficial effects on biodiesel oxidation stability. [Schober – Mittelbach, 2004] By harmonized European Standards, fuels can be sold on market if their quality is up to standard of Directive 98/70/EC. Standards for quality of biofuel contain technical and environmental parameters which have to be in line with requirements of car's producers.

2. Prerequisites and means for solving the problem

Used measuring norm is an international standard which is used for non-road engines. By *International Organization for Standardization (ISO)*, this norm specifies the test cycles for the measurement and the evaluation of gaseous and particulate exhaust emission from reciprocating internal combustion engines and it is applicable to engines for mobile, transportable and stationary use.

ISO 8178-4, C1 (8-points cycle)

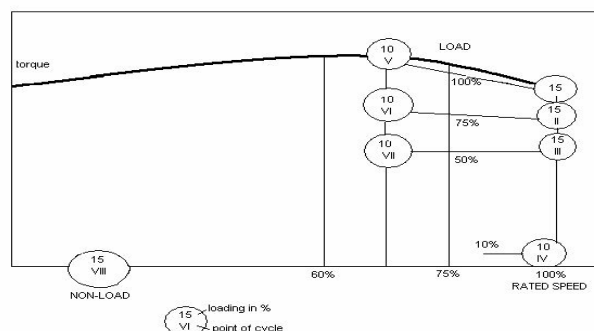


Fig. 1 Characteristics of 8-points cycle by ISO 8178-4, C₁

Measured objects

Engine n. 1: Z – 8002 with the next technical parameters:

Engine type: Z – 8002 Turbo

Producer: ZTS a. s. Martin

Position and cylinder' configuration: vertical, in-line

Working cycle: four-stroke, single-acting, supercharged

Injection: direct

Number of cylinders: 4

Capacity of cylinders: 4562 cm³

Cavil/stroke: 110 mm/120 mm

Power: 70.5 ± 5% kW

Rated revolution: 2200 min⁻¹

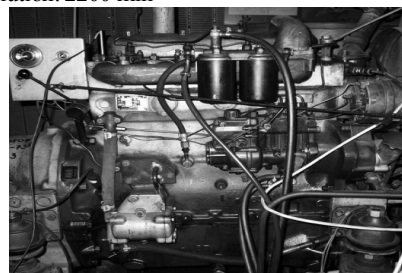


Fig. 2 Combustion engine type Z - 8002

Engine n. 2: MD – 8701.12 with the next technical parameters:

Engine type: MD – 8701.12
 Power/rated revolution: 85 kW / 2200 min⁻¹
 Number of cylinders: 6
 Capacity of cylinders: 6840 cm³

Tractor Hürlimann H-488 DT with the next technical parameters:

Producer: Hürlimann/Same (I.) a)
 Engine: S. L. H - H 100.4 WT b)
 Number of cylinders: 4
 Capacity of cylinders: 4000 cm³
 Cavit/stroke: 105 mm/115.5 mm
 Rated revolution: 2500 min⁻¹
 Power: 65 kW
 Emission class: Stage I.



Fig. 3 Hürlimann H-488 DT

Tractor Hürlimann XB Max 100 with the next technical parameters:

Producer: Same-Deutz Fahr
 Engine: Deutz 2012, TCD 2012 L04 2V
 Number of cylinders: 4
 Capacity of cylinders: 4038 cm³
 Cavit/stroke: 101 mm/126 mm
 Rated revolution: 2300 min⁻¹
 Power: 72.5 kW
 Emission class: Stage III.A



Fig. 4 Hürlimann XB Max 100

At DTH, there were technical - exploitable characteristics of internal combustion engines tested with the next alternative fuels:

1. RME (pure),
2. RME (of the new sample ŠI – experimental sample from the company Agrochemix Sereď).

The results of technical – exploitable measurements were compared with the results by reference sample (it was diesel oil). The used meters' devices at DTH were connected by the scheme as in Fig. 5.

