A laboratory emission study on biodiesel fuelled low duty engines

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INTRODUCTION

Diesel engines are known to emit high numbers of aerosol particles, which are under discussion in relation to global climate and their possible cause of health effects. In particular, the role of soot particles is of high importance as these particles are expected to be detrimental to human health. Due to regulations in Europe, particulate mass emissions from diesel engines were reduced to a large extent. Future regulations are expected to control these emissions also in terms of their number and size (Tsolakis, 2006).
In this study, the particulate emissions from different low duty diesel engines were investigated in dependence on the use of fuel (standard diesel – biodiesel blend). The engine fleet was represented by a EURO 2, a EURO 4 without diesel particle filter (DPF), and a EURO 4 with DPF engine. The experiments with biodiesel are of increasing importance as the amount of this fuel type is expanding (Swanson et al., 2007).

METHODS

The low duty engines were operated with differing types of fuel: here standard petrochemical (reference) diesel, 20% (B20) and 100% (B100) biodiesel based on animal fat (AFME) and 20% (B20) biodiesel based on rapeseed oil (RME) were used. All engine emissions were investigated within different operational modes according to ISO/EN 8178 directives simulating various driving conditions.
Particle measurements were undertaken using a Scanning or Differential Mobility Particle Sizer (SMPS or DMPS) obtaining particle number size distributions between 2 and 650 nm or 10 and 700 nm. The SMPS/DMPS was connected to a rotating disc diluter, that was situated downstream of the raw gas exhaust. Gas phase species (NO, NO_2, CO, CO_2, Total Volatile Organic Compounds, TVOC) were sampled from the raw gas exhaust. Quarts filters for chemical analysis were sampled in a dilution tunnel that was connected to the raw gas exhaust. Elemental and organic carbon (EC/OC), polycyclic aromatic hydrocarbons (PAH), and hopanes and steranes from lubricating oils were available from these filters in a limited number of experiments.

RESULTS

In general, substantial differences in emitted particle number size distribution were observed when operating different engines with one and the same type of fuel or one and the same engine with different types of fuel.
With respect to the EURO 4 engine with DPF, emission studies in particle number size distribution were obtained for all four types of fuels. Results from this study investigating emissions obtained when fuelling the engine with standard reference diesel, B20 AFME, B20 RME, and B100 AFME are shown in Figure 1 (left). It was found that the mean diameter of emitted submicrometer particles was decreasing with increasing fraction of biodiesel used in the fuel.
The change in particle number size distribution in dependence on the used fuel type is shown in Figure 1 (right) for the EURO 4 engine without DPF. The total particle concentration was significantly lower when fuelling this engine with any kind of biodiesel. As an example, particulate

emissions from the EURO 4 engine without DPF decreased by 56% in volume when operating the engine with 20% (B20) biodiesel compared the standard petrochemical (reference) diesel.
Mass concentrations of PAHs emitted from the EURO 2 engine appeared to be 11 to 56% lower when the engine was fuelled with 20% (B20) biodiesel compared to the reference.

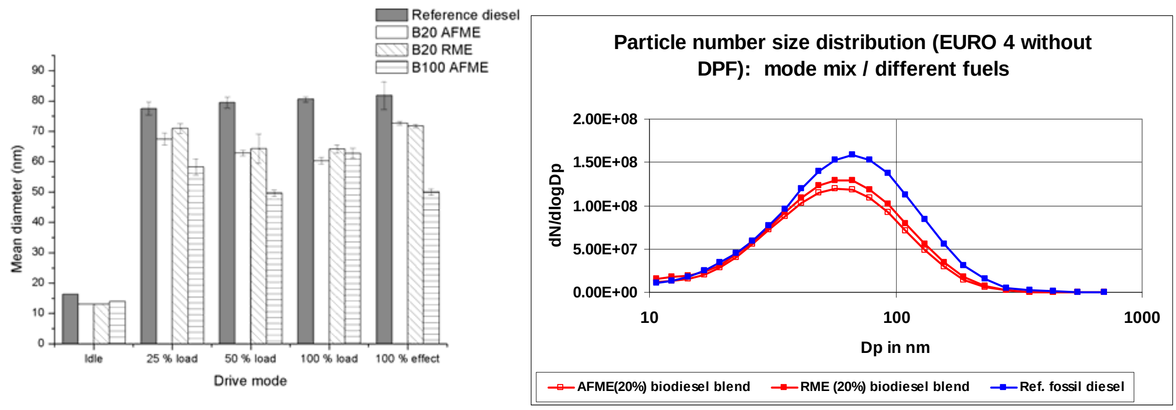

Figure 1: Mean diameter of particle number size distribution (left) and particle number size distribution (right) in dependence on used fuel type.

