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Influence of different process parameters during the run-in procedure on the emission behaviour

TECHNISCHE UNIVERSITÄT ILMENAU
Fachgebiet Kraftfahrzeugtechnik

Department of automotive engineering
Prof. Klaus Augsburg
David Hesse, Toni Feißel

BMW Group
Ulrich Kuhn, Rasmus Leicht, Georg Eichner

1. Experimental setup
1.1 Measurement devices and sampling system

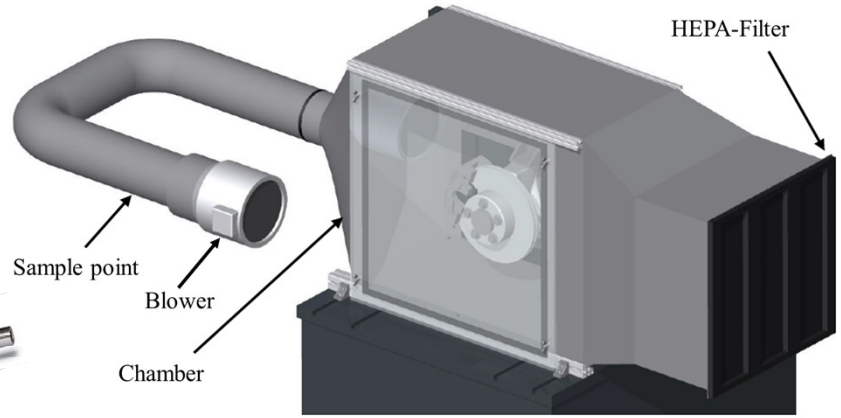
Measurement devices

HORIBA MEXA-2100SPCS
- CPC (10 - 2.500nm)
  - ➢ Measures PNC
- modified sub23nm-version
- Integrated vpr and catalytic stripper

TSI 3708
4-way splitter

Cambustion DMS500
- DMA (5 – 1.000nm)
  - ➢ Measures PSD
- Inversion matrix (calibration file): Bimodal

Sampling system

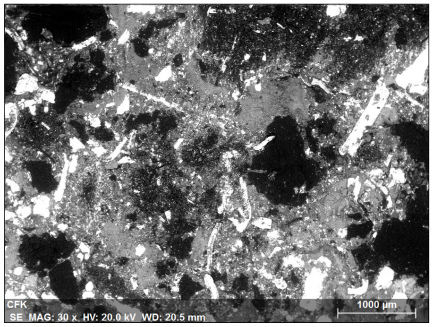


CVS-system (2nd Generation)
- Volume flow: 850m³/h
- High inlet efficiency
- Isokinetic-sampling (calc. probe diameter)
- decoupling from the environment (filter)
- Multi-measurement (flow-splitting)

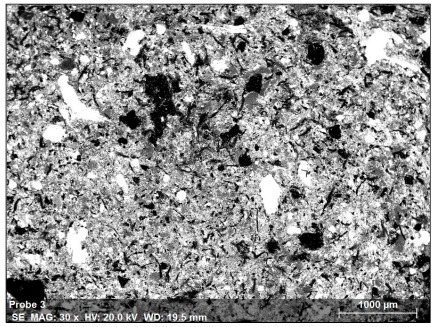
1. Experimental setup
1.2 Braking system

SEM images of the used friction materials

ECE



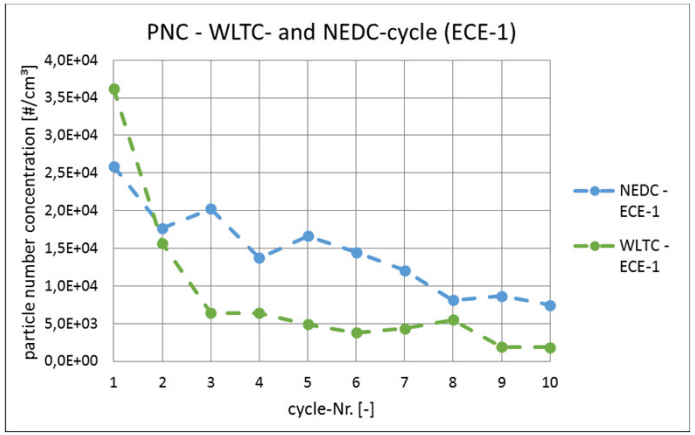
NAO



GEOMET® (front-axle brake - unused state)

- Anti-corrosion coating
  - ➢ **not the delivery state of the car**
- entry-level luxury car (floating caliper)

Typical **run-in behavior** over 10 test cycles



Conditions:

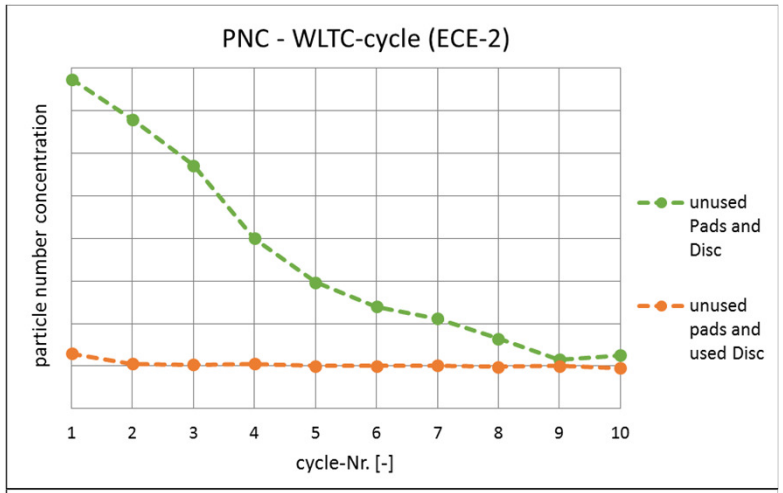
- Comparison of different test cycles (NEDC, WLTC) for ECE-friction material

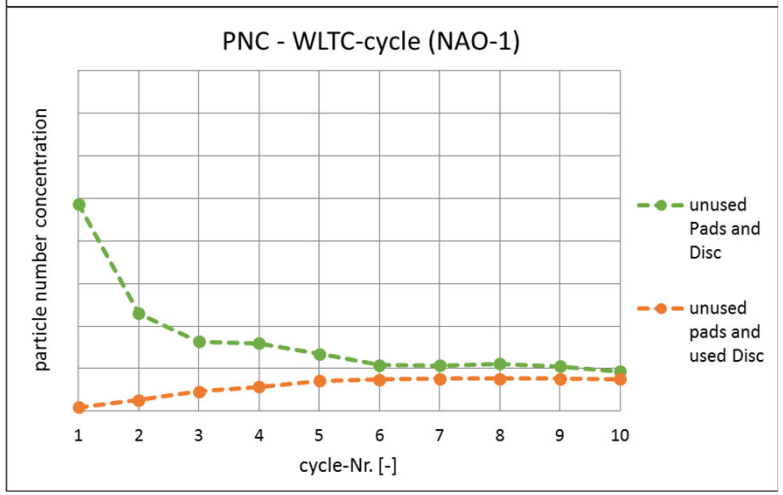
Results:

- Continuous decrease of the intensity over the number of cycles
- Intensity of conditioning has a direct influence on the run-in behavior
- No reproducible emission level after a number of 10 cycles

2. Run-in behavior - Introduction
2.2 Comparison of different initial states

GEOMET® coated disc vs. running disc





Conditions:

- Initial states (Brake system 2):
  1. Unused Pads and unused Disc
  2. Unused Pads and running Disc

Results:

- Unused Disc: Descent of the mean PNC
- Used Disc: Characteristic course depending on the friction material
  - ➢ Horizontal course of PNC for ECE-2
  - ➢ Increase course of PNC for NAO-1
- The curves converge in the direction of a comparable emission level (quasi-stationary state)

3. Influence of the preconditioning
3.1 Introduction

Features in the design of a test run-in procedure (PN-measurement)

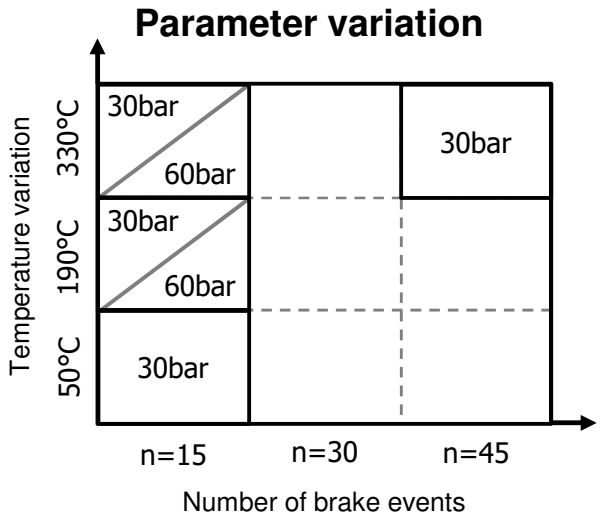
- Which condition of pad and disc should be aimed for at the beginning of a test cycle (reproducible emission level, coefficient of friction)
- Through which preconditioning a run-in state is achieved?
  - ➢ test cycles or brake events
- Which duration und number of repetitions are necessary to reach the initial state
- Which influence does the disc coating / coating composition have (duration, number of brake events)?
- Which influence does the composition of friction materials have (Duration, number of brake events)
- Influence of the background concentration on the measured emission level
  - ➢ Ensuring a reproducible background concentration

