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Exhaust Gas Particulate Filter Systems for Rapeseed Oil Fuelled Combined Heat and Power Units

Combined heat and power units (CHP) fuelled with rape seed oil stand out through their especially efficient utilisation of renewable agricultural energy sources. However, harmful exhaust gas emissions like particles must be minimised. For this reason the functionality of Diesel particulate filters was investigated in a rapeseed oil fuelled CHP. Particle mass reduction rates of up to 98 % were achieved. But, within only a few operation hours, exhaust gas counter pressure rises and hence fuel consumption and exhaust gas emissions. Afterwards the filter must be removed and cleaned. Diesel particulate filter systems must be optimised in order to attain an acceptable maintenance level.

The demand for combined heat and power units (CHP), fuelled with vegetable oil is presently very high. The reasons are high heating oil prices and a lucrative power feed-in remuneration of up to 19.33 Cent per kWh by the 2004 amendment of the Act on Granting Priority to Renewable Energy Sources [1]. Despite many advantages, harmful emissions, especially particles need to be minimised. First results show that the target value, under consideration of the limiting value for particle mass emission of 20 mg/Nm^3 (related to 5 % O_2-content) for plants < 1 MW combustion heat performance, can only be met if the CHP was equipped with an exhaust gas particulate filter [2]. So far there is only little knowledge about particulate filter systems, used for vegetable oil fuelled engines.

Objective

Objective of a research work, funded by the Bavarian Environmental Protection Agency (BayLfU) in Augsburg and the Bavarian State Ministry of Environment, Public Health and Consumer Protection (BaySt-MUGV) in Munich was to test promising diesel particulate filter systems in a small scale rapeseed oil fuelled CHP unit. There important operation and emission data were determined, to get results about functionality and efficiency of this exhaust gas cleaning technique.

Methodology

A rapeseed oil fuelled CHP (8 kW_{el}, 15 kW_{th}) is equipped with five different particle filter systems (one after the other), developed for the use in diesel fuelled engines (*Table 1*). With any of these particulate filter systems, a long-term study was scheduled and if possible conducted, to assess exhaust gas components, such as particle mass, CO, NO_x, HC and CO_2 frequently and several important operating parameters, like exhaust gas temperature and exhaust gas pressure continuously. Furthermore system maintenance, fuel and engine oil qualities as well as particle compositions were recorded.

Results

Particle mass emissions of rapeseed oil fuelled CHP units can be reduced effectively

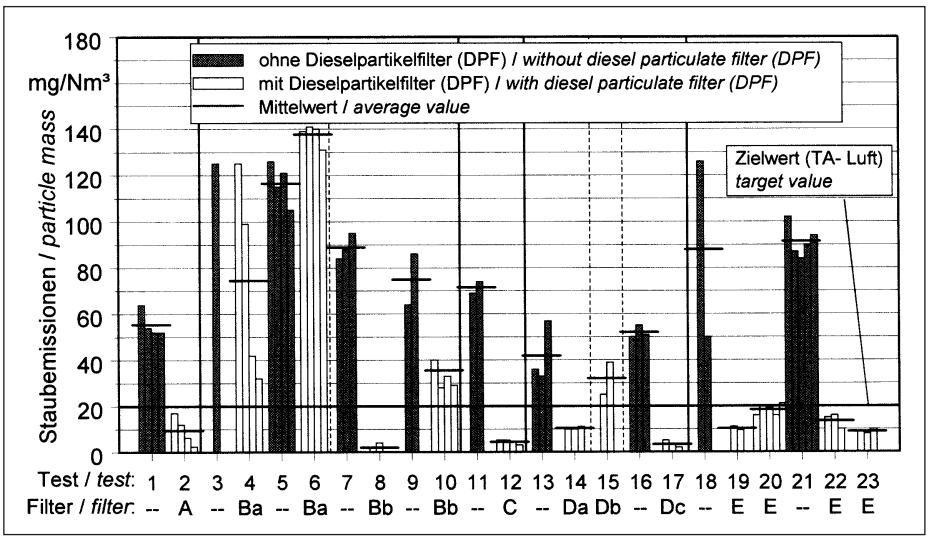

Fig. 1: Particle mass of a rapeseed oil fuelled CHP unit (8 kW_{el}) without and with different diesel particulate filters (half-hour average values for exhaust standard conditions, 5 % O_2)

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Keywords

Rapeseed oil fuel, CHP, exhaust gas, particulate filter

with the tested particulate filter systems. In 9 of 13 tests all five tested particle filter systems are suitable to reduce particle mass below the target value according to the German TA-Luft (Technical Instruction on Air Quality) of 20 mg/Nm^3 (*Fig. 1*). When achieving this target value, reduction rates from 74 to 98 % were measured compared to the operation without particulate filter systems.

