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Emissions and Optimisation Potentials for New Diesel Fuels

Various fossil and biogenic fuels were tested for their emissions. Included were four biodiesel blends, with varying percentages of rape seed, soy and palm oil methyl ester, a gas-to-liquid fuel (GTL), the recently introduced V-Power diesel from Shell and Ultimate diesel from Aral, as well as conventional diesel fuel (DF) for comparison. The fuel formulation has a definite influence on the emissions. For biodiesel this is especially important, because the potential for optimising this fuel has not yet been exploited in regard to NO_x-emissions.

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Keywords

Exhaust gas emissions, diesel fuels, FAME, biodiesel

Recently biodiesel (fatty acid methyl ester, FAME - in Germany mainly rapeseed oil methyl ester (RME) as a neat fuel, which means B100) became an important alternative fuel. Approximately 1,200,000 tons were sold in Germany in the year 2004 [1]. Today biodiesel is available at nearly 1,900 filling stations in Germany. One driving-force for biofuels is the Directive 2003/30/ EC of the European Parliament [2]. It aims for a future share of biogenic fuels in the traffic sector of 2 % in the year 2005 up to 5.75% in 2010. Regarding the finiteness of fossil resources this directive can be considered as noticeable contribution to a future sustainable mobility.

However, the use of any fuel ñ also biogenic ones - in internal combustion engines results in substances formed during incomplete combustion like nitrogen oxides (NO_x). NO_x emissions are considerably higher when using biodiesel, compared to fossil diesel fuel [3]. Due to that significant disadvantage of biodiesel, recently a biodiesel sensor was developed. The sensor discriminates the blends of biodiesel and fossil diesel fuel (DF) and provides a blend signal to the engine management unit [4, 5]. Thus it enables the reduction of NO_x to the level of DF through appropriate control of the timing and dosage of the fuel injection [6].

It was the goal of the research work reported here to reveal further potentials for reduction of emissions by fuel design. Also in these investigations the reduction of NO_x emissions was in the focus of our interest.

Test stand and fuels

The test engine was a six-cylinder, 205 kW Mercedes-Benz OM 906 that meets the exhaust gas standard according to Euro 3. On the engine test bench the 13-mode ESC test was run, using an eddy-current break. The sampling of regulated gaseous compounds was taken from the pure exhaust gas stream. For particulate matter (PM) a dilution tunnel was used. Both samples were taken in the last minute of each phase. PM was sampled on a PTFE-coated glass fibre filter. For each fuel a two-times repeated determination of all emissions was carried out.

Different FAME qualities were blended from rape seed, palm, and soybean oil methyl esters. In unblended form, only RME met the standard DIN EN 14214. It is named FAME2 in the following. Soybean and palm oil methyl ester were blended with RME such that the resulting blends were within the limits of the standard (exception: the oxidation stability of FAME1 and 4). FAME1 and FAME3 were binary mixtures, whereas FAME4 was a ternary mixture. The FAME qualities mainly varied with respect to iodine number and pour point. V-Power diesel fuel and Ultimate diesel fuel were bought in filling station quality.

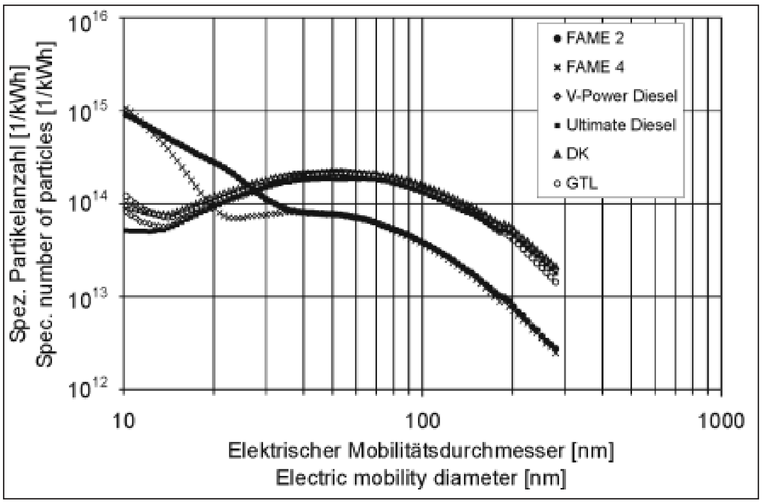

Fig. 1: Particle number distribution, measured with SMPS

Results

Regarding all fuels it can be summarized that CO emissions are always much lower than the Euro 3 limit of 2.1 g/kWh. It became obvious that FAME reduces CO versus DF by approximately 40 %, whereas GTL, Ultimate and V-Power lead to an increase.