3. Influence of the preconditioning
3.2 Methodology

a. Parameter variation
temperature, brake pressure and number of brake events

Cooling period
Cooling time: 60min

b. reference procedure

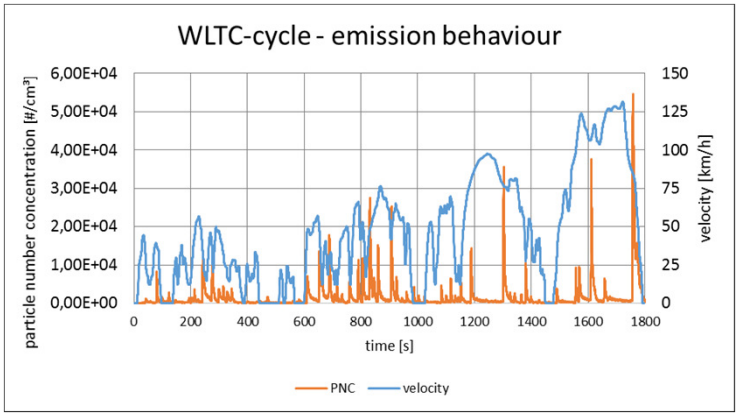


Test parameters:

1. 50°C, 30bar, n=15
2. 190°C, 30bar, n=15
3. 190°C, 60bar, n=15
4. 330°C, 30bar, n=15
5. 330°C, 30bar, n=45
6. 330°C, 60bar, n=15

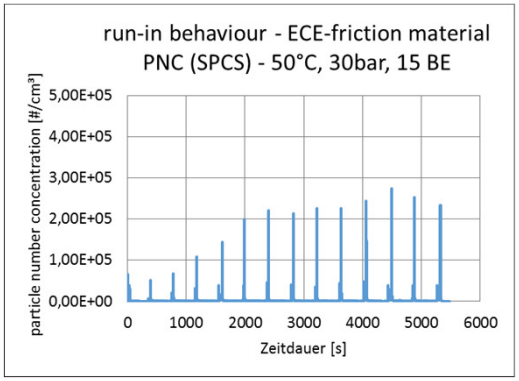
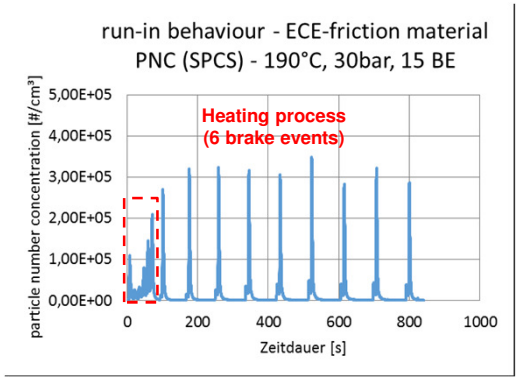
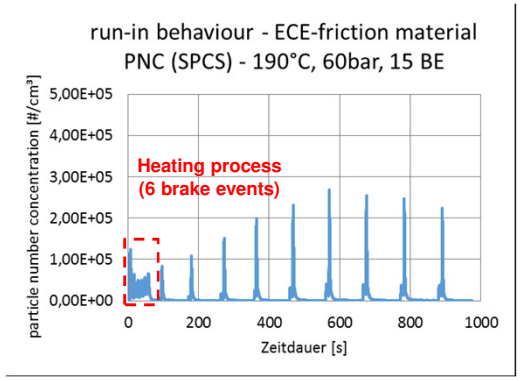
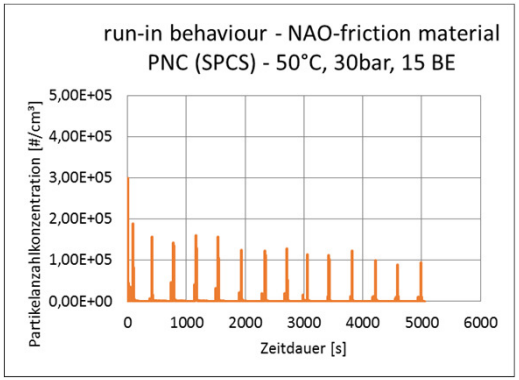
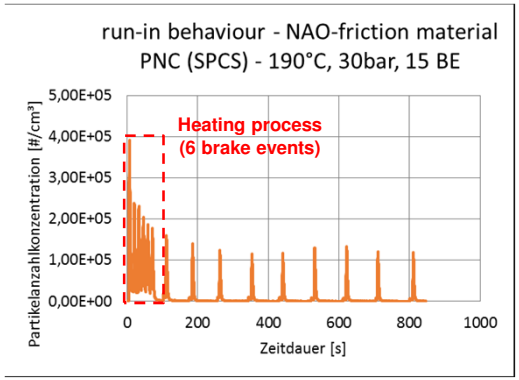
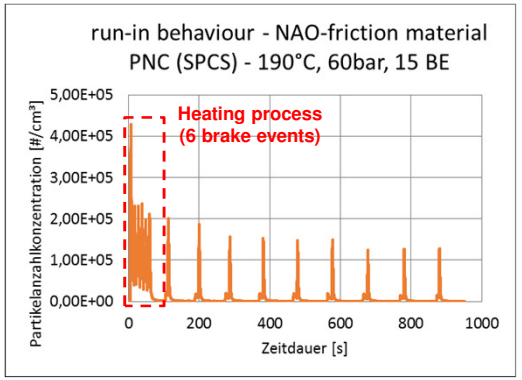
WLTC (global harmonized)