The highest reduction was measured with unused particle filter "Bb", where only 2 mg/Nm^3 were emitted with installed filter compared to 89 mg/Nm^3 without filter (test 8). After 220 operating hours of filter "Bb" particle mass reduction dropped from formerly 98 % to 57 % (test 10). The reason therefore was a filter break, probably due to excessive counter pressure or/and faulty filter production.

The results with the unused filters "A" and "Ba" feature a decrease of particle mass emissions with every subsequent measurement (test 2 and 4). Obviously filter efficiency is higher during the first operating hours when a filter cake is built up by soot particles. However, the big differences in particle mass emissions especially of particle filter "Ba" are abnormal and might also be attributed to an unsuitable filter type. The same particulate filter caused in a second measurement after 132 operating hours 17 % higher particle mass emissions (test 6), than without the filter, mainly because of a very high counter pressure.

With increasing operating hours all investigated particulate filter systems show an high increase of exhaust gas counter pressure, from about 40 hPa to more than 250 hPa, within 200 operating hours despite initial effective regeneration. The reasons for this are higher ash entries due to contents of calcium and phosphorus (5-15 ppm each) in the fuel and an inactivated catalytic layer by soot and ash coating. High exhaust gas counter pressures lead to higher fuel consumption and also to higher exhaust gas emissions. In *Figure 2* exhaust gas pressure and temperature is shown for particulate filter system "E", which achieved with 620 hours the longest overall operation time.

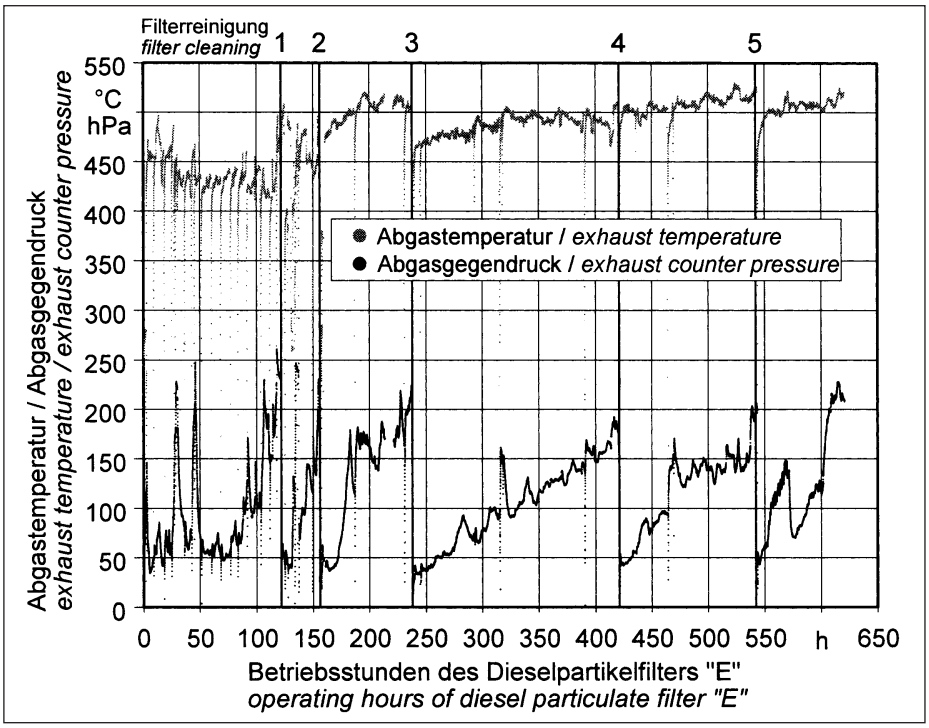

Fig. 2: Exhaust counter pressure and exhaust temperature of diesel particulate filter system „E" over 620 operating hours with five filter cleaning interruptions

Conclusion

Exhaust gas particulate filters efficiently reduce particle mass emissions, fulfilling the target value for particle mass of 20 mg/Nm^3. However, deficient or blocked particulate filters cause higher fuel consumption and higher exhaust gas emissions and shorten engine life. For all tested particulate filter systems frequent extensive cleaning is required. Further investigations and tests are necessary to reduce system maintenance for the application of particulate filter systems in vegetable oil fuelled combined heat and power units. In particular higher ash capacities, simple filter cleaning or different deposition techniques need to be developed. A mutual adjustment of fuel, engine and exhaust gas after-treatment is the precondition for a practice suitable diesel particulate filter application in rapeseed oil fuelled combined heat and power units.

Literature

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Particulate filter		Filter regeneration	
System	Filter type	type of support	temperature *)
A	keramic Monolith	katalytic layer	~ 300 °C
Ba, Bb	Wire-/ceramic-filament-fabrics winding	katalytic layer	~ 430 °C
C	keramic Monolith	none	~ 650 °C
Da, Db, Dc	keramic Monolith	NO_2 (oxidation katalysator)	~ 300 °C
E	Mikrofibre Candle filter	katalytic layer	~ 450 °C

*) according to manufacturer

Table 1: Tested Diesel particulate filter systems