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PARTICULATE FILTER SYSTEMS FOR VEGETABLE OIL FUELLED CHP-UNITS

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ABSTRACT: Combined heat and power units (CHP), fuelled with pure vegetable oil, have major environmental advantages. The target value for particle mass emission can only be achieved with exhaust gas particle filters. In a present research work usability, functionality and efficiency of particle filter systems in a rapeseed oil fuelled CHP unit is being investigated. Thereby exhaust gas emissions, such as particle mass, CO, NO_x, HC and CO_2 are measured recurrently and important operating parameters are recorded. All four tested particle filters are suitable to reduce particle mass emissions below the target value. Particle mass reduction rates achieve values up to 98 % but vary widely, depending on the filter type, filter operation hours and state of filter maintenance. With increasing operating hours exhaust gas counter pressure rises quickly, which results in higher fuel consumption and increase of exhaust gas emissions such as CO and also particle mass. Further investigation and regeneration system performance is necessary for the broad application of particle filter systems in rapeseed oil fuelled combined heat and power units.
Keywords: rapeseedoil, emission reduction, combined heat and power generation (CHP)

1 INTRODUCTION AND PROBLEM

Combined heat and power units (CHP), fuelled with pure vegetable oil, have major environmental advantages. In addition to efficient energy conversion through co-generation, the use of vegetable oil as a fuel has positive impact on the protection of resources and the atmosphere. Furthermore the fast biodegradability and low toxicity of pure vegetable oil provides the opportunity to make a decisively contribution to soil conservation and water pollution control.

With rising power feed-in proceeds of up to 0,195 €/kWh by the 2004 amendment of the Act on Granting Priority to Renewable Energy Sources, the shortage of mineral oil and the growing environmental awareness the demand of small-scale vegetable oil fuelled CHP is further increasing in Germany.

Insecurities have been for a long time regarding the reliability and the emission characteristics of rapeseed oil fuelled combined heat and power units. Within a research project "Combined heat and power units, fuelled with pure vegetable oil - emission and operating characteristics of chosen Bavarian plants, weak point analysis and assessment", supported by the Bavarian State Ministry of Environment, Public Health and Consumer Protection (BayStMUGV) and the Bavarian Environmental Protection Agency (BayLfU) numerous open question were investigated [1][2][3]. The works showed that the target value, under consideration of the limiting value for particle mass emission of 20 mg/Nm³ (related to 5 % O_2-content) for plants < 1 MW combustion heat performance, could only be achieved when the CHP was equipped with an exhaust gas particle filter.

Particle filters efficiently reduce particle emissions and accomplish consequently a contribution to air purification. However, experiences with engines, operated with rapeseed oil are generally little. Especially small scaled CHP (<100 kW_{el}) are usually not equipped with particle filter systems.

2 PURPOSE

Obstacles for the application of particle filter systems are insecurities regarding functional efficiency and high investment costs. There is a need to investigate if particle filter systems can be used properly in vegetable oil fuelled cars or stationary engines.

Objectives of a present research work funded by the Bavarian State Ministry of Environment, Public Health and Consumer Protection (BayStMUGV) and the Bavarian Environmental Protection Agency (BayLfU) are:

- Research on available particle filter systems for reducing particle mass of diesel engines, which are placed in stationary engines with low capacity
- Observation of selected particle filter systems in a field test at the CHP unit (8 kW_{el}) of the Technologie- und Förderzentrum (TFZ)
- Registration of important motor operating conditions, like fuel consumption, exhaust gas temperature and counter pressure
- Recurring measures of particle mass emissions and further exhaust gas components (CO, NO_x, HC, CO_2)
- Assessment of usability, functionality and efficiency of particle filter systems in rapeseed oil fuelled CHP units

3 APPROACH

A rapeseed oil fuelled CHP (8 kW_{el}, 15 kW_{th}) is equipped with different particle filter systems (Table). During the investigation period of almost two years, exhaust gas emissions, such as particle mass, CO, NO_x, HC and CO_2 are measured frequently and several important operating parameters, like fuel consumption, exhaust gas temperature and exhaust gas counter pressure are recorded. Furthermore fuel and engine oil qualities as well as particle (soot and ash) compositions are analysed.

Table: Features of tested particle filter systems

Diesel particle filter system manufacturer	Filter type	Filter regeneration (soot oxidation) technique	Regeneration temperature
A	Ceramic wall flow monolith	Catalytic layer	300 °C
Ba / Bb	Wire-/ceramic-filament panels	Catalytic layer	430 °C
C	Ceramic wall flow monolith	--	650 °C
D	Wall flow monolith	by NO_2 from catalytic converter	300 °C

4 RESULTS

The recorded particle mass emissions vary widely, depending on influences, such as state of CHP maintenance, installed particle filter type (e.g. filter material, catalytic layer) and the operating hours, respectively state of filter maintenance. All four tested particle filters (A, B C, D) are suitable to reduce particle mass below the target value of the German TA-Luft (Technical Instruction on Air Quality) of 20 mg/Nm³.

