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

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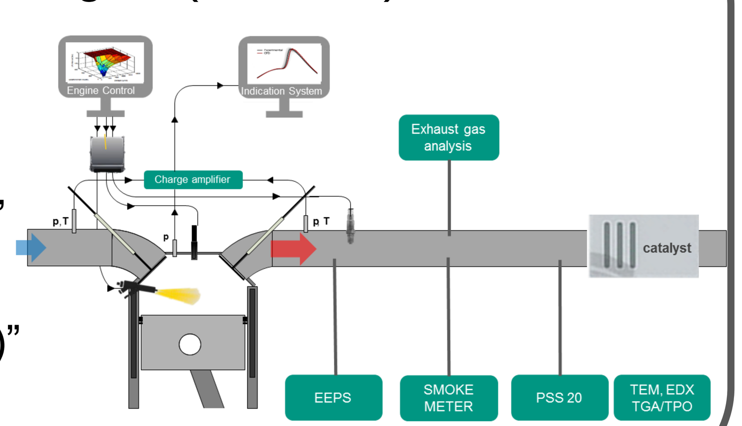
Motivation and Goals

- 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 CO_2 emissions during active regeneration of GPF the control of the burn-out of particles within GPF has a 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

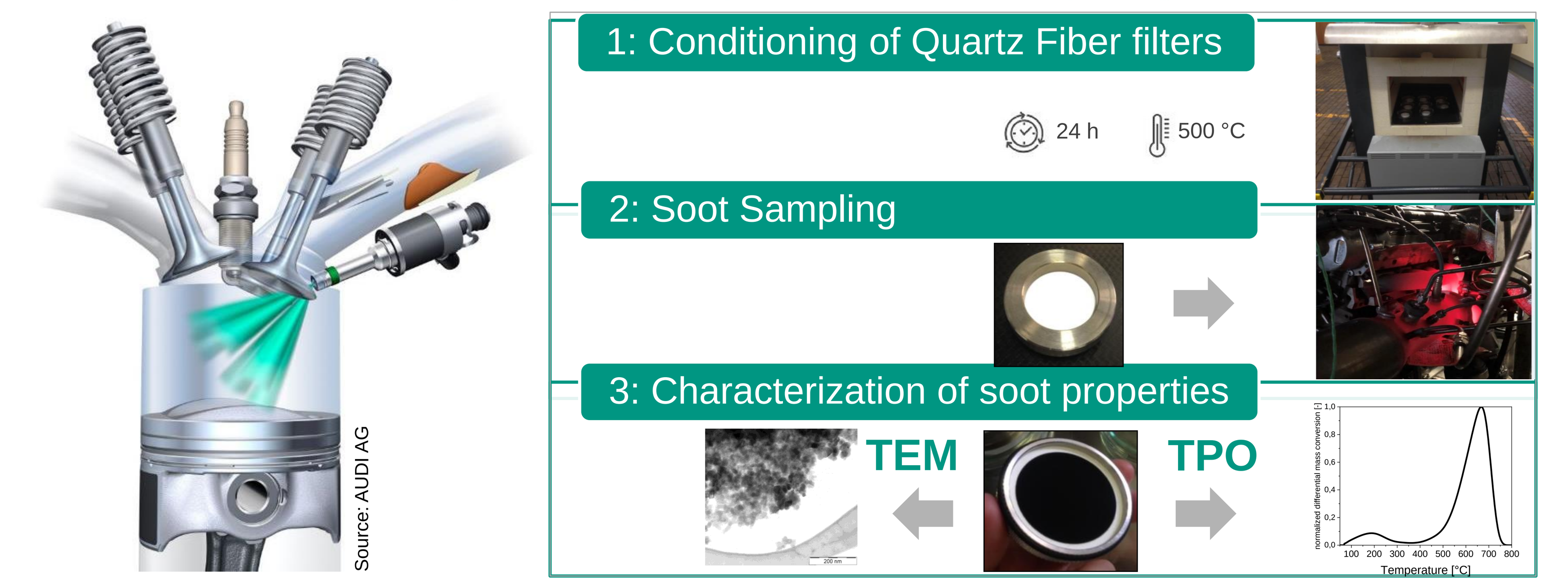


Methods

- Characterization of soot particle properties by variation of single engine parameters in stationary operating points

