Influence of engine operating conditions on soot loading and regeneration behavior of diesel particulate filters

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BACKGROUND

- Regeneration of diesel particulate filters (DPF) is necessary to avoid engine damages
- PM oxidation should lead to a regeneration process that minimizes fuel penalty, avoid high temperature peaks and gradients inside DPF by maintaining a high regeneration efficiency
- Lack of knowledge about thermal control of DPF regenerations and the variety of influencing factors

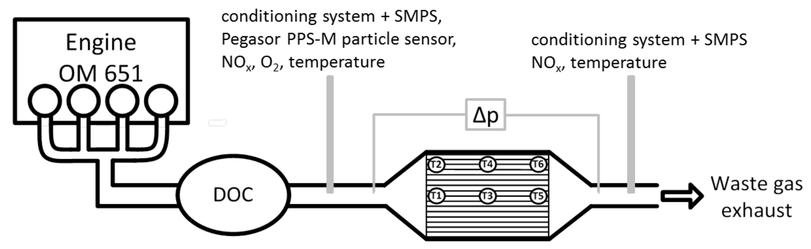
How do different engine operating conditions influence DPF loading and regeneration behavior?

EXPERIMENTAL SETUP

Engine characteristics

Manufacturer, Type	Daimler, OM 651
Capacity	2143 cm³, 4 cyl.
Rated RPM	4200 min^{-1}
Rated power	150 kW
Injection pump	Delphi Piezo
Emission standard	Euro 5

- Engine control via open ECU and INCA software from ETAS GmbH
- SMPS from TSI Inc. (EC 3080, CPC 3022)
- Particle Sensor PPS-M from Pegasor Oy (Ltd)



Material	Uncoated SiC
Volume	5,66” x 6”
Cell density	300 CPSI

EXPERIMENTAL APPROACH

Sequential steps of the investigation

pretreatment
- cleaning of DPF with compressed air
- 600 °C for 30 minutes in muffle furnace
- determination of initial weight

loading
- 10 minutes warm-up
- loading with stationary engine mode (see table right aside)

weighing
- hot weighing
- DPF loading up to 8 g/l

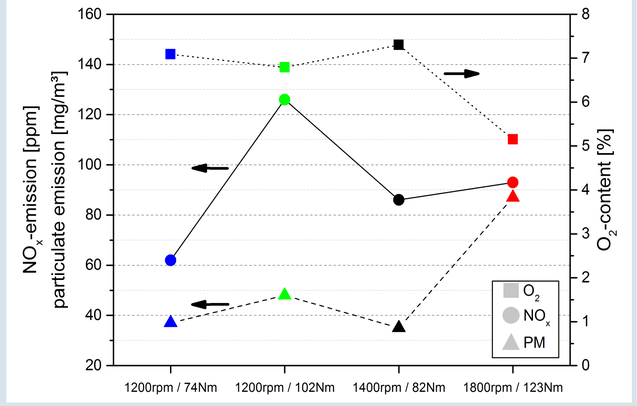
regeneration
- engine warm-up
- DPF regeneration with 1500 rpm and 63 Nm via post-injection

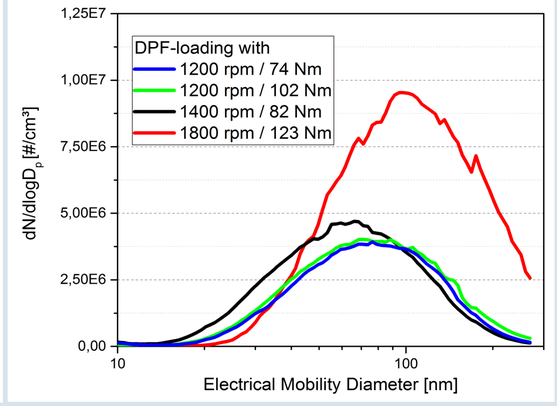
Conditions of stationary engine modes

	engine speed [rpm]	load [Nm]	exhaust flow rate [kg/h]	exhaust air-fuel-ratio [-]	O_2 [%]	Temperature before DPF [°C]	Final soot loading [g]
loading conditions	1200	74	53	22,5	7,1	235-248	18,9
	1200	102	67	22,1	6,8	261-279	19,9
	1400	82	68	22,8	7,2	255-266	18,9
	1800	123	116	19,5	5,2	321-328	20,2
regeneration conditions	1500	63	106	20,0	5,5	600-612	---