Particle mass reduction rates (1 minus particle mass with installed particle filter divided by particle mass without particle filter) range from very efficient 98 % and 94 % to - 0,17 % (Figure 1). Latter means an increase of 17 % in particle mass emissions with installed filter.

The highest reduction was measured with unused particle filter "Bb", where only 2 mg/Nm³ were emitted with installed filter compared to 89 mg/Nm³ without filter. After 220 operating hours of filter "Bb" particle mass reduction dropped from formerly 98 % to 43 %. The reason therefore was a filter breakthrough, 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. Obviously filter efficiency improves during early 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 particle filter caused in a second measurement after 132 operating hours 17 % higher particle mass emissions, than without the filter, mainly because of a very high counter pressure.

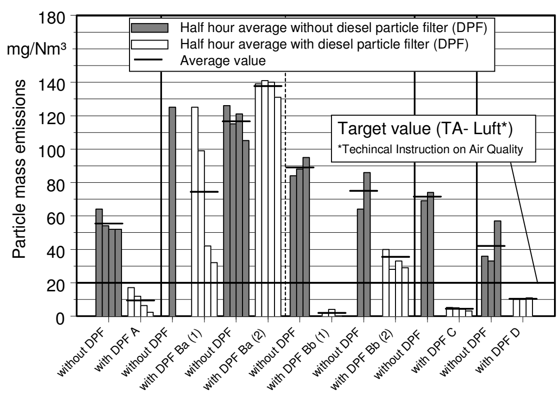

Figure 1: Particle mass emissions with and without particle filters

Other emission components are also influenced by the filter system, especially by the activity of a catalytic layer on the filter body and the exhaust gas counter pressure. In Figure 2 carbon monoxide emissions are shown. The lowest CO concentrations were recorded for filter "A" an "D". In the case of filter "A" the highly active catalytic layer on the filter body and in case of filter "D" a pre-mounted catalytic converter, installed for NO oxidation to NO_2, which is used for filter regeneration, caused an effective CO conversion. The benchmark of 300 mg/Nm³ CO can not be achieved when the back pressure is high and catalytic layers or converters are less efficient.

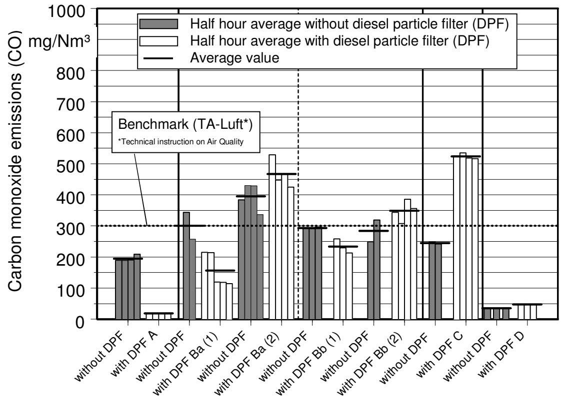

Figure 2: Carbon monoxide emissions with and without particle filters

With increasing operating hours all four investigated particle filter systems show an high increase of exhaust gas counter pressure from about 20 hPa to more than 250 hPa, which can have positive effects on filter regeneration (higher exhaust gas temperature). On the other hand high exhaust gas pressure results in an high thermal load for engine components, higher fuel consumption and in an increase of exhaust gas emissions such as CO and also particle mass. Possible reasons for counter pressure increases are fuel and engine oil derived contents of calcium and phosphorus, which lead to unburnable ashes in the exhaust gas or a deficient filter regeneration, due to insufficient soot burning in the filter.

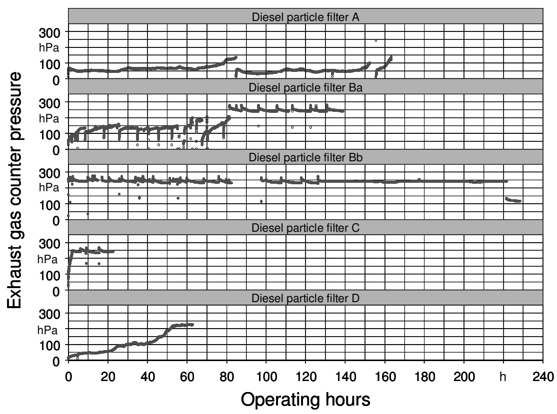

Figure 3: Exhaust gas counter pressures with installed particle filters during operating

5 CONCLUSIONS

Exhaust gas particle filters efficiently reduce particle mass emissions. With all four tested particle filter types the target value for particle mass can be achieved. Counter pressure increases quickly during operation with subsequent effects, such as higher particle mass and carbon monoxide emissions and higher fuel consumption. Further investigations and performances especially of filter regeneration systems are necessary for the application of particle filter systems in vegetable oil fuelled combined heat and power units.

6 ACKNOWLEDGEMENT

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