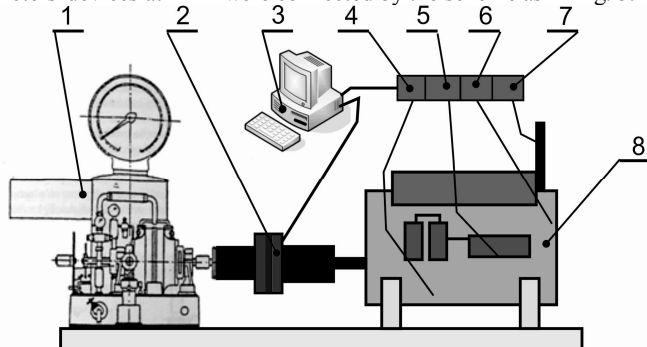


Fig. 5 Scheme of the used meters' devices at DTH

1 - dynamometer VD 110/6, 2 – torque scanner T12, 3 - PC with evaluation of measured data's software, 4 – temperature of oil sensor, 5 – combustion meter Flowtronic, 6 – temperature of coolant sensor, 7 - analyzer MAHA MDO 2 LON, 8 – combustion engine

At research station ART, there were tested tractors with fuel FAME and as the reference sample was used diesel oil. In this case, trials were directed not only for technical – exploitable characteristics but also on limited emissions' measurements - CO, CO₂, HC, NO_x and particle by the norm ISO 8178-4, C₁ – 8 point cycle (Fig. 1).

There were used two different samples of fuel for measurement –

1. diesel oil (SN 181160-1:2009),
2. RME (EN 14214) – (from the company EcoEtoyEnergy in Switzerland)

The used meters' devices were connected by the scheme in Fig. 6.

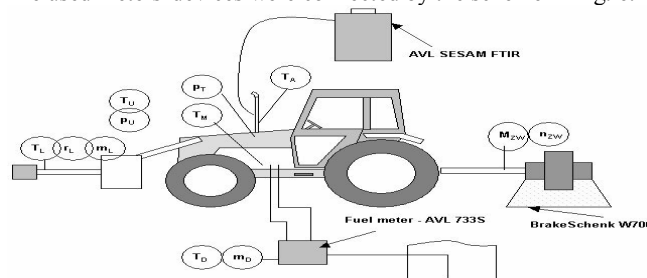


Fig. 6 Sight of the test bench

Measurements were done by full-load curve according to OECD Code2. Measured points were by all 100 min⁻¹ of the engine. Based on the results of the full-load curve, there were made the calculation of the measuring points for exhaust measurement. These measuring points were in accordance to ISO 8178-4. Each measuring point takes 10 minutes and the main result of each point lasts 60 seconds after 6th minute. The emission testing system AVL – SESAM FTIR uses two calculation methods – Diesel and Biodiesel. It was set up depending on the type of used fuel. The value of smoke will be done at 95% and 70% of nominal speed and at maximum torque.

3. Results and discussion

By accelerative trials on tractor, there were not discovered substantial differences between using of diesel oil and methylester. Established differences are insignificant and we can state that decreasing of effective power about 15% does not impinge for accelerative attributes of no-load tractor. But it is needed to emphasize that by the loaded tractor, there should be reached results a bit different and because of it there are needed more experimental measurement. By increasing loading, the power will be decrease and acceleration could decrease.

Tab. 1 Measured value of emitted smoke for Z – 8002 via accelerative test (diesel oil)

N. m.	revolution of neutral, min ⁻¹	maximal revolution, min ⁻¹	emitted smoke, m ⁻¹
1	810	2450	3.09
2	820	2450	2.85
3	800	2450	2.92
Average value of emitted smoke			2.95
Range of emitted smoke			0.24

Tab. 2 Measured value of emitted smoke for Z – 8002 via accelerative test (sample ŠI)

N. m.	revolution of neutral, min ⁻¹	maximal revolution, min ⁻¹	emitted smoke, m ⁻¹
1	810	2450	2.39
2	820	2450	2.89
3	800	2450	2.87
Average value of emitted smoke			2.72
Range of emitted smoke			0.5

Tab. 3 Accelerative test for tractor type Z 12245 (sample ŠI)

N. m.	distance, m	time, s	acceleration, m.s ⁻²
1.	43.17	10.5	0.78
2.	42.40	9.8	0.88
3.	42.20	9.2	0.99
4.	42.00	10.0	0.84
5.	43.00	10.2	0.83

It is needed to make long-lasting testing of these fuels' impact on fuel system of tractor, reliability of operation and working life of engine and injection system. Because of higher viscosity of alternative fuels, there exists faster wastage of injector pump and injectors. It is linked also with shorter interval of fuel filters' exchange whose micron openings are faster stuffed with biofuel than classical diesel oil.