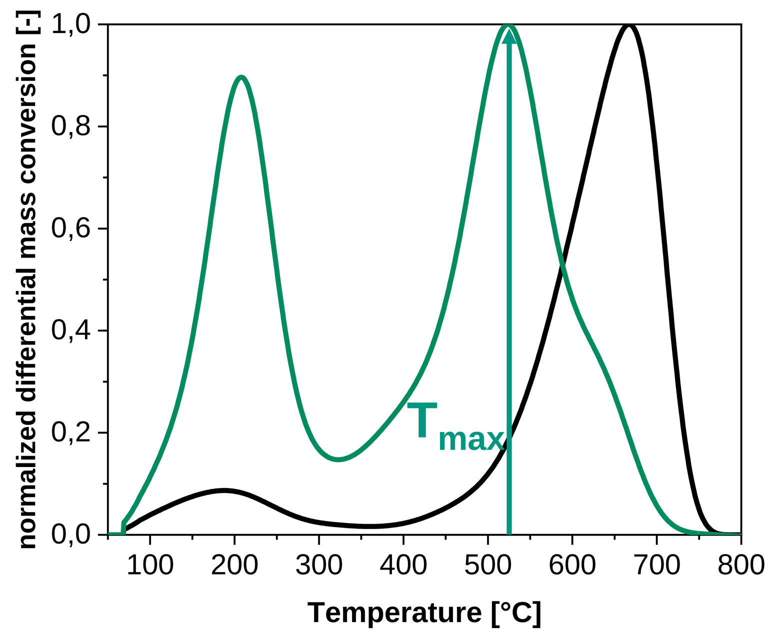
I. Investigation of particle properties

- Variation **Start of Injection (SOI)** and **soot sampling**



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 O_2 and 95 %vol N_2.



Soot Sample 1: T_{max}= 520°C
- ➢ high soot reactivity
- ➢ low regeneration temperature T_{GPF}= 520°C
- ➢ low CO_2 emissions

Soot Sample 2: T_{max}= 667°C
- ➢ low soot reactivity
- ➢ high regeneration temperature
- ➢ high CO_2 emissions

III. Carbon Nanostructure analysis

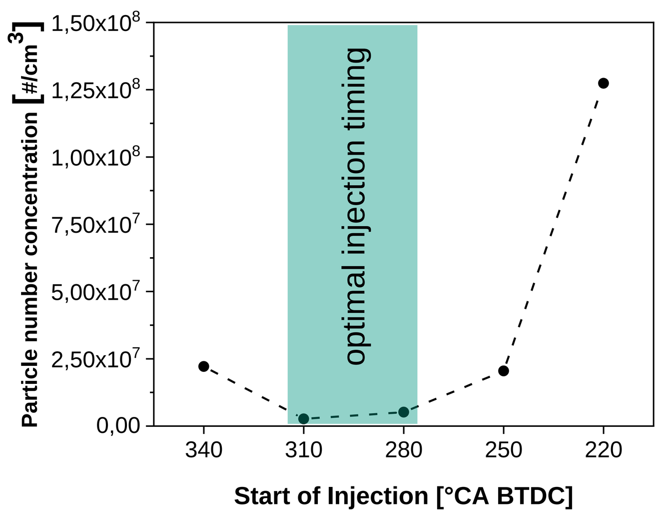
- **H**igh-**R**esolution **T**ransmission **E**lectron **M**icroscopy (HRTEM) and image analysis algorithm to study carbon nanostructure (length, curvature and seperation distance of graphene layers) within primary soot parcticles.

