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Comparison of the run-in and emission behavior of different disc concepts


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0. Introduction

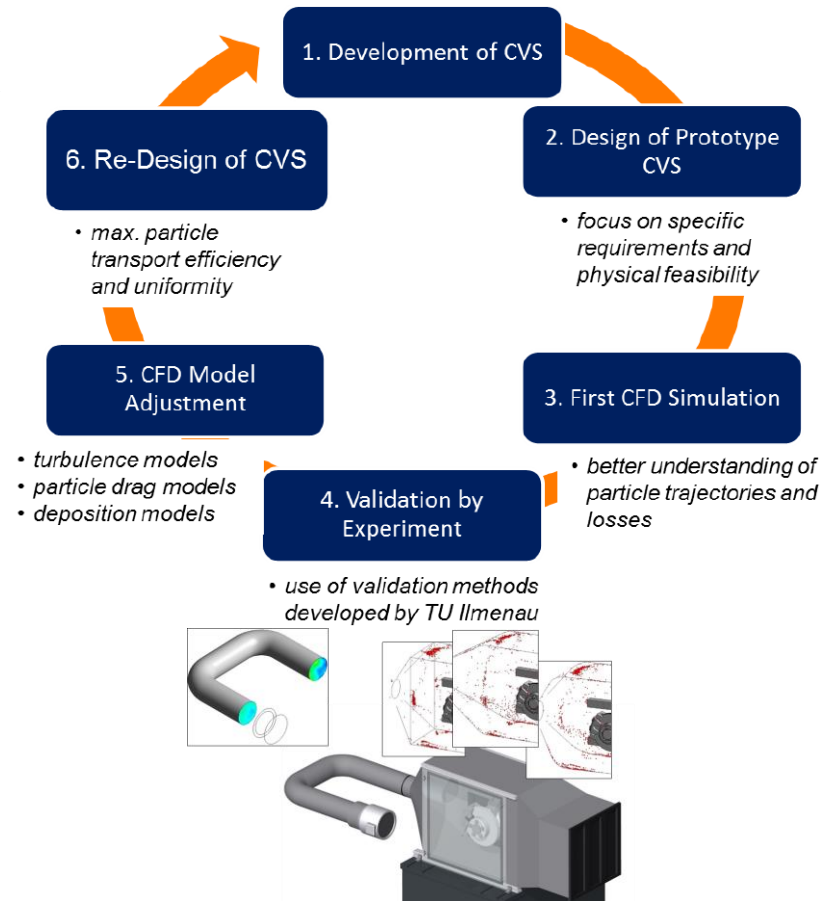
0.1 Development of a sampling system

Main function: Providing a representative sample

Requirements for a high-quality measurement / methodology:



<ul style="list-style-type: none">• high measurement efficiency	<ul style="list-style-type: none">• function of transport- and sampling efficiency
<ul style="list-style-type: none">• high reproducibility	<ul style="list-style-type: none">• well premixed and constant aerosol flow
<ul style="list-style-type: none">• minimized background concentration	<ul style="list-style-type: none">• decoupling from the environment
<ul style="list-style-type: none">• multi-device-measurement	<ul style="list-style-type: none">• particle number and mass measurement

