Reactivity of Particles from Gasoline Direct Injection Engine: Correlation of Engine Parameters and Particle Characteristics

S. Koch1, F. P. Hagen2, H. Kubach1, A. Velji1, T. Koch1, H. Bockhorn2, A. Loukou2, D. Trimis2

*sergej.koch@kit.edu **fabian.hagen@kit.edu

Motivation and Goals

- Due to the increasingly stringent emission legislation, the development of gasoline engines aims at the reduction of particulate emissions by application of particulate filters.
- The regeneration behaviour of Gasoline Particulate Filter (GPF) is determined by reactivity and properties of captured soot.
- To reduce the regeneration temperature, technical effort in exhaust gas aftertreatment and consequently CO₂ emissions during active regeneration of GPF the control of the burn-out of particles within GPF has an enormous significance.
- Aim of the study: Control of the soot reactivity by engine parameters and the enhancement by the optimization of these parameters.

Engine Test Bench at IFKM

- Turbocharged 4 cylinder research GDI engine (2.0 liters)
- Indication system
- Optical access
- Particle measurements with
  - "Engine Exhaust Particle Sizer (EEPS)"
  - "Smoke Meter"
  - "Particulate Sampling System (PSS 20")
- for temperature programmed oxidation

Methods

- Characterization of soot particle properties by variation of single engine parameters in stationary operating points
  - I. Investigation of particle properties
    - Variation Start of Injection (SOI) and soot sampling
    - 1: Conditioning of Quartz Fiber filters
    - 2: Soot Sampling
    - 3: Characterization of soot properties
  - II. Soot reactivity
    - Oxidation rates of different soot samples were investigated through temperature programmed oxidation (TPO) by employing thermogravimetric analysis (TGA).
    - The temperature at maximum oxidation rate (T_{max}) is widely used to indicate soot reactivity towards oxidation.
    - Dynamic, non-isothermal measurements were performed using a heating rate of 5 K·min⁻¹ and a gas atmosphere consisting of 5 %vol O₂ and 95 %vol N₂.
  - III. Carbon nanostructure
    - Carbon nanostructure affects the energy level of C-atoms accessible for oxidation and therefore soot reactivity.
      - Amorphous, disordered graphene layers increase soot reactivity.
      - Small primary particles increase specific surface and increase in soot reactivity.
      - Ordered and expanded graphene layers cause low soot reactivity.
      - Increasing primary particle diameter decrease soot reactivity.

Conclusions

- The results show a high correlation of homogenization of mixture formation and soot reactivity indicated by T_{max}.
- Good mixture formation enhances soot reactivity towards oxidation.
- By knowing property-reactivity relations, the oxidation of particulates within the GPF can be enhanced and controlled via the operation conditions of the engine.

Acknowledgements

- The authors gratefully acknowledge the financial support by Deutsche Forschungsgemeinschaft (DFG).