Results

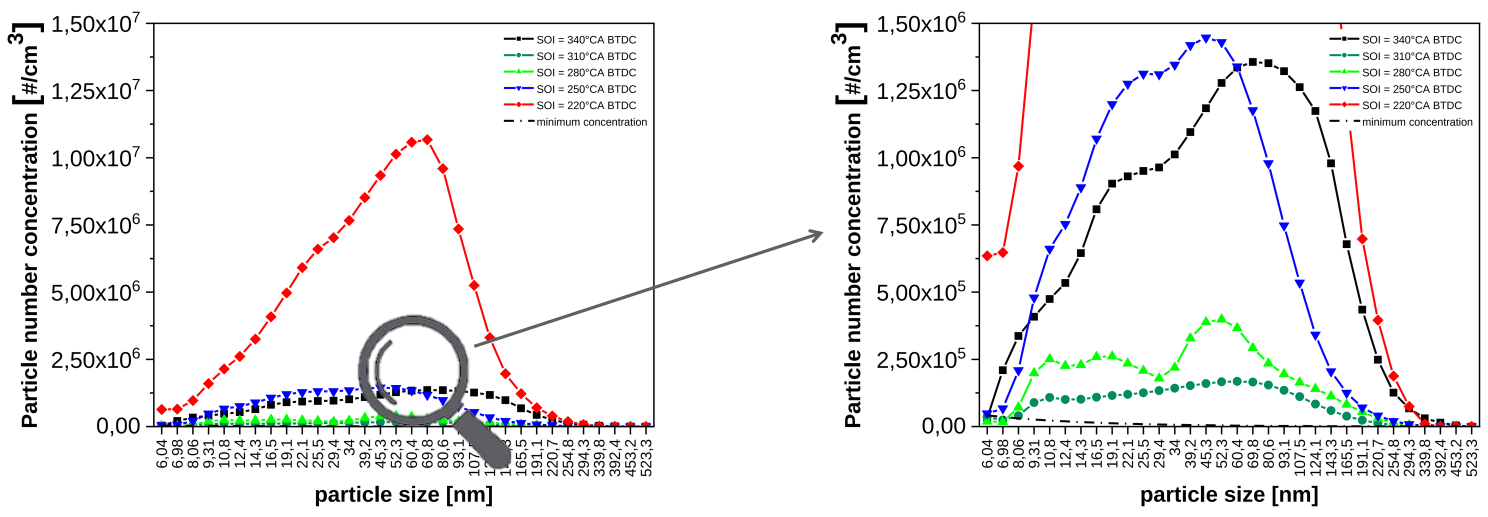
Impact of Start of Injection (SOI) on particle characteristics

Engine parameters SOI= 340 – 220°CA BTDC
n = 2000 min -1 BMEP = 8 bar ST = 26,25°CA BTDC pRail = 100 bar

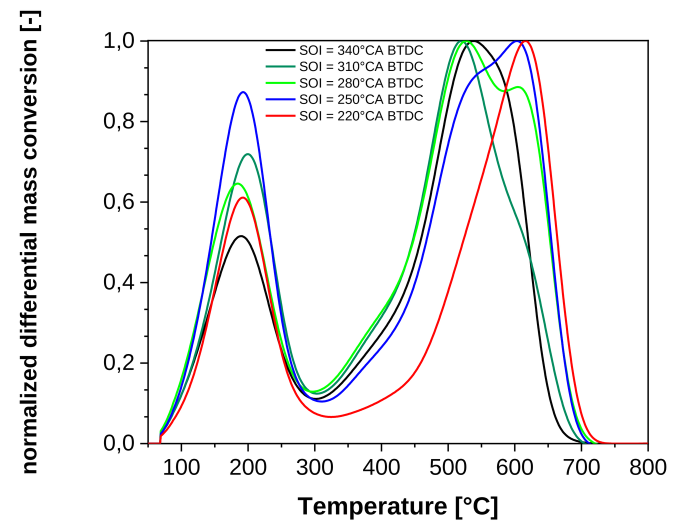
I. Particle number concentration and size distribution