- Class 3 - high-power vehicles with PWr > 34 (kW/1000kg): 1.800s
- 48 brake events per cycle
- four driving speed-specific sections (Low, medium, high, extra high)



3. Influence of the preconditioning
3.3 Emission behaviour over the preconditioning

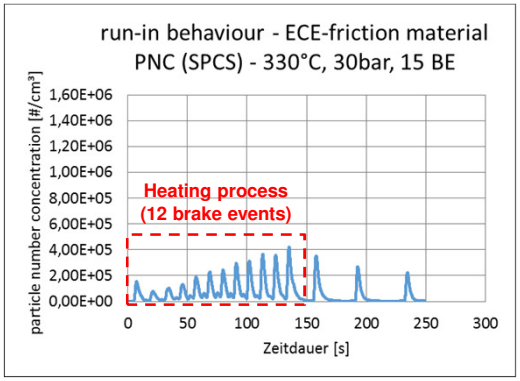
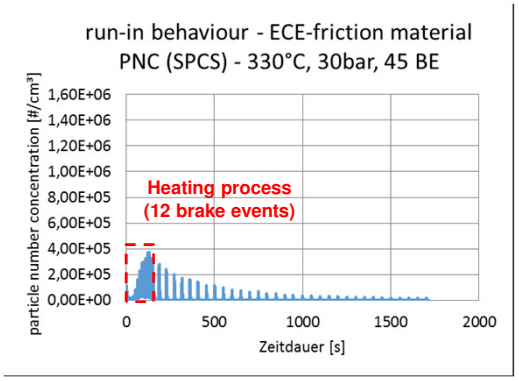
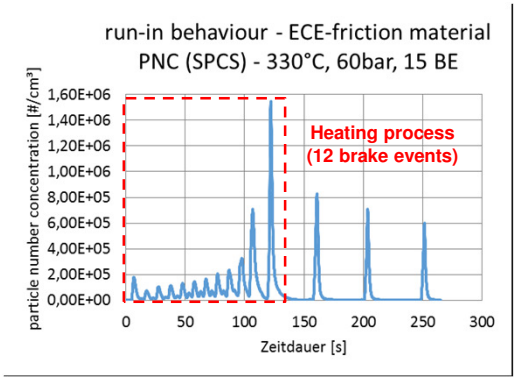
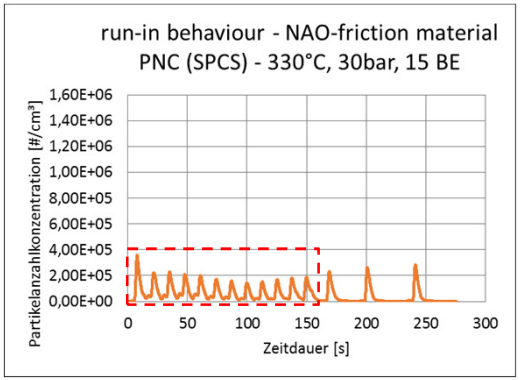
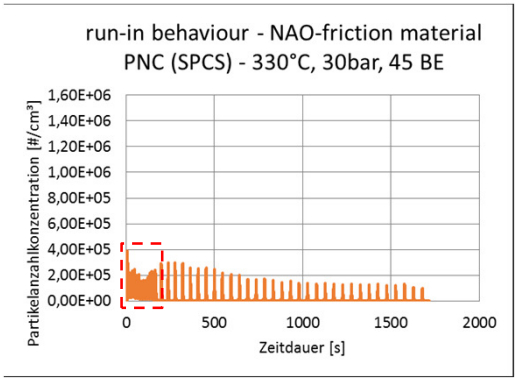
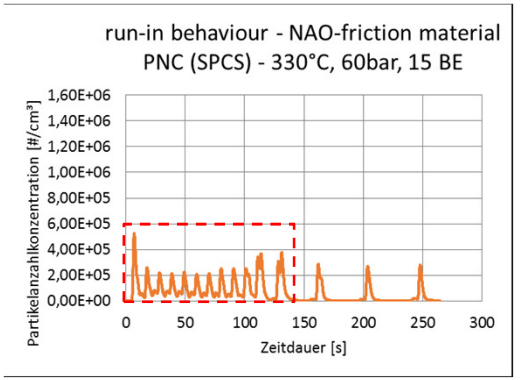
particle number concentration (PNC) – Horiba SPCS