Also for hydrocarbons (HC) the FAME qualities reduced the emissions by ~ 30 %, compared to DF. GTL and Ultimate led to a reduction of ~ 20 %, V-Power to ~ 10 %, but these three new fuels showed higher emissions than the biogenic fuels. With all fuels, the Euro 3 limit of 0.66 g/kWh was not reached by far.

Regarding PM emissions DF led to the highest value; GTL and V-Power were ~ 20% better than DF, and Ultimate was even slightly lower. The results of all FAME qualities were, again, significantly lower. In contrast to the findings with respect to HC and CO the FAME results here noticeably differ from each other. FAME2 showed 170 % of the emissions from FAME4. FAME3 and FAME4 proved to be considerably better than FAME1 and, in particular, FAME2. The Euro 3 limit of 0.1 g/kWh was met by all fuels used in the test.

The particle number distribution with respect to the particle size was analysed by an electronic low pressure impactor (ELPI) and a Scanning Mobility Particle Sizer (SMPS; from TSI). The physical operation principles of these analysers are given in [7]. In the SMPS measurements the particle number of sizes over 30 nm of electrical mobility diameter was found to be distinctly lower for the FAME qualities than for the other fuels tested (*Fig. 1*). Below 30 nm, the results are much different. In this range the particle numbers for DF and GTL show a slight decrease. For the biodiesel qualities, however, a 10-fold increase was detected. FAME2 and 4 only differed in a small range from 15 to 30 nm. At present the origin of these ultra-fine particles from biodiesel remains unclear. Whether this is soot or unburned fuel must be revealed by further research.

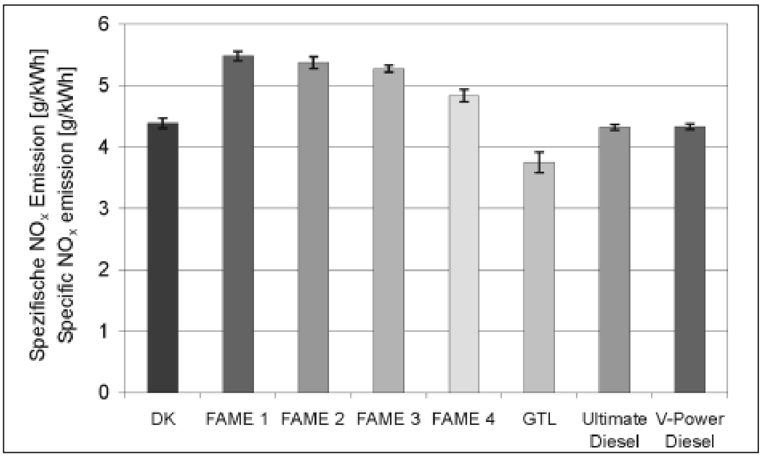

Fig. 3: Specific emissions of nitrogen oxides

For the comparison of the mutagenic potencies of four fuels (DF, V-Power, Ultimate, and RME), glass fibre filters were extracted, which had been exposed to concentrated offgas during the ESC test. Following several processing steps the extracts were tested for mutagenicity in the Salmonella typhimurium assay, which is also well-known, after its inventor, as Ames test [8].

The fuels Ultimate diesel and RME showed less than 50 % mutagenic effects in tester strain TA98 compared with DF (*Fig. 2*). The lowest genotoxicity was observed for RME. When the engine was fuelled with V-Power diesel, the mutagenicity was reduced by 40 %. By adding a metabolic activation system (S9) the mutagenic response was decreased further in each of the four fuels.