At research station Agroscope ART in Tänikon, there were tested tractors with fuel FAME and as the reference sample was used diesel oil. In this case, trials were directed not only for technical – exploitable characteristics but also on limited emissions' measurements – CO, CO, HC, NO_x and particle by the norm ISO 8178-4, C₁.

Measurements of limited emission

There were done measurement of both tractor for limited emission which are – CO, HC, NO_x and particle. On Tab. 4, there are figured standard deviation from three repetitions.

Tab. 4 Values of limited emission *

Hürlimann H-488 DT	CO	NO _x	HC	Partikel
	g/kWh			number/kWh
Diesel	1.8	11.13	0.77	3.93E+14
RME	1.61	12.42	0.6	3.33E+14
Hürlimann XB Max 100	CO	NO _x	HC	Partikel
	g/kWh			number/kWh
Diesel	1.05	5.09	0.19	4.31E+14
RME	0.91	5.92	0.13	2.66E+14

* average value, based on PTO power

Limited emission values for Hürlimann H-488

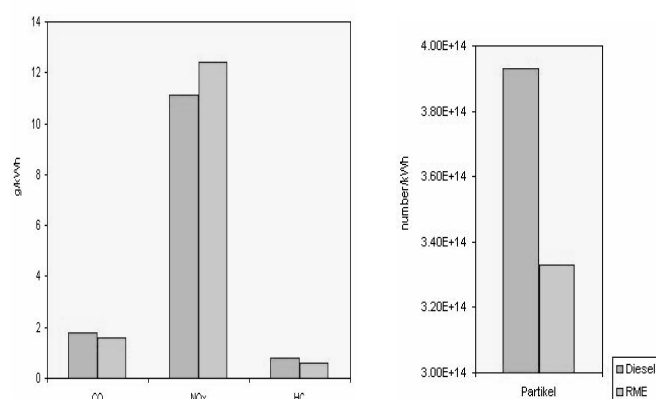


Fig. 7 Limited emission values for Hürlimann H-488

The values of CO and HC and also particle emission are lower for RME as in Figure 32. But values of NO_x are lower for diesel oil. It is evident that newer engine of Hürlimann XB Max 100 decreases emission significantly. Measured values are based on PTO power, so can not be evaluated by Emission Standards for Off - Road Vehicles.

If these measurements were done on engine both tractors will meet the emission norm for CO and HC of RME and Diesel. The values of NO_x are higher about of 21% for both fuel by Hürlimann H-488 and about of 25% for Hürlimann XB Max 100 than is determined the emission limit.

Limited emission values for Hürlimann XB Max 100

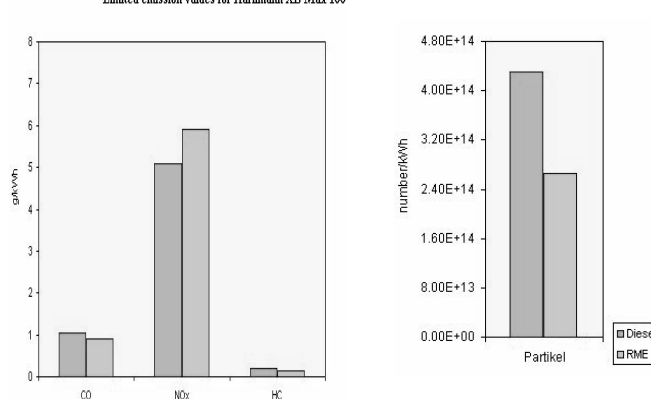


Fig. 8 Limited emission values for Hürlimann XB Max 100

Measurements of unlimited emission

There were also done measurements of unlimited emission which are possible to measure by AVL SESAM FTIR 4 – CO₂, NO, NO₂, N₂O, NH₃, CH₄, C₄H₆, HCN, AHC, SO₂, HCHO and MECHO. On Tab. 5, there are figured average values from three repetitions for each fuel (diesel oil, RME).