	50°C, 30bar, 15 BE	190°C, 30bar, 15 BE	190°C, 60bar, 15 BE
ECE			
NAO			

- Cont. increase (PNC) with increasing number of brake events for ECE, decrease for NAO
- Higher emission level (max. peak) for NAO at the first brake event

3. Influence of the preconditioning
3.3 Emission behaviour over the preconditioning

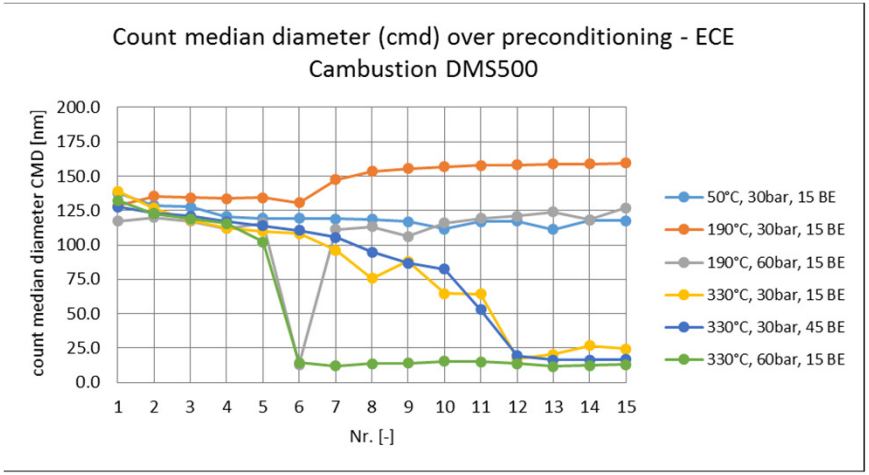
particle number concentration (PNC) – Horiba SPCS

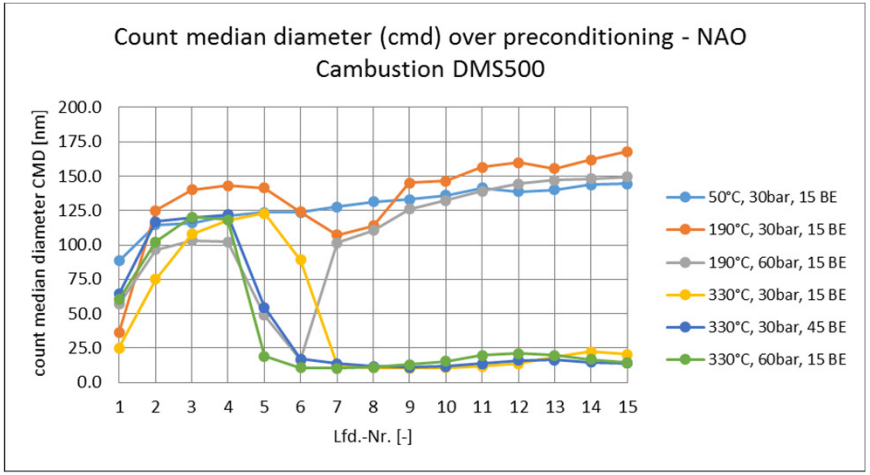
	330°C, 30bar, 15 BE	330°C, 30bar, 45 BE	330°C, 60bar, 15 BE
ECE			
NAO			

- Continuous increase in the intensity of PNC with increasing temperature for ECE (up to a higher level than the NAO), cont. decrease after reaching maximum concentration

