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Analysis of a new diesel soot generator with regard to particle size and number concentration

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Introduction

The influence of soot particles on climate and human health leads to a persistent tightening of European limit values for engine exhaust emissions. These regulations also promote the development of new techniques for measuring soot particle properties. This has to be supported by a manufacturer independent infrastructure for validation and calibration under metrological criteria like the traceability to SI units. The choice of a proper calibration aerosol plays an important role, as the function of the instruments is strongly influenced by chemical and morphological aerosol parameters. The calibration aerosol should resemble the particle characteristics of the emission source to avoid systematic deviations. The characteristics of engine exhaust particles, however, are known to depend on engine type, its operation conditions and in particular on engine fuel.

Reference type soot generators like diffusion flame burners based on propane combustion are considered suitable as soot aerosol source for calibration purposes because of their stable and reproducible soot generation properties. But several studies indicate significant differences between engine and propane flame soot particles with respect to agglomerate density and surface. A solution to minimize aerosol morphology and composition differences could be the use of a lab generated combustion of real diesel fuel which is realized by the newly developed Diesel-miniCAST (Model 5201 Type D, Jing Aerosol Ltd.) based on a premixed flame matrix.

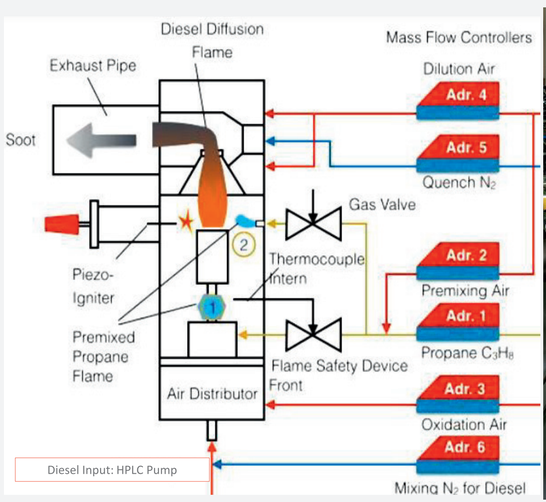
Current Setup of Diesel Soot Generator

Working Principle

- Diesel fuel evaporates by heating with premixed propane flame sideways of the actual diesel flame
- The combustion of the diesel vapor allows to build a soot generating diffusion flame.
- The top of the flame stands out of the burning chamber into a transverse zone for quenching → nitrogen stops further combustion processes

Setup

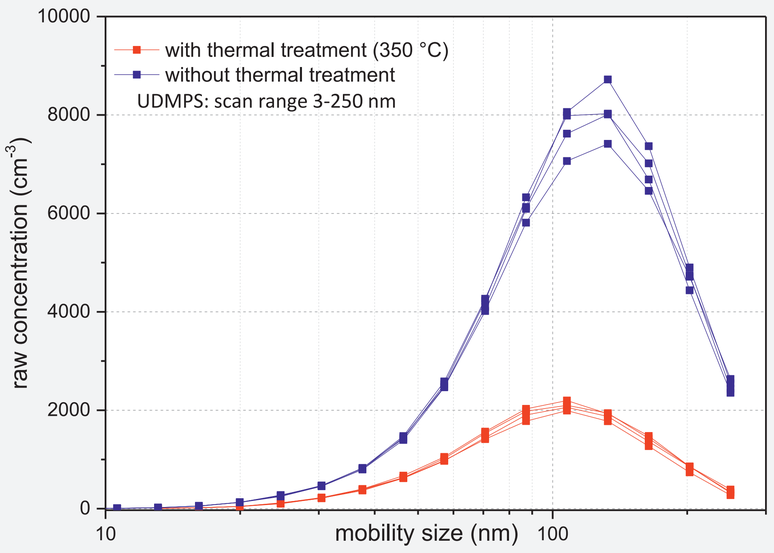
- HPLC Pump: stable fuel supply in the microliter range
- Diesel fuel: EN590 standard (up to 7 % biodiesel)
- MFC controlled gas flows: 1x propane, 3x compressed air, 2x nitrogen
- Aerosol conditioning by thermo dilution (Thermodenuder, Topas) + 10x dilution (Injector Diluter, Palas) + UDMPS/SMPS