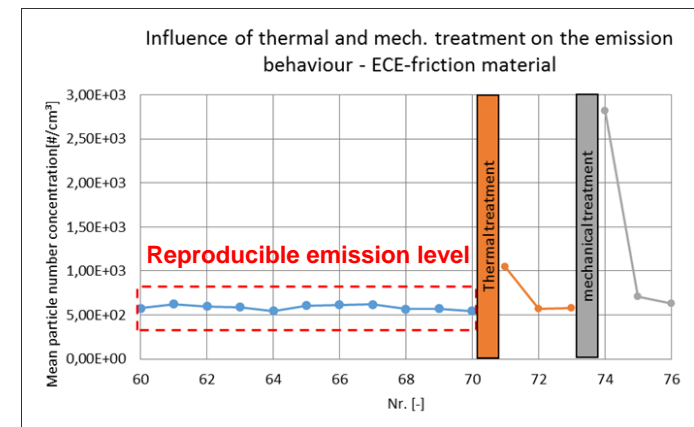
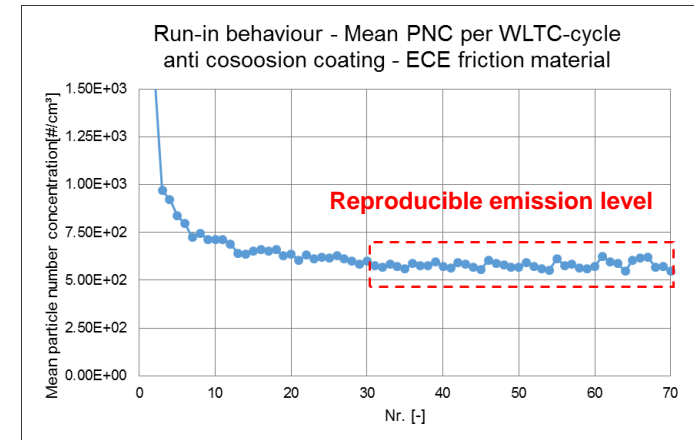


0. Introduction

0.2 Influence of the run-in and conditioning procedure

Previous results

- A number of 30 WLTC-cycles in total are needed to achieve a reproducible emission level for cast iron discs (anti corrosion coating)
- The preconditioning of brake pads has a significant effect on the particle number emissions
 - NAO shows a higher stability against mechanical treatment
 - ECE shows a high dependence on thermal and mechanical treatment and duration of preconditioning (number of brake events)
- Recovery of the braking system / Compensation of the influence of the preconditioning with increasing number of cycles / brake events



1. Experimental setup

1.1 Measurement devices and testparts

Measurement devices



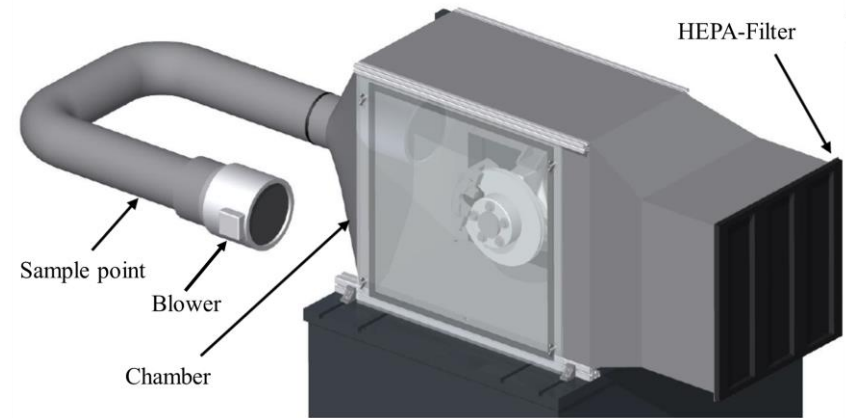
HORIBA MEXA-2100SPCS

- CPC (10 - 2.500nm)
 - PNC measuring
- modified sub23nm-version
- Integrated vpr and catalytic stripper

Brake discs tested

- Left front wheel of an full luxury car
- Disc concepts:
 - **Standard cast iron disc** (anti corrosion coating)
 - **Hard metal coated disc**
- Pads: specific pads per disc concept
- simulated Inertia: 96.8 kg*m²
- Effective radius: 144 mm
- Rotor size: 374 mm

Sampling system



Constant volume sampling system

- Volume flow: 850m³/h
- High inlet efficiency for particles $\leq 2.5\mu\text{m}$ (PN >90%)
- Isokinetic-sampling (calc. probe diameter)
- decoupling from the environment (filter)



2. Influence of the conditioning / preconditioning

2.1 Introduction

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

- Which condition should be aimed for at the beginning of a test cycle?
- How does the type of preconditioning depend on the actual test cycle?
- Through which preconditioning, duration and number of repetitions a run-in state/ initial state is achieved?
- Which parameters serve to verify the initial conditions of the friction system?
 - Number concentration, coefficient of friction, number of brakes / cycles
- What influence do different friction concepts or the composition of friction materials have on the duration, numbers and intensity of preconditioning?
 - **The definition of a suitable run-in procedure requires the consideration of different factors**