3. Influence of the preconditioning
3.3 Emission behaviour over the preconditioning

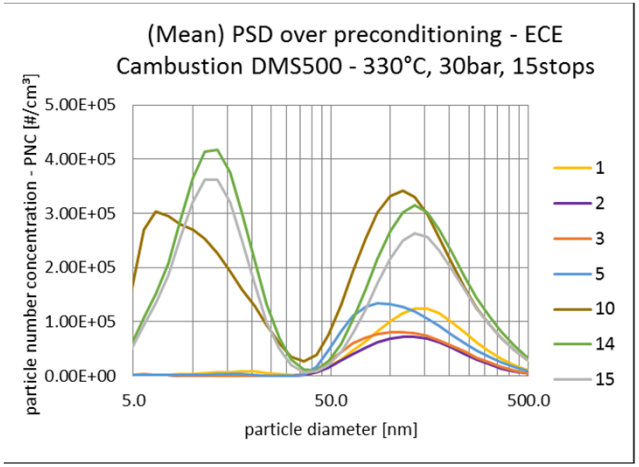
particle size distribution (PSD) – Cambustion DMS500





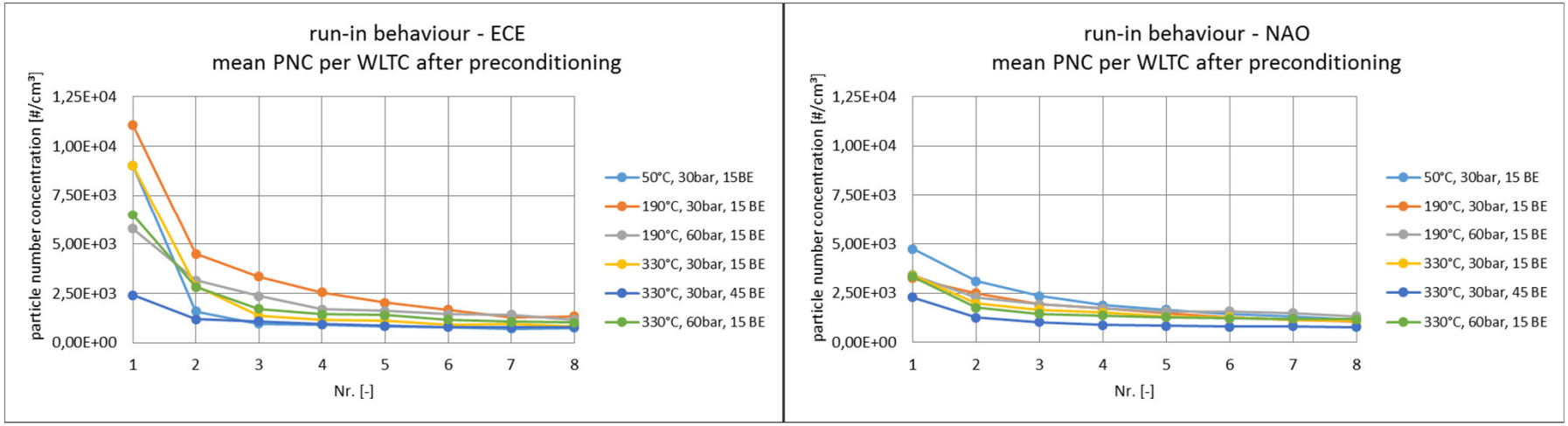
- Count median diameter (cmd) as reference – particle size range: 5 – 1.000nm (DMS500)
- Bimodal distribution for 330°C and 60bar-preconditioning - count mean diameter (cmd) reaching 15-25nm

➢ PSD as a function of therm. and mech. treatment



3. Influence of the preconditioning
3.4 Reference procedure (WLTC)

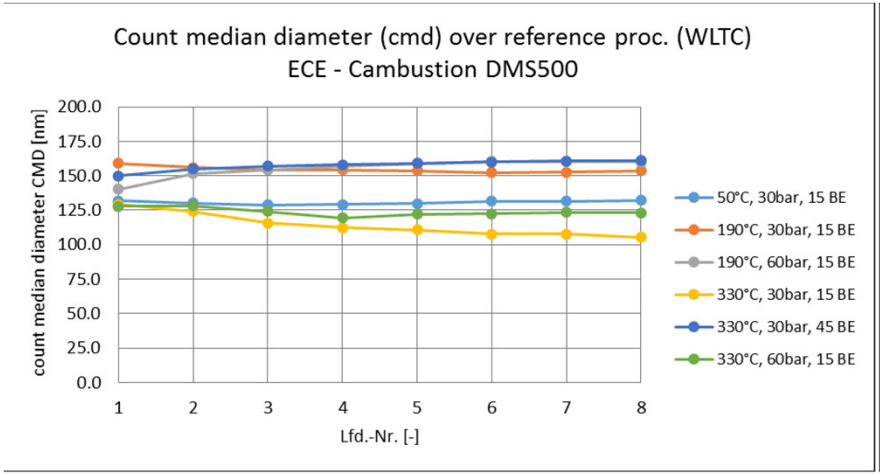
particle number concentration (PNC) – Horiba SPCS

