Influence of engine operating parameters on PM size, structure and reactivity

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BACKGROUND

- Necessity of diesel particulate filters (DPF) due to protection of environmental and human health [1,2]
- Soot collection in DPF results in higher fuel consumption and loss of engine power [3]
- Regeneration behavior of diesel particulate filter is determined by the properties of the collected soot [4,5]

➡ **Targeted manipulation of soot oxidation behavior by means of modification of soot properties using different engine parameters**

➡ **Development of a correlation between reactivity and measurement equipment**

EXPERIMENTAL SETUP

Characteristics of the engine

Manufacturer, Type	Daimler, OM 651
Capacity	2143 cm³
Rated RPM	4200 min^{-1}
Rated power	150 kW
Model	4 Cylinder in line
Injection system	Common Rail
Injection pump	Delphi Piezo
Supercharging	2-stage turbo
Emission standard	Euro 5

Engine operating parameters

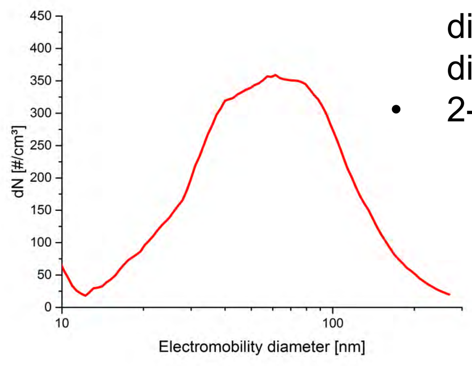
- 1000 rpm, 25% pedal position
- SOI = -6 °BTDC, EGR = 0 %
- Variation of injection pressure and boost pressure
- Soot sampling from diesel exhaust after oxidation catalyst
- Steady state tests
- Use of B7 diesel fuel (DIN EN 590)

CHARACTERIZATION METHODS

Pegasor PPS-M

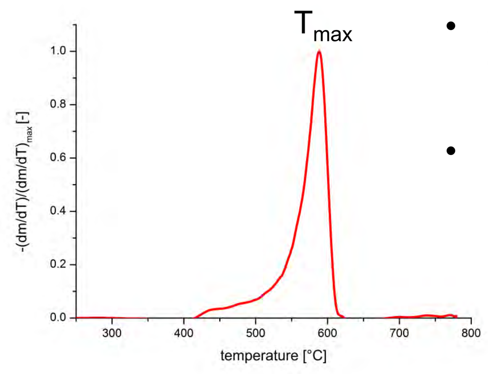
- Measuring of current caused by electrified particles
- Correlation to particle mass

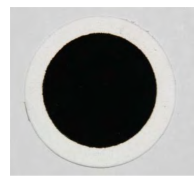
Scanning Mobility Particle Sizer (SMPS)



- Particle size distribution by different electrical mobility diameter
- 2-stage dilution

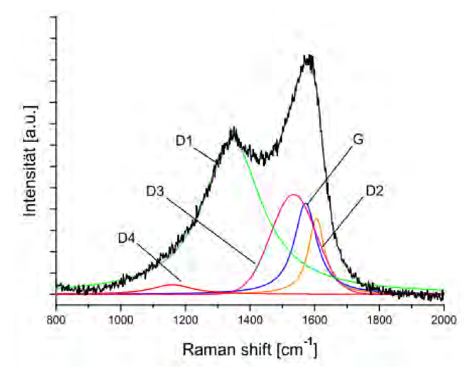
Thermogravimetric Analysis (TGA)





- Soot reactivity
- 5 % Oxygen
  95 % Nitrogen
  Heating rate 5 °C/min
- Determination of T_{max}

Raman Spectroscopy



- Raman-spectra of soot show D- and G-band
- 5-Band-fit after Sadezky et al. [7]
- Structural changes of amorphous and graphitic components
- Analysis of D1-FWHM, I_D/I_G, rel. D3-Intensity(= $\frac{D3}{D3+D2+G}$)

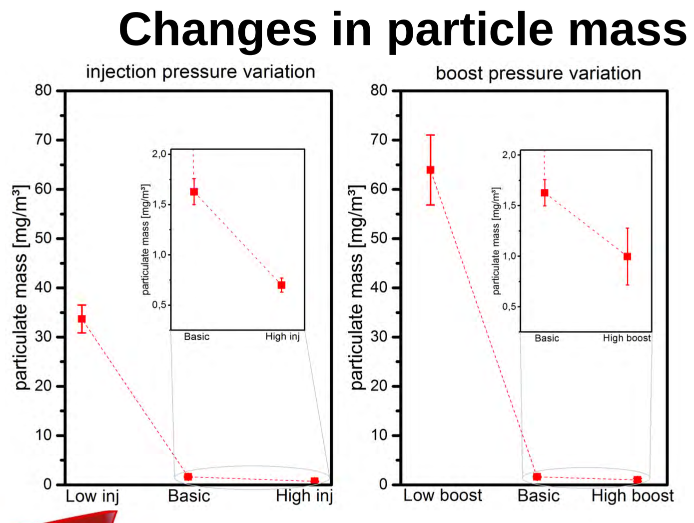
RESULTS

Engine performance and TGA results in consequence of different engine operating parameters