2. Influence of the conditioning / preconditioning

2.2 Methodology / test procedure

Comparison of cast iron brake disc and hard metal coated disc

I. Investigation of run-in behavior for green friction partners according to the following methodology

Run-in procedure	reference
400x AK-Master sec. 3 80 → 30km/h; 30bar	3x WLTC-cycle

a. Test 1: WLTC-cycle (50x)

b. Test 2: AK-Master sec. 3 (400x) + 3xWLTP

Run-in procedure according to AK-Master sec. 3: initial temperature 100°C; pressure: 30bar; Speed range: 80 - 30km / h

II. Parameter variation - influence of the (pre-) conditioning on the emission behavior

- Parameter variation under performance conditions (temperature and brake pressure)
- Intermediate conditioning (IC) to ensure reproducible initial conditions
- Measuring of particle number concentration (10 - 2,500nm) across all sections

Run-in procedure	sec.1		sec. 2		sec. 3		sec. 4		sec. 5		sec. 6	
400x 80 → 30km/h; 30bar	20x 50°C 30bar	20x IC	20x 50°C 60bar	75x IC	30x 190°C 30bar	75x IC	30x 190°C 60bar	75x IC	40x 330°C 30bar	100x IC	40x 330°C 60bar	100x IC

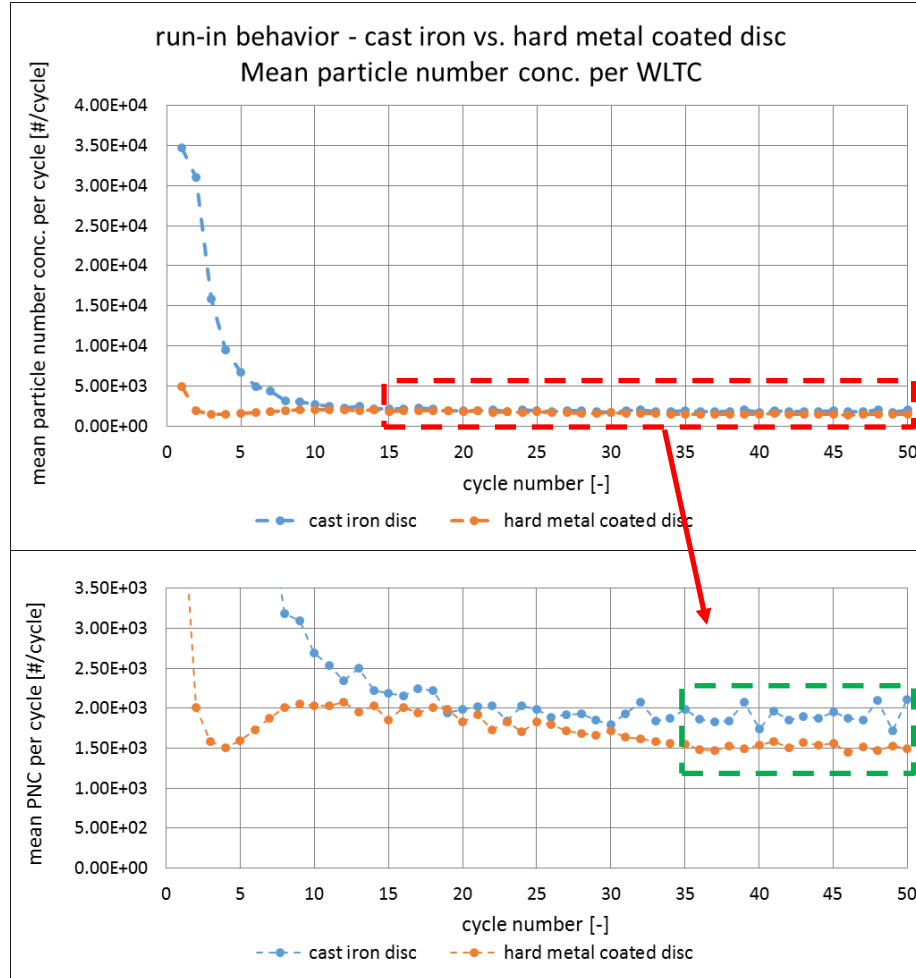
Initial situation: Parameter variation according to the run-in procedure 2