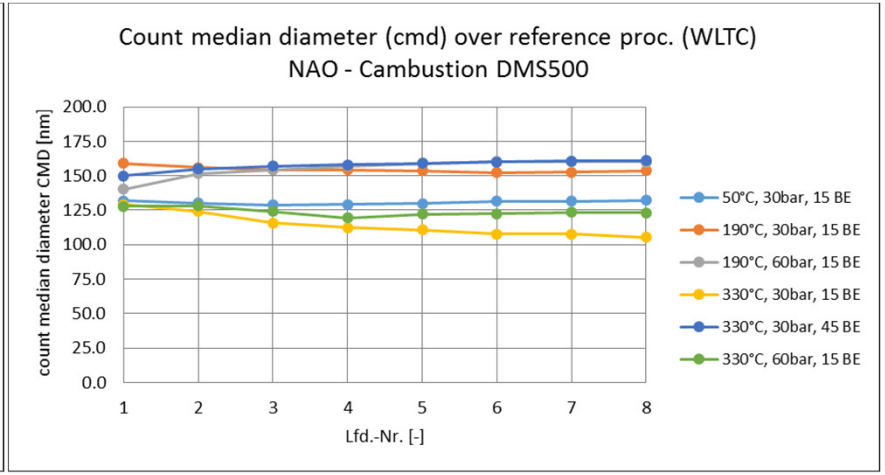


- ECE shows a higher level of dependence on the intensity of the preconditioning (especially mechanical), a steeper decrease in the mean PNC, a higher intens. and range of variation
- ECE and NAO friction materials converge towards a comparable emission level (no reproducible emission level) - *recovery of the braking system*
  - ➢ Compensation of the influence of the preconditioning with increasing number of cycles
- Overall lower emission level due to thermal treatment (330°C)

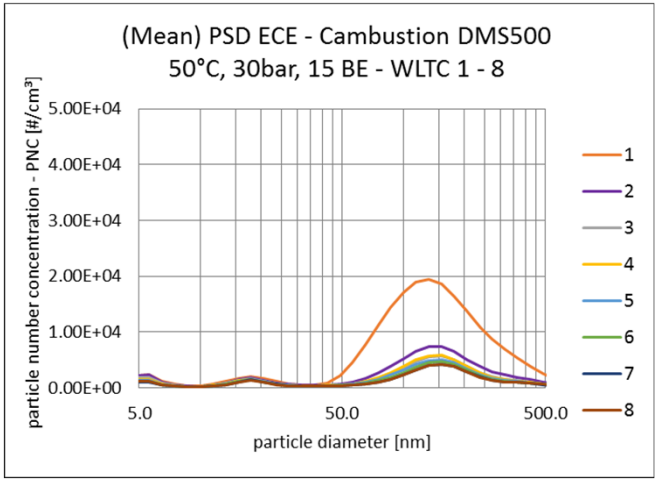
3. Influence of the preconditioning
3.4 Reference procedure (WLTC)

Analysis of the particle size distribution (PSD) – cmd as reference – Cambustion DMS500



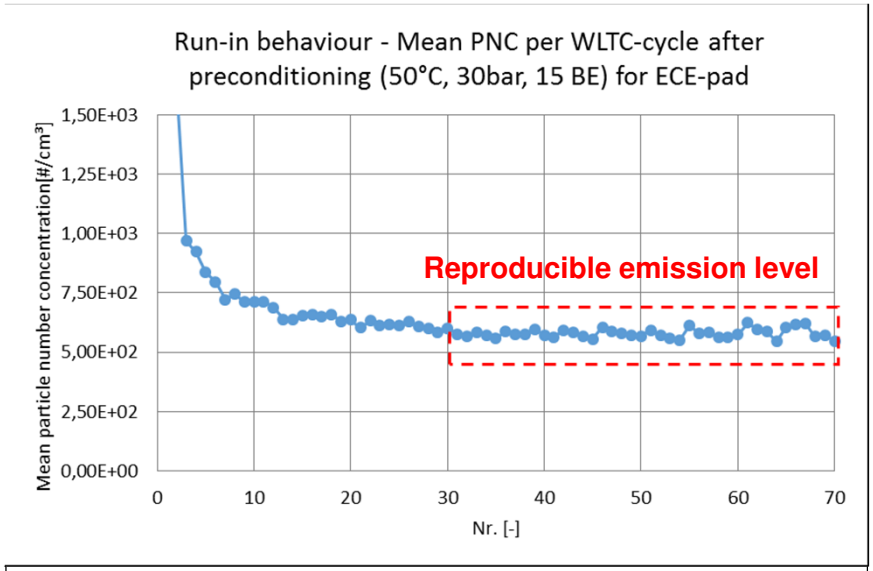


- Monomodal distribution during the WLTC-cycles – precondition has no significant influence on the modal distribution
- contineous decrease of the intensity of PNC - mean mobility particle diameter in the range 100 – 160nm



