Nanoparticle Emissions of CR Diesel Engines EURO 4 Fuelled by Plant Oils

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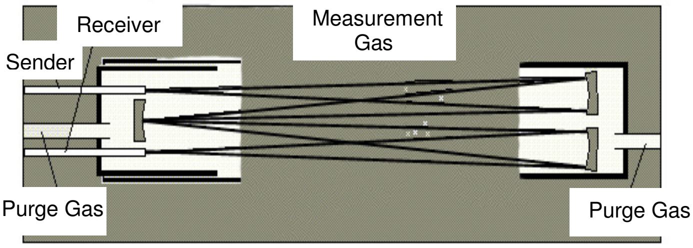
INTRODUCTION

Non-esterified plant oils gain ecological and economical importance, particularly in the EU where it is intended to increase the share of renewable energies. Plant oils do not require any chemical treatment so do not cause secondary pollution. The importance of plant oil will increase in Germany for mobile and stationary applications. The generation co-generation of heat and power is subsidized by the German “Erneuerbares Energiegesetz” and the “Kraft-Wärme-Kopplungsgesetz” when renewable fuels are used such as plant oils..

Plant oils have a much higher viscosity than conventional gas oil. It is mandatory to decrease the oil viscosity by heating prior to injection to assure proper injection and to avoid engine damage due to coke formation in the combustion chamber and at the injection nozzle. The German quality standard of Weihenstephan (RK-Qualitätsstandard 05/2000) for rape seed oil should be followed for use as diesel fuel. The chemical composition of plant oils is appreciably different in comparison to diesel fuels derived from mineral oils suggesting also different emission behavior.

MEASUREMENT TECHNIQUE

The particle emission is measured on-line by LPME (long path multi-wavelength extinction), using a White cell, Fig. 1, with an optical path length of 8 m. A light beam of three different wavelengths is attenuated by absorption and extinction of the particles. The main aerosol parameters “mean particle diameter” and “volume concentration” are derived by applying the Mie theory. LPME is described in detail in [1,2]. Fig. 2 depicts the measurement device.



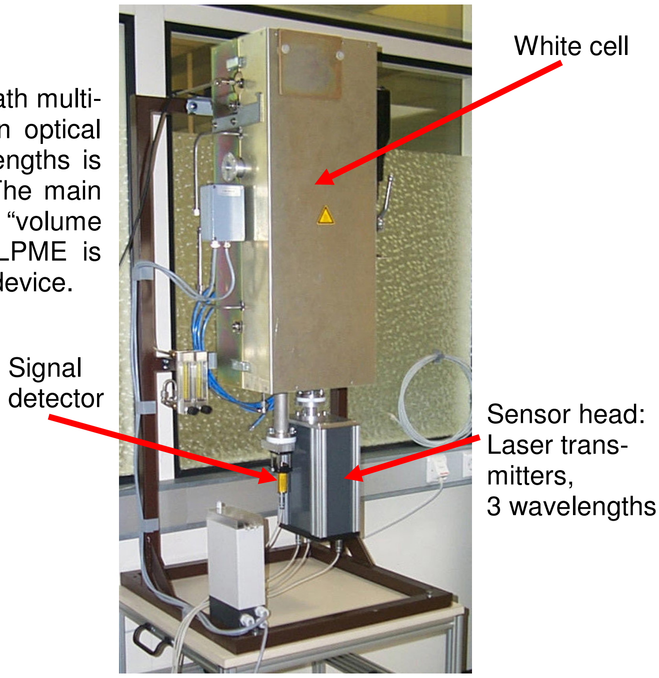


Fig. 1 (left): White cell principle
Fig. 2 (right): On-line particle analyzer LPME

It is the unique feature of LPME that the size of the primary particles of the chain-like soot aggregates is derived. These primary particles are well in the nanometer range, typically between 10 and 30 nm, whereas the soot aggregates yield an equivalent kinetic diameter of approx. 100 nm and above as measured by DMA. It is clear that only the primary particles in the nanometer range are relevant for environmental or biological reactions and not the loose, randomly formed aggregates (i.e. mainly particles in the low nanometer size range are translocated in lungs [3]).

EXPERIMENTAL SET-UP AND MEASUREMENT RESULTS

A state of the art common rail 4 cyl., 1.7 l EURO 4 engine with 16 valves, EGR and VTC turbo charger (but no diesel particulate filter) was used. The injection pressure is up to 1,800 bar. A heat exchanger using engine coolant is installed which heats the plant oil up prior to injection to approx. 80 to 90^{0}C. A special pump for plant oils is installed to yield the pre-pressure necessary for the high pressure pump. The engine is started by conventional gas oil and the common rail system is flushed by gas oil before turning it off to avoid a start with cold plant oil. This procedure assures good injection conditions for plant oils. No other modifications are made and the injection control remains unchanged as supplied by the engine manufacturer for gas oil operation.