2. Influence of the conditioning / preconditioning

2.3 WLTC-cycle

Mean particle number concentration per WLTC-cycle



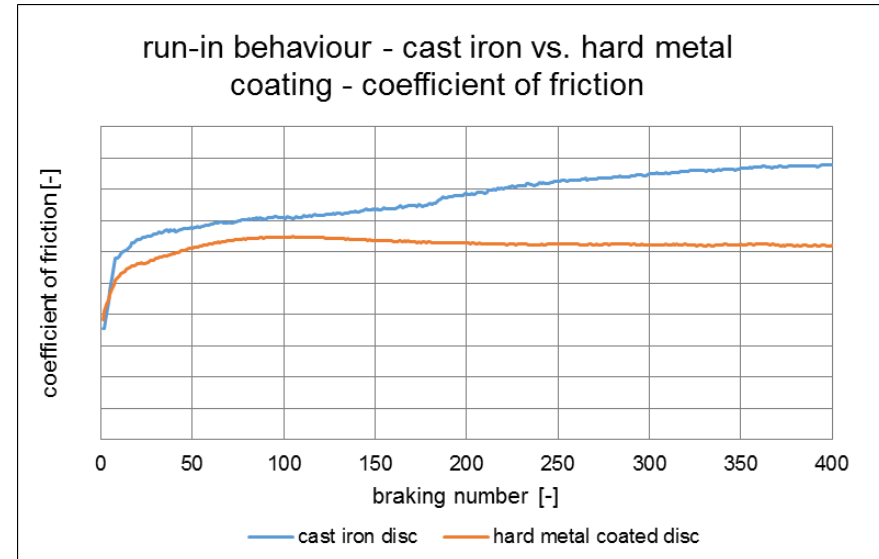
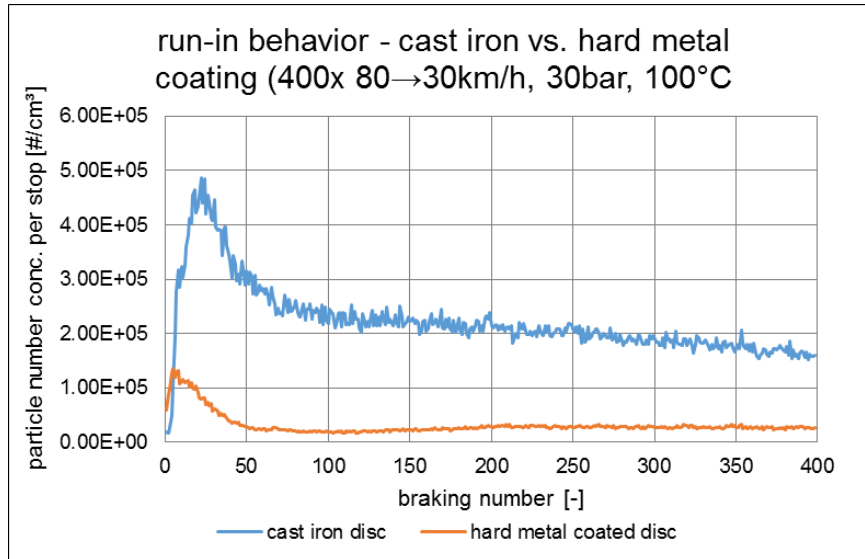
- 50xWLTC: 1163km / 2400 brake events
- Cast iron: high emission level over cycles 1 - 10 (corrosion coating)
- Coated disc: significantly lower emission level over all cycles (green / run-in state)
- Coated disc: Significantly higher reproducibility of the mean number concentration over the analyzed cycles
- Reproducible emission level from WLTC cycle 35
- Potential of the coated disc: approx. 20% PN reduction (based on cycles 35 - 50 for particles $\leq 2,5\mu\text{m}$)
 - Low therm. + mech. Stress results in a reduction of wear (cast iron)