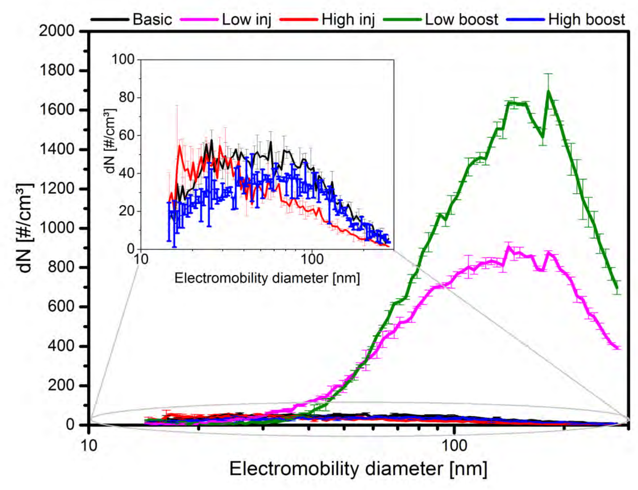
	Operating parameters		Engine torque [Nm]	relative BSFC	relative NO_x	λ	TGA T_{max} [°C] [6]
Basic	p_{inj}=620 bar	p_{boost}=1,33 bar	176	1	1	1,38	588
Low inj	**p_{inj}=300 bar**	p_{boost}=1,33 bar	170	-3,5 %	-32 %	1,32	673
High inj	**p_{inj}=1000 bar**	p_{boost}=1,33 bar	172	+0,9 %	+51 %	1,42	525
Low boost	p_{inj}=620 bar	**p_{boost}=1,1 bar**	157	+15 %	-21 %	1,14	690
High boost	p_{inj}=620 bar	**p_{boost}=1,45 bar**	180	-2,2 %	+14 %	1,48	531

- *Low boost* pressure results in significant reduction of engine torque and increase of break specific fuel consumption compared to *Basic* operation
- *Low boost and injection* pressure: ➡ reduction of NO_x emissions and lambda ➡ low soot reactivity
- *High boost and injection* pressure: ➡ higher NO_x emissions and lambda ➡ high soot reactivity

Changes in particle mass and particle size distribution [6]



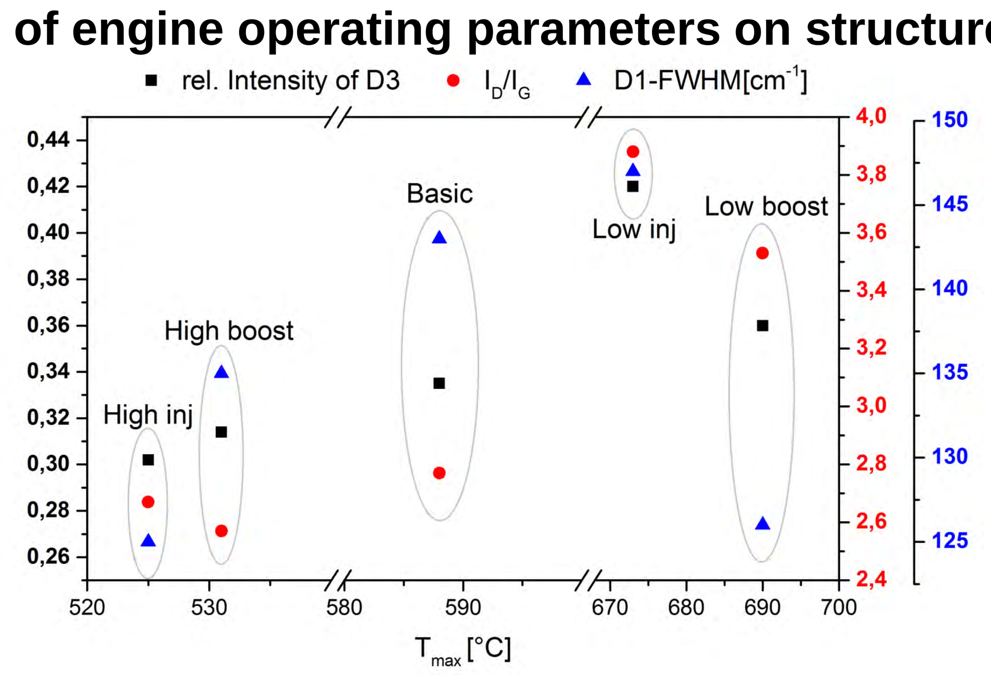
Particle mass with Pegasor PPS-M



Particle distribution with SMPS

- *Low boost and injection* pressure emits more and larger particles with drastic increase of soot mass emissions
- *High boost and injection* pressure show only small decrease of soot mass emissions, compared to *Basic* application
- *High injection* pressure emits less and smaller particles compared to *Basic* application
- *High boost* pressure shows a decrease in number but quite the same mean diameter as *Basic*

Influence of engine operating parameters on structure of particles



- Structural differences by using different engine operating parameters
- No clear correlation between results from different analysis methods and reactivity
- Soot samples with high reactivity have smaller rel. D3-intensity and I_D/I_G ratio
  → less amorphous components but higher reactivity of *High boost and injection* pressure
- *Low injection and boost* pressure show higher rel. D3-intensity and I_D/I_G ratio
  → more amorphous components but lower reactivity
- D1-FWHM decreases with increasing reactivity with the exception of *Low boost*

CONCLUSIONS

- Engine operating parameters have huge influence on particle mass, size, structure and therefore reactivity
- Trade-off between soot, NO_x and fuel consumption
- Raman spectroscopy as a useful tool for analysis of soot structure but further investigations for meaningful results are necessary

FUTURE RESEARCH

- Detailed optical analysis of soot trapped in diesel particulate filters using microscopic tools and Raman spectroscopy
- Further investigations on influence of different space velocities, temperatures and engine operating parameters on characteristics of trapped soot
- Investigation of oxygen functional groups
- BET analysis for investigation of surface area

References

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