The results add further evidence that genotoxic and obviously also carcinogenic effects of diesel engine emissions can successfully be reduced by an optimisation of the fuel composition.

The results for NO_x emissions are presented in Figure 3. The Euro 3 limit of 5 g/kWh is obeyed by the fuels of fossil origin, where GTL showed a decrease of ~ 15 % versus DF, V-Power and Ultimate. FAME1, 2, and 3 exceeded the limit, FAME4 lay slightly below the limit. Here it becomes obvious that the fuel composition of the biofuels was able to reduce the NOx emission by 10 %. Thus a use of biofuels that meets the NOx limit without change in the engine operation takes on a concrete form.

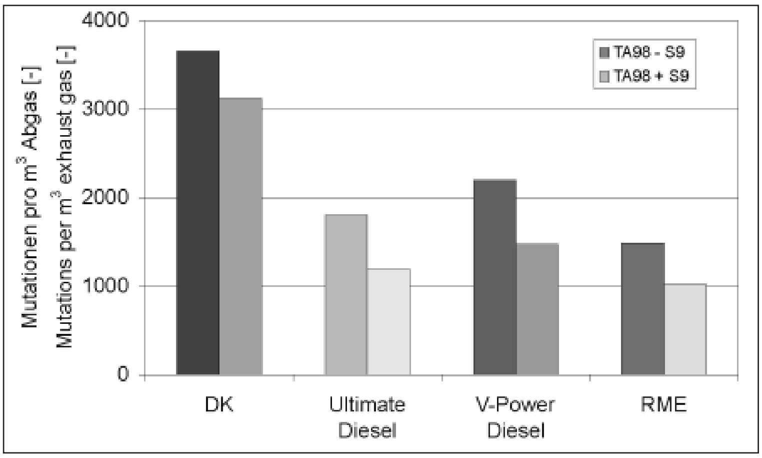

Fig. 2: Mutagenicity of particulate matter in engine emissions

By these results the potential of an improvement of exhaust gas quality from biodiesel via an optimised fuel formulation is demonstrated. A systematic and optimised blending of fuels can have comparable effects as a variation of injection timing and dosage. At present, we can only report these effects but are not able to explain them. What can be stated today is that a systematic fuel research can play a constructive role in joint optimisation of engine and fuel. In the past this aspect did not gain the necessary attention.

Acknowledgement

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Literature

[1] VDB: Pressemitteilung 6-2004 des Verbands deutscher Biodieselhersteller, 2004

[2] Europäisches Parlament: Richtlinie 2003/30/EG Förderung der Verwendung von Biokraftstoffen, 2003

[3] *Krahl, J., A. Munack, M. Bahadir, L. G. Schumacher und N. Elser*: Review: Utilization of rapeseed oil, rapeseed oil methyl ester or diesel fuel: Exhaust gas emissions and estimation of environmental effects. SAE Paper 962096, 1996

[4] *Munack, A., J. Krahl, A. Marto und R. Bantzhaff*: Grundlegende Untersuchungen zu einem Biodieselsensor, Entwicklung eines Prototyps und Herstellung der Serienreife. VDI-Berichte 1798, (2003), S. 331-336

[5] *Bantzhaff, R., A. Marto, J. Krahl und A. Munack*: Verfahren und Schaltungsanordnung zum Erfasen und/oder Bestimmen der Beschaffenheit eines Mediums. München: Deutsches Patent und Markenamt, 7 S., Patent Nr. 10258417, 2004

[6] *Blaßnegger, J., und S. Schlag*: Biodiesel in modernen Nutzfahrzeugmotoren. Landbauforschung Völkenrode, Sonderheft 239 (2002), S. 63-68

[7] *Bischof, O.F., und H.-G. Horn*: Zwei Online-Messkonzepte zur physikalischen Charakterisierung ultrafeiner Partikel in Motorabgasen am Beispiel von Dieselmotoren. MTZ 60 (1999), S. 226-232

[8] *Ames, B.N., F. D. Lee and W. E. Durston*: An improved bacterial test system for the detection and classification of mutagens and carcinogens. Proc Natl Acad Sci USA 70 (1973), pp. 782 - 786