3. Influence of the preconditioning
3.4 Reference procedure (WLTC)

Run-in behaviour for 50°C, 30bar, 15 BE-preconditioning over a number of 70 WLTC (SPCS)



Description:

- 70xWLTC = 1628km / 3360 brake events
- Decrease in the PNC by 92% (cyc. 1 to 10)
- reproducible PNC after 30 cycles (700km)
- Max. variation of ±8% (mean PNC) from cycle 30 to 70

Conditions:

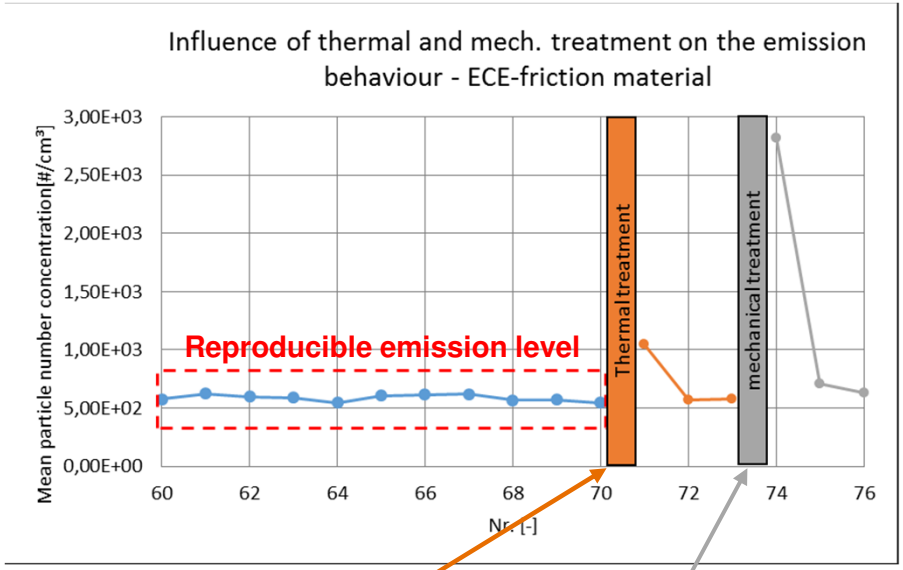
- Preconditioning: 15 brake events (initialtemp.: 50°C, 30bar, 80 → 30km/h)
- **Course of the mean PNC** per WLTC-cycle (number of 70 cycles in total)

Results:

- Typical course during the run-in behavior (continuous decrease of the intensity)
- 30 cycles (plus 15stops preconditioning) in total are need to achieve a reproducible emission level
- Reduction of the intensity from cycle 1 to 10 by **92%** and from cycle 10 to 30 by **16%**

3. Influence of the preconditioning
3.4 Reference procedure (WLTC)

Influence of thermal and mechanical treatment . Horiba SPCS



Thermal treatment:

6 brake events in direct sequence

a=40%g, v=100→5km/h,

max. Temp. BE 6: **356°C**

Mechanical treatment:

3 brake events

p=80bar, v=200→170km/h,

Init. temp.: 100°C

Conditions:

- Thermal and mech. treatment + 30min cooling time before the first WLTC
- 3 WLTC-cycles as reference

Results:

- Thermal treatment: Increase of emission level by factor 2 over the first WLTC
- Mechanical treatment: Increase of emission level by factor 5 over the first WLTC cycle
- Recovery of the braking system: Reaching the entrance emission level after 2 (therm.) or 3 (mech.) cycles

4. Summary and Outlook

- A number of 30 WLTC-cycles (plus 15stops preconditioning) in total are need to achieve a reproducible emission level
- The preconditioning of brake pads have a significant effect on the particle number emissions from brake events
  - NAO shows a higher stability against mechanical treatment (homogeneous surface structure) in comparison with ECE – lower number of brake events necessary to achieve a reproducible emission level
  - ECE shows a high dependence on thermal and mechanical treatment and duration of preconditioning (number of brake events)

- Definition of a stabil run-in procedure
  - ➢ Applicability for various friction materials
  - ➢ Consideration of reproducibility, duration, thermal and mechanical treatment

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Thank You for Your Attention!