With respect to the EURO 4 engine, particulate emissions in EC/OC were investigated using a thermal optical carbon analyzer. The total content of carbonaceous material as well as the ratio of elemental and organic carbon significantly decreased when investigating 20% (B20) biodiesel (AFME) emissions compared to the reference diesel emissions. Results are shown here in Figure 2 (left).
In addition, concentrations of hazardous gas phase carbonyls were measured when operating the EURO 2 engine fuelled both with reference diesel and 20% (B20) biodiesel (AFME). Results show a clear decrease in gaseous emissions of carbonyls when comparing experiments when the engine was fuelled with biodiesel compared to standard petrochemical (reference) diesel.

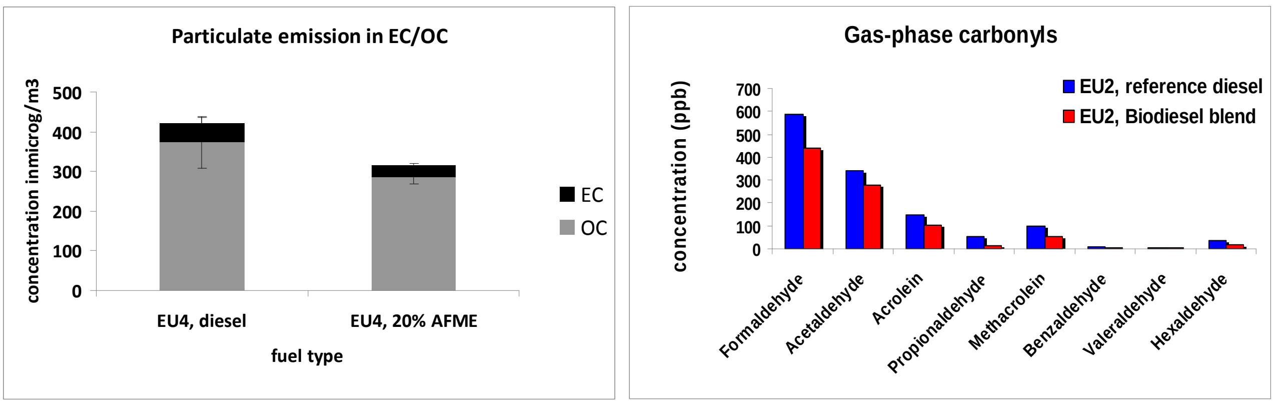

Figure 2: Particulate emission of elemental and organic carbon (left) and contribution of gas-phase carbonyls (right) in dependence on used fuel type.

REFERENCES

Swanson K.J., Madden M.C., Ghio A.J. (2008) Environmental Health Perspectives 115, 496-499.
Tsolakis, A. (2006) Effects on particle size distribution from diesel engine operating on RME biodiesel with EGR, Energy and Fuels 20, 1418-1424.

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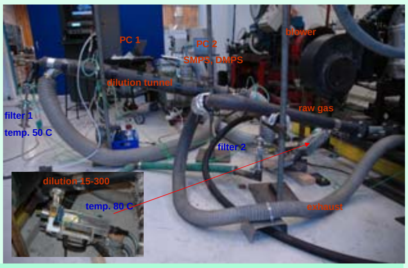
INTRODUCTION

- Anthropogenic emissions of particles are under discussion in relation to global climate change and their cause of health effects.
- In particular, the role of soot particles is of high importance as these particles are expected to be detrimental to human health .
- Diesel engines are known to emit high numbers of aerosol particles (especially soot).
- Fleet of low duty diesel engines is rapidly changing (EURO 2 – EURO 4) as well as the type of fuel (standard diesel – biodiesel blend) used.

OBJECTIVE

- Investigate particulate emissions from different low duty diesel engines (EURO 2 and EURO 4) in dependence on the use of fuel (standard petrochemical reference diesel - 20% (B20) and 100% (B100) biodiesel – based on either animal fat (AFME) or rapeseed oil (RME)) in a lab experiment.



Laboratory set up at the Danish Technical Institute.

METHODS

All emissions were investigated by running the engines at different operational modes simulating various driving conditions according to ISO/EN 8178.