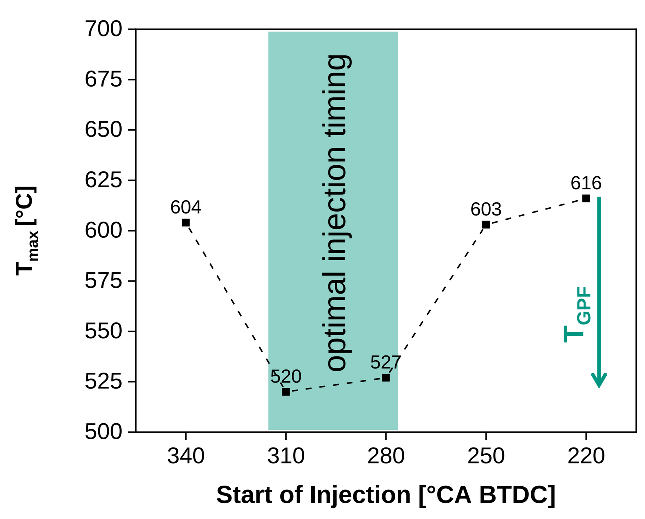


- Particle number concentration and size distribution is determined by quality of the mixture formation.
- A decreasing soot aggregate diameter causes an increased soot reactivity, which is most likely due to the increased specific surface area.



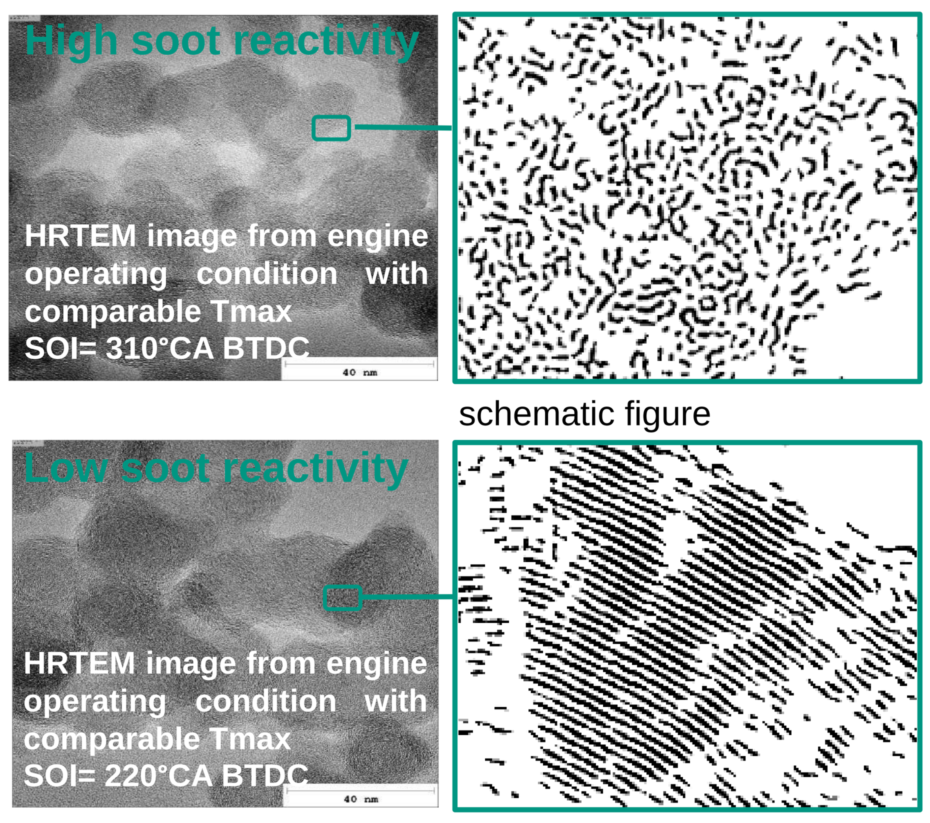
II. Soot reactivity





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
- → 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

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