Four different plant oils have been investigated in comparison to conventional gas oil: Rape seed oil, sunflower oil, soya oil, peanut oil.The common rail engine has three injection phases: Pre-injection, main injection and post-injection. The post-injection can clearly be seen in Fig. 4. The different fuels do not show large differences in the nature of the emitted particulate matter with this engine (compare [1]). Hardly any variations in the primary particle size can be detected. All the measured primary particle sizes are in the range of approx. 15 nm. The TEM pictures, all similar to Fig. 3, confirm these results. The composition is graphite carbon. Ash traces could not be found on the particles (compare particles emitted by the heavy duty engine, as reported in [2]). This suggests a similar, rather ideal combustion, also for the biogenic fuels, confirming the somehow universal, fuel independent nature of soot formation. This is in considerable contrast to the results of the old heavy duty engine [2].

Load condition:	1500 rpm app. 25 kW	2300 rpm app. 55 kW	3300 rpm app. 60 kW
Fuel	Mean volume concentration in 10^{-9} m³/m³ and standard deviation		
Gas oil	44	17	16
Rape seed oil	50	15	12
Sun flower oil	33	16	19
Soya oil	42	11	17
Peanut oil	26	13	19
Rel. standard deviation	5 to 10 %	10 to 25 %	10 to 25 %

Table 1: Volume concentration of particulate matter at full load and relative standard deviation

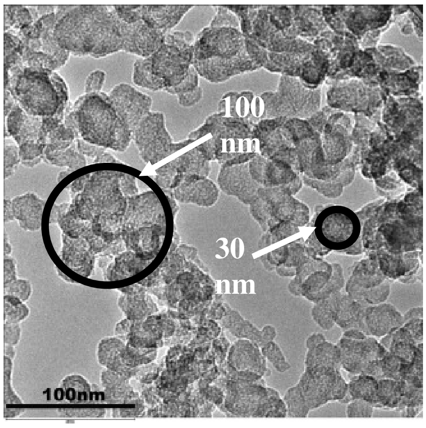


Fig. 3: Typical TEM picture of diesel soot
Large circle: aggregate, small circle: primary particle

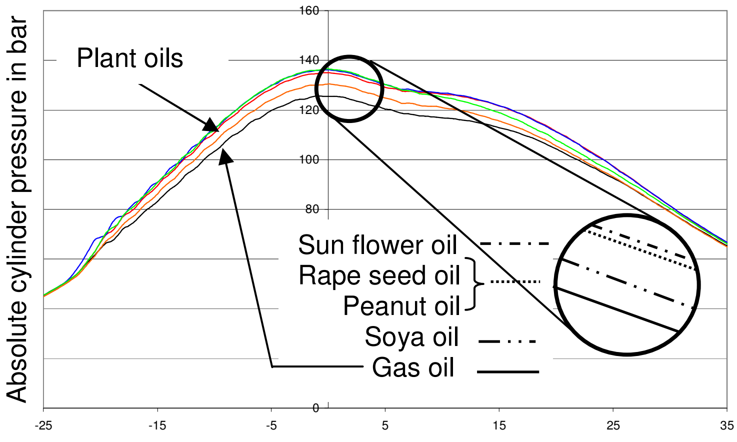


Fig. 4: Indicator diagram for different fuels at 2300 rpm/47 kW

Appreciable differences are found in the emitted particulate matter concentration for the different fuels. Table 1 lists the volumetric concentrations of the fuels compared by three engine load conditions. The scattering in the data (i.e. the relatively large standard deviations) are due to measurement uncertainties, the somehow unsteady engine/brake control and the variation in the environmental conditions (humidity, temperature). As expected, the concentration depends strongly on the load, but with individual trends for each fuel, not showing a real clear emission advantage for plant oils. Consistent differences are found in the cylinder pressures, Fig. 4. All plant oils yield a higher internal pressure. Only the NOx emission is consistently higher for plant oil fuels when the gaseous emissions are compared to gas oil operation, as listed in Table 2.

2300 rpm 47 kW	CO_2 [% vol]	O_2 [% vol]	NO_x [ppm vol]	Lambda
Gas oil	9,2	8,3	652	1,6
Rape seed oil	9,3	8,7	670	1,6
Sun flower oil	9,0	8,7	716	1,6
Soya oil	9,5	8,5	720	1,5
Peanut oil	9,4	8,6	779	1,6

Table 2: Gaseous emission at 2300 rpm and 47 kW

The AMES tests for the mutageneous impact of the emissions of plant oil fuelled diesel engines are under way. The very first results indicate that there is no significant difference in the mutagenity between plant oil and gas oil particulate matter emissions. This is in sharp contrast to a recent report [4]. But this publication investigated the emissions of an engine which was not adjusted to plant oils so that incomplete combustion is most likely (e.g. [2]).

CITED LITERATURE

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