GAS PHASE MEASUREMENTS

- NO, NO_2, CO, CO_2, and total organic volatile compounds (TVOC)

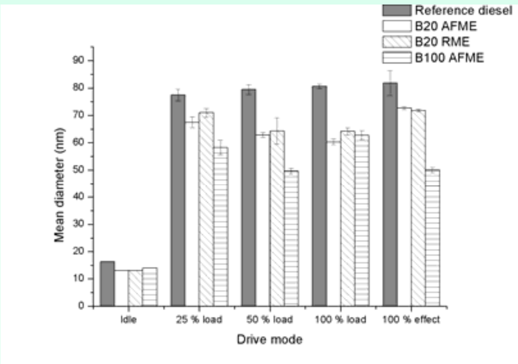
  were measured in the raw gas exhaust.

PARTICLE PHASE MEASUREMENTS

- Carbonyls, particle-bound polycyclic aromatic hydrocarbons (PAH), Elemental carbon (EC) / Organic carbon (OC)

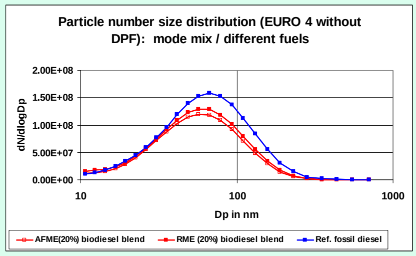
  were sampled from the dilution tunnel (dilution ratio 1:10) connected to the raw gas exhaust.
- Particle number size distributions (DMPS/SMPS with size range between 10 – 700 / 6 - 650 nm)

  were measured downstream of a rotating disc diluter (variable dilution: 15-300 times) connected to the raw gas exhaust.



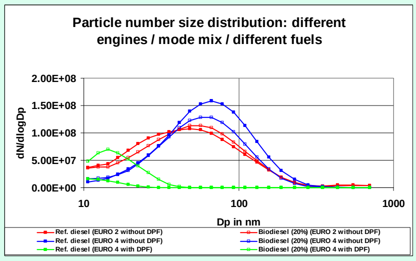
RESULTS

Mean diameter of particle number size distribution tends to decrease with increasing fraction of biodiesel used.



RESULTS

Mean diameter of size distribution, particle number and mass decrease, when 20% (B20) biodiesel is used compared to the standard petrochemical (reference) diesel.

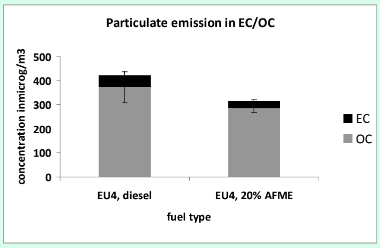


RESULTS

Mean diameter of size distribution, particle number and mass increases for EURO 4 engine compared to EURO 2 engine.

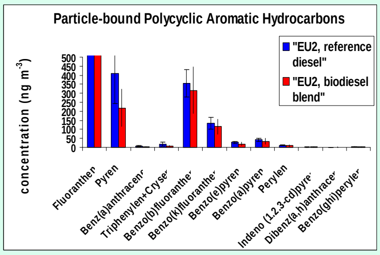
RESULTS

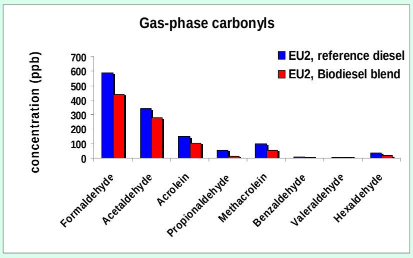
Total carbonaceous volume concentrations and EC/OC ratio emitted from the EURO 4 engine (without DPF) decrease, when 20% (B20) biodiesel is used compared to standard petrochemical (reference) diesel.



RESULTS

Masses of PAHs emitted from the EURO 2 engine are 11 to 56% lower, when the engine is fuelled with 20% (B20) biodiesel compared to standard petrochemical (reference) diesel.





RESULTS

Gas-phase carbonyl concentrations show a tendency to decrease, when 20% (B20) biodiesel is used compared to standard petrochemical (reference) diesel.

SUMMARY

- Substantial differences in submicrometer particle number, volume and mass mass were found in dependence on used engine type (EURO 4 and EURO 2).
- Emissions from standard petrochemical (reference) diesel were compared to those from 20% (B20) biodiesel:
  - Particle mean diameter of number size distribution, number-, and volume concentration decreased
  - Gas-phase carbonyl concentrations decreased
  - Particle-bound PAH volume concentrations decreased

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