RESULTS

DPF loading

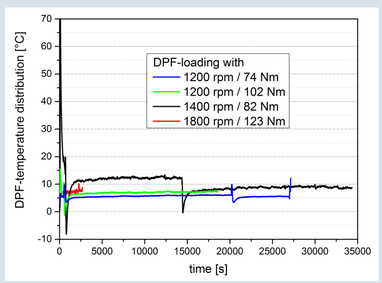




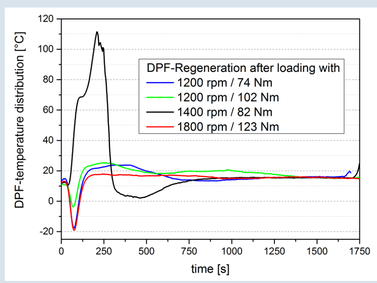
- Engine modes with 1200 rpm do not differ crucially in O_2-content, PM and particle size distribution
- 1400 rpm / 82 Nm: higher amount of small particles
- 1800 rpm / 123 Nm: higher amount of PM with larger particle diameter and lowest O_2-content in the exhaust

Internal DPF temperature distribution

loading

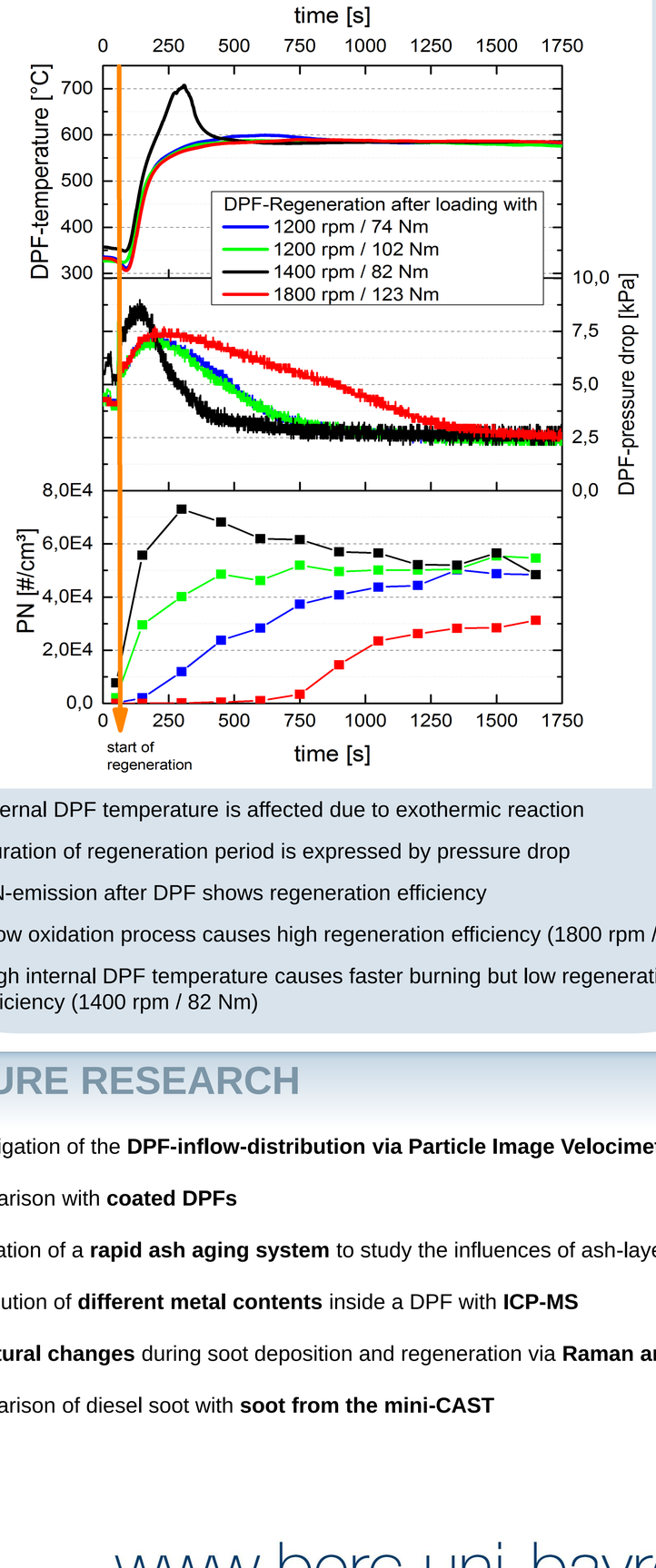


regeneration

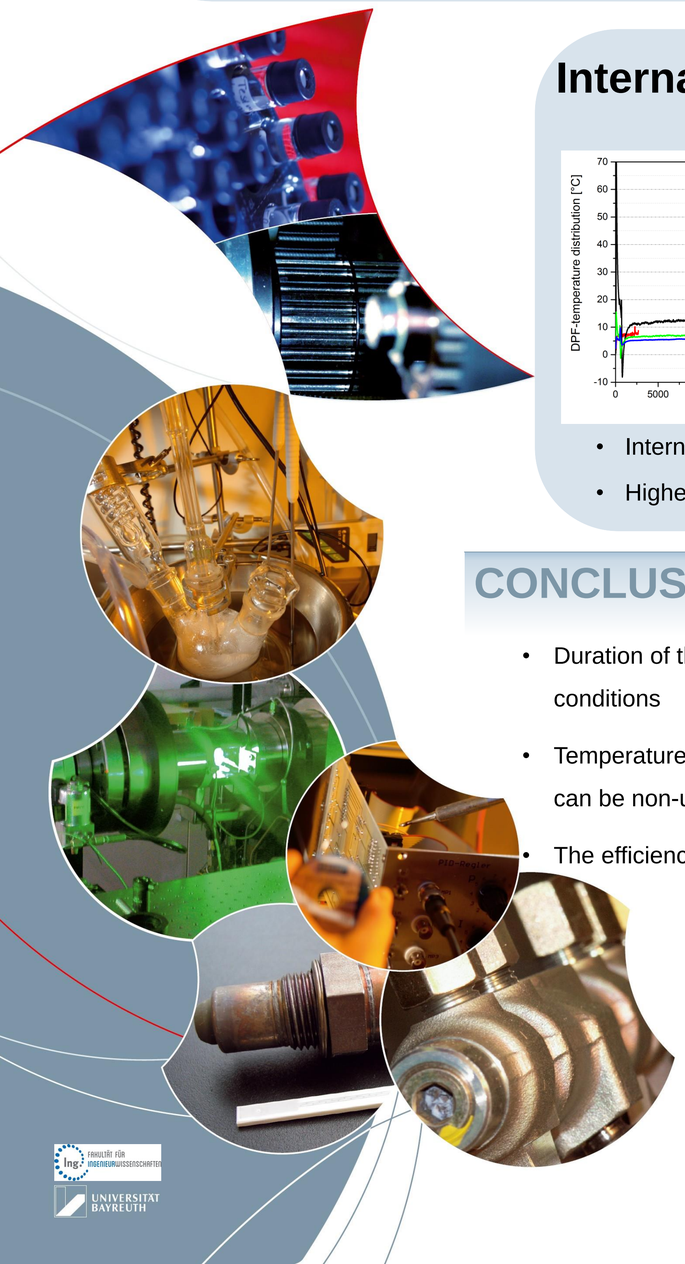


- Internal DPF temperature is nearly uniform during loading
- Higher temperature gradients in the DPF during regeneration

DPF regeneration



- Internal DPF temperature is affected due to exothermic reaction
- Duration of regeneration period is expressed by pressure drop
- PN-emission after DPF shows regeneration efficiency
- Slow oxidation process causes high regeneration efficiency (1800 rpm / 123 Nm)
- High internal DPF temperature causes faster burning but low regeneration efficiency (1400 rpm / 82 Nm)



CONCLUSIONS

- Duration of the regeneration is highly affected by the different loading conditions
- Temperature distribution inside the DPF is almost uniform during loading and can be non-uniform during regeneration with high local gradients
- The efficiency of the soot oxidation depends on soot loading conditions

FUTURE RESEARCH

- Investigation of the **DPF-inflow-distribution via Particle Image Velocimetry**
- Comparison with **coated DPFs**
- Integration of a **rapid ash aging system** to study the influences of ash-layers
- Distribution of **different metal contents** inside a DPF with **ICP-MS**
- **Structural changes** during soot deposition and regeneration via **Raman and HR-TEM**
- Comparison of diesel soot with **soot from the mini-CAST**

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