2. Influence of the conditioning / preconditioning

2.4 Performance conditions

Run-in behavior - 80→30km/h, 30bar, initial temperature: 100°C



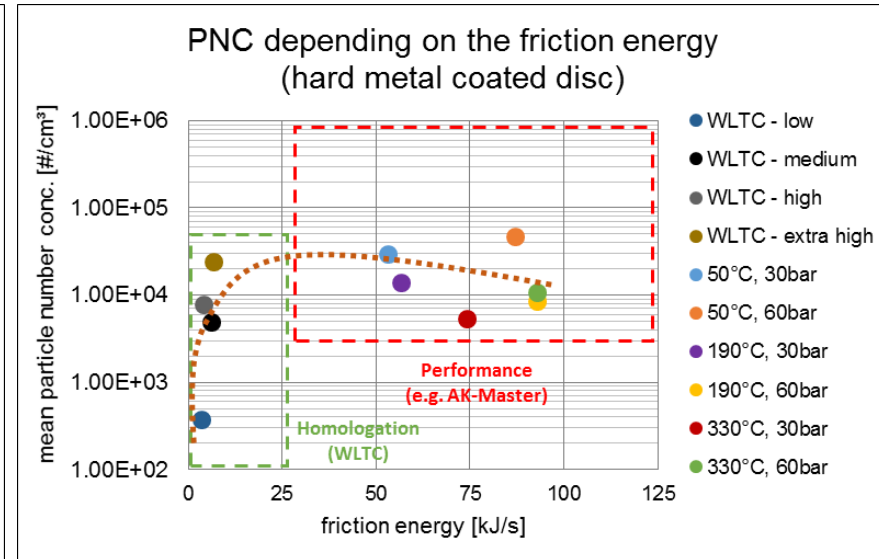
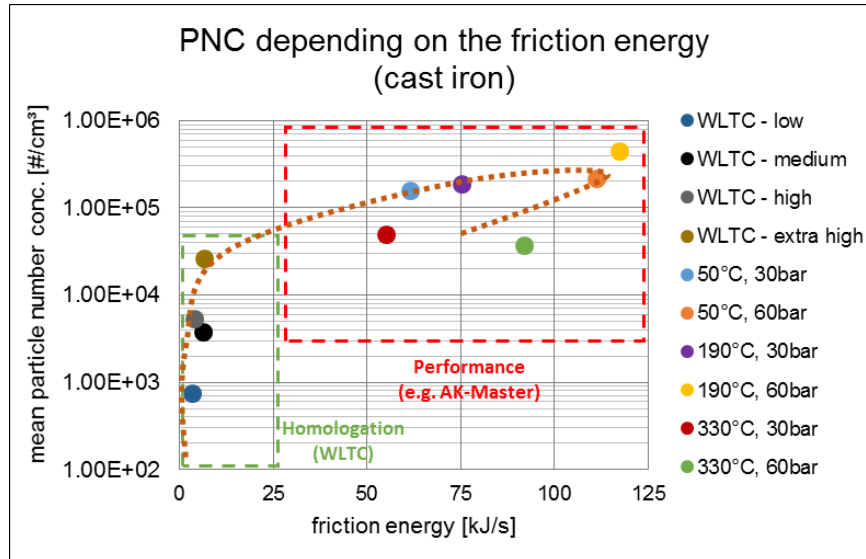
- Initial conditions: unconditioned state of the discs (cast iron: anti corrosion coating)
- Correlation between coefficient of friction and emission characteristic
- Cast iron: higher emission level compared to hard metal coated disc and WLTC
- Cast iron: run-in period >400 brake events to achieve a reproducible emission level
- Coated disc: resistance to mechanical stress (reproducible emission levels after 200 stops)
 - Potential of the coated disc: approx. 80% PN reduction (after 400 brake events)



2. Influence of the conditioning / preconditioning

2.4 Performance conditions

Correlation between particle number concentration and friction energy



