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Exhaust gas measurements from a diesel engine with an RME-optimised injection

Through using RME with special catalysator and a high-pressure injection system, the nitric oxide and particle emissions of a diesel engine can be substantially reduced. The Euro-III standard limits were still not complied with. The reasons for this are the HPP system, which is still in the development phase and capable of further improvements, and the unsuitable standard of the testing equipment.

The investigations into the mutagenicity, toxicity and the distribution and the range in particle size resulted in the RME exhaust gas achieving in total better values than that of diesel fuel. Further emissions investigated lay in areas where they could be kept at the border of legal requirements through mechanical processing or further exhaust treatment.

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Keywords

RME, particulate and nitric oxide reduction

In most serial diesel engines it is possible to use rape methyl ester (RME) without problems. Within the remit of this project, the effects of an injection system developed by the company FMC (Fiedler Motor Consulting GmbH, Kiel) and described as a high pre-pressure (HPP) injection system were investigated. This injection system comprises a camshaft-controlled injection pump, a pre-pressure pump and special injector jets. Where RME is used as fuel, the choice of the point of injection and application of the injector pressure is critical to the effect on exhaust emissions. The investigations carried out compared the exhaust gas qualities when conventional diesel fuel (DF) and RME were used with original injector pump and with the HPP system. Additionally, an oxidation catalysator from the company Oberland-Mangold optimised for RME was used.

Trial method

Within the framework of the trial took place not only the establishment of the limited exhaust components carbon monoxide (CO), hydrocarbon (HC), nitric oxide (NO_x) and particle volumes but also the differentiating of the particle volume flow into organic soluble and organic insoluble components as well as into size range. Further, the mutagenicity of the particle volumes was determined and also aldehyde and ketone measured as possible ozone precursor.

The MWM 302-2 is an air cooled two-cylinder in-line engine (95 mm bore, 105 mm stroke) with direct injection and performance of 17 kW at 2000 rpm^{-1}. As standard equipment the engine has a Bosch in-line injection pump with mechanical governor and fixed injection point at 6.5 °ca pre upper dead centre (udc). The injection jets with this series are Bosch four-apperture models.

The HPP system was set-up for investigating an injection point of 4 °ca after udc. The HPP plant was fitted with jets from Bosch (three-apperture jets which have a 65% smaller jet area compared with the original equipment, according to FMC information).

The investigations were carried out at modes 3 (1500 rpm^{-1}, 25% load), 6 (1500 rpm^{-1}, 100% load), 8 (2000 rpm^{-1}, 100% load) and 11 (2000 rpm^{-1}, 25% load) of the 13-mode test (council guideline 88/77IE-WG). Used as fuel was RME from Oilmills Connemann GmbH & Co., Leer and diesel from Shell.

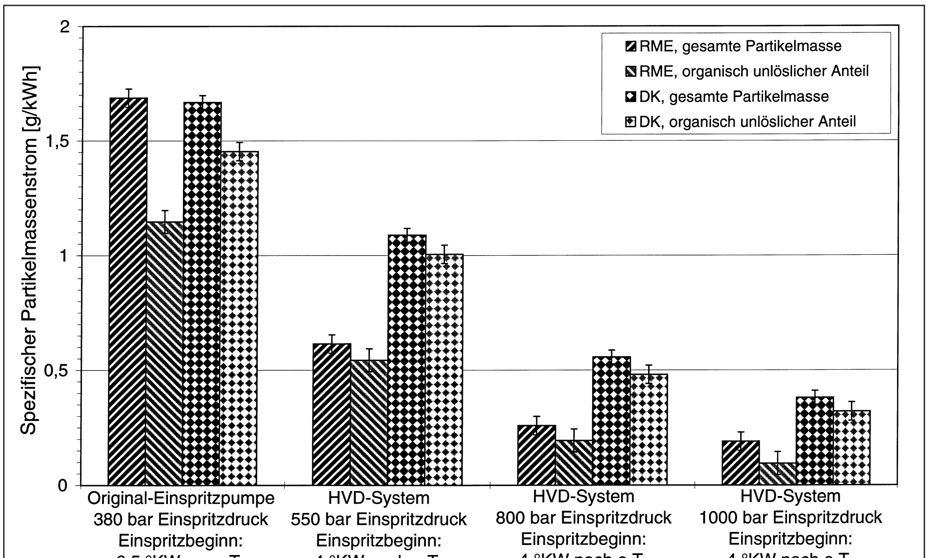

Fig. 1: Specific particulate matter emission of the MWM 302-2 in mode 8 and standard deviation