First results of Particle Number Size Distribution measurements

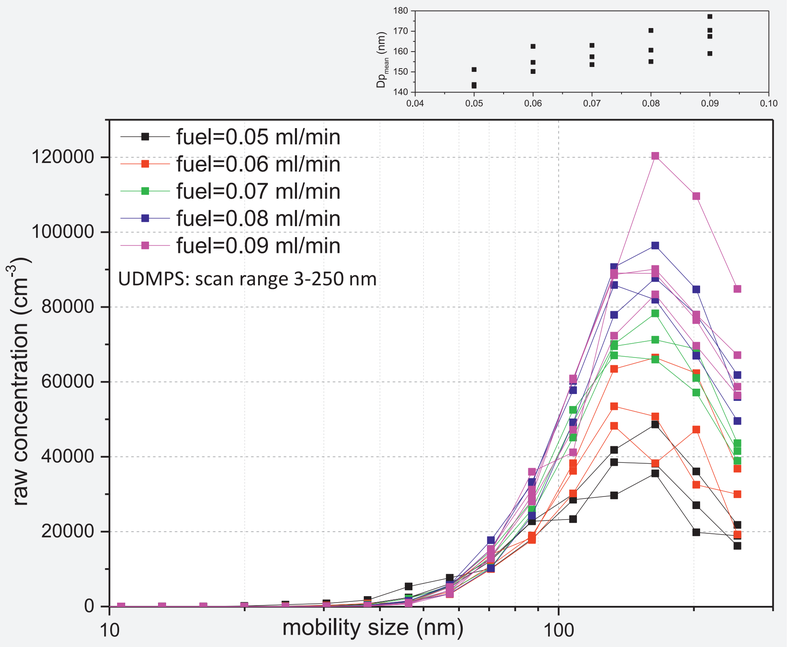
Influence of thermal treatment on the diesel soot aerosol

- C_3H_8: 30 ml/min, Dilution Air: 20 l/min, Premixed N_2: 10 ml/min + Thermodenuder (350 °C)
- Heating of the diesel soot aerosol leads to higher evaporation of volatile components and reduction of particle concentration than expected.



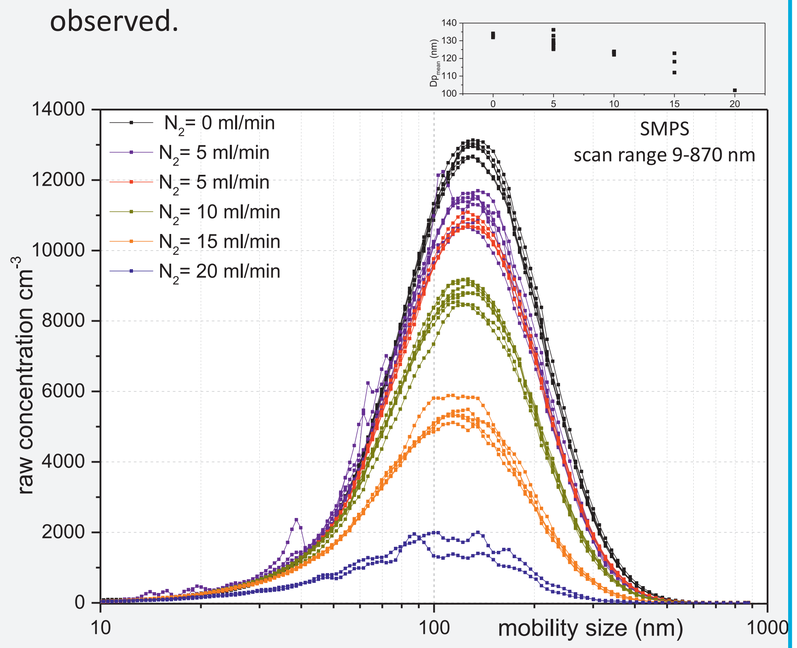
Influence of diesel fuel quantity on the PNSD

- C_3H_8: 30 ml/min, Dilution Air: 60 l/min, Premixed N_2: 5 ml/min
- Higher amount of fuel leads to significant increase in particle concentration and a moderate increase of particle size.



Influence of Premixed Nitrogen

- C_3H_8: 30 ml/min, Dilution Air: 20 l/min, Fuel: 0.05 ml/min + tenfold dilution
- Mixing of diesel fuel with nitrogen leads to a lower particle number concentration.
- Up to now only a small shift in particle size from 135 nm to 110 nm at high premixed nitrogen was observed.



Conclusion and Outlook

First results of the Diesel-miniCAST characterization by variations of the diesel supply, premixed N_2 inside the burner as well as the influence of thermal treatment on the soot particles were presented. The measurements of PNSD with SMPS and UDMPS showed a range of mean particle diameters from 100 to 140 nm with number concentrations up to 2×10^5 cm^{-3}.

Midterm goals

- Modification of the generator´s burning chamber in cooperation with the manufacturer to optimize a stable soot particle production.
- Comprehensive tests of the gas and diesel flow settings resulting in different particle sizes focused in a range of 50 to 200 nm with sufficient number concentrations (> 10^5 cm^{-3}).
- Determination of stable and reproducible operation points of the generator.
- Analysis of the diesel soot aerosol with regard to morphology and carbon content .
- Processing of the diesel soot aerosol to increase the comparability to exhaust emissions of diesel engines.

Overall goal

- Development of a metrological diesel based soot aerosol transfer standard for the calibration of instruments used for particle number concentration measurements.
- Establishment a secondary calibration aerosol for the calibration of particle counters and classifiers at the PTB, the German Metrology Institute.

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