Tab. 5 Values of unlimited emission

H-488	CO ₂	NO	NO ₂	N ₂ O	NH ₃	CH ₄
ppm						
DI	55867	845	40	0.5	0.13	0.52
RME	56769	890	43	0.66	0.21	1.27
ppm	C ₄ H ₆	HCN	AHC	SO ₂	HCHO	MECHO
DI	0.97	0.57	2.1	4.6	8.1	2.7
RME	1.98	0.57	1.19	1.40	9.95	0.57
XB Max	CO ₂	NO	NO ₂	N ₂ O	NH ₃	CH ₄
ppm						
DIESEL	64426	378	16.9	0.43	0.12	0.1
RME	66040	431	16.8	0.57	0.13	0.1
ppm	C ₄ H ₆	HCN	AHC	SO ₂	HCHO	MECHO
DIESEL	0.44	0.59	0.77	5.0	2.23	0.49
RME	0.90	0.45	1.19	2.9	2.08	0.73

The values of both fuels are almost equivalent. Tractor which used RME had got not only higher values of NO_x (NO, NO₂ and N₂O) but also almost 50% higher values of ammonia, methane, and 1.3-butadiene which are considered to dangerous substances. By newer tractor Hürlimann XB Max, there are higher values of NO_x, acetaldehyde and 1.3-butadiene for RME but the difference is not so big. On the other side, lower values are with RME for sulphur dioxide and acetaldehyde for Hürlimann H-488 and for sulphur dioxide, hydrogen cyanide and formaldehyde for Hürlimann XB Max. Nevertheless, the values of unlimited emission are negligible, except carbon dioxide where can be seen higher values of RME by both tractors.

Measurements of emitted smoke

The values of smoke in exhaust gases are usually a lot lower with RME than diesel oil. For older tractor Hürlimann H-488, the value of smoke was more than 50% lower with RME than Diesel oil. From Fig. 9, it is evident that newer tractor Hürlimann XB Max 100 had much lower value of smoke. These values went near to zero and it does not matter if used RME or Diesel oil.

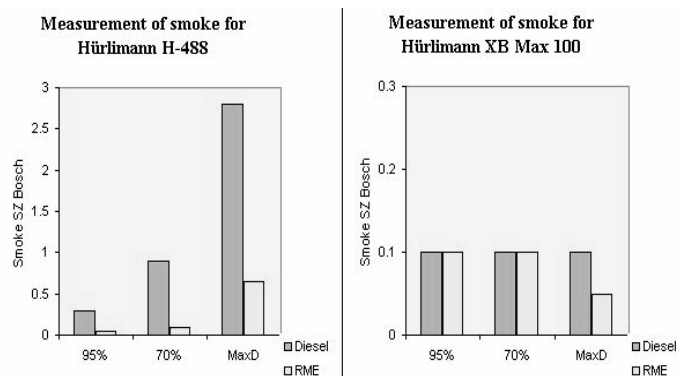


Fig. 9 Measurement of smoke

3. Conclusion

In this publication, there are presented results reached from application of biofuel into the machinery working in condition which are sensitive to environment contamination. At present, our environment is excessively overloaded by all kinds of emission and the idea of fuel using with marginal impact on environment is very important. The main significance of biodiesel is that almost each diesel engine is capable of biodiesel combustion. Take into account that up to 90% of goods and persons' transport is done by vehicle running with diesel (trucks, buses, locomotives, boats, tractors) this is real potential. Anyway, there exist a lot of vehicles for personal using equipped with diesel engines which can also use biodiesel as their drive. The number of these vehicles is about 15 – 40% in European Union. Very important indicators from the point of view of ecology are smoke and emission values – limited and also unlimited. During smoke measurement which was realized by steady mode and by free acceleration, the decreasing of emitted smoke value was from 10 – 50 % in favour of tested biofuel. From the ecological point of view, the most important are values of limited emission, mainly NO_x (nitrogen oxide). After conversion of these values from ppm to $\text{g} \cdot \text{kW}^{-1} \cdot \text{h}^{-1}$, the values are higher about 1 $\text{g} \cdot \text{kW}^{-1} \cdot \text{h}^{-1}$ for biofuel RME in comparison with values obtained by diesel oil and this is approximately 16 % higher value for non-overfilled and 10 % for overfilled engines. In both events presented above, the most important are absolute values of NO_x which are double lower for non-overfilled engine and this are the same facts for diesel oil and biofuel RME. The research presented in this publication is a successful step forward into that way which makes sense for development and searching of new technical improvements with respect to clean environment.

5. References

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