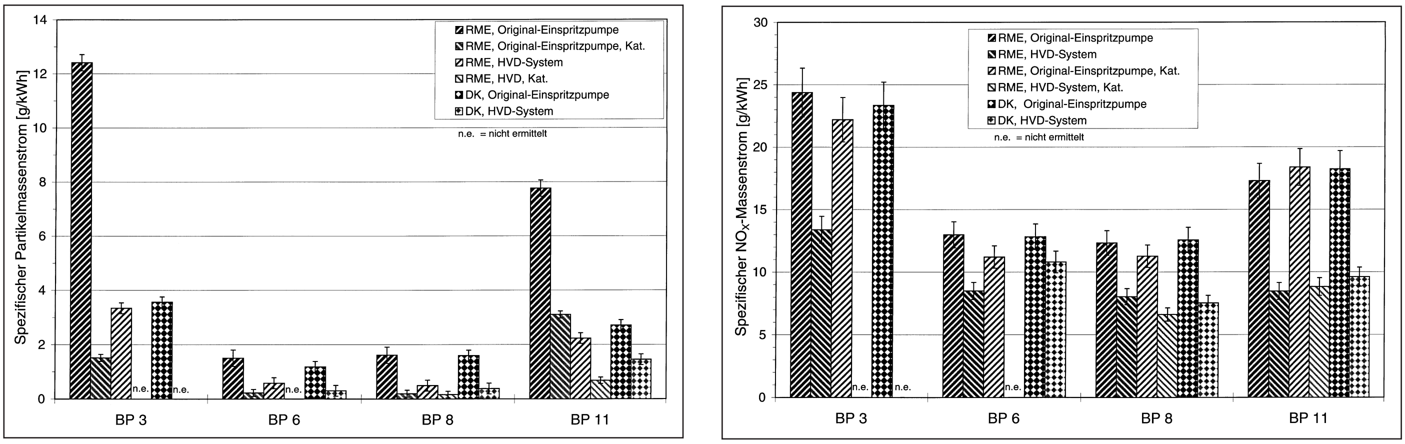

Fig. 2: Measurements in selected modes of the 13-mode test using the original injection pump (injector pressure 380 bar, injection timing 6,5 °ca pre udc) and the HVD system (injector pressure 1000 bar, injection timing 4 °ca after udc) and standard deviation

Particle emissions

The influence of the HPP system in the reduction of particle emissions is most pronounced at mode 8. In *figure 1* is demonstrated the particle volume flows resulting from both fuels using the original injection pump and the HPP system with three different injection pressures [2].

The particle volume flows are almost the same with both fuels when the original injection pump is used. With RME, the proportion of insoluble organic particles is about 20% less than with diesel. More soot was produced where diesel was burned. This connection was verified by the evaluation of the blackening index as measured by Bosch.

With 550 bar injection pressure, the reduction in the particle volume flow can be attributed mainly to the retarded beginning of the injection process in that the injection pressure is only minimally higher than with the original injection pump. The particle volume flows with RME are reduced by over 60% compared with those from the engine with original equipment. The effect from diesel was less, with a reduction rate of around 35%.

With an injector pressure of 1000 bar created by the HPP system, the particle volume flow with RME represented only around 10% of that from the original equipment, and that with diesel around 25%.

With both injection systems the use of RME meant the insoluble organic faction of the particles was less. When using the HPP system with an injector pressure of 1000 bar, insoluble organic particles made up 50% of the total particle volume when RME was used, and 84% with diesel. As already established in other investigations [3], the particles in RME exhaust gases indicate a larger proportion of soluble organic material. It can be assumed that the soluble organic proportion of the particles consist of unburned fuel and are of engine oil. At the highest pressure possible with the HPP system the effect of the retarded beginning of injection timing chosen for the use of RME fuel was very pronounced.

In *figure 2 (left)* the effect of the chosen mode and the influence of the oxidation catalysator on the MWM 302-2 is demonstrated under utilisation of both injection systems and both fuels. The adjustment of the injector pump is not altered from that used at mode 8.

With RME, the particle volume flow was reduced by 60% through the use of the HPP system compared with the original injection pump at mode 11, by 85% at modes 3 and 6 and by around 90% at mode 8. Where diesel fuel was used, the HPP system reduced the particle emissions compared with output from the original injection pump by some 50% at mode 11, and 75% at modes 6 and 8. With RME, the reduction rates at the respective modes are higher.

The oxidation catalysator, optimised for the use of RME, reduced particle emissions in the respective modes by around 60% where the original injection pump was used. With the HPP system and the oxidation catalysator, the particle volume flows were only determined at modes 8 and 11. In this case the oxidation catalysator reduced the particle volume flow at mode 11 by 75% and by at least 20% at mode 8. Under the Euro-III standards modes 8 and 11 are the only modes fully measured. With the results from the particle volume flows from 0.16 g/kWh for mode 8 and 0.68 g/kWh for mode 11, the aimed-for range was achieved.

Nitric oxide emissions

The nitric oxide volume flows in the four chosen modes are shown in *figure 2 (right)*. Compared with one another here were both injection systems, the two fuels RME and diesel, and the oxidation catalysator optimised for RME because of its nitric oxide reduction effect.

With the original injection pumps the difference between both fuels lay within the margin of error. Using the HPP system with RME resulted in a NO_x emission reduction of 45% at modes 3 and 11. At modes 6 and 8 the reduction was 35% compared with the results from the original injection pump. The reduction rates from using diesel in the HPP system were about 15% at mode 6 and in each case 40% for modes 8 and 11. The reduction in the nitric oxide emissions can be traced back to the retarded injection beginning of 4 °ca after udc. Where the injection beginning is retarded even further in the „late" direction, an increase in particle emissions and in fuel consumption resulted.

The effects of the oxidation catalysator with regard to the NO_x emissions with the original injection pump as well as with the HPP system are too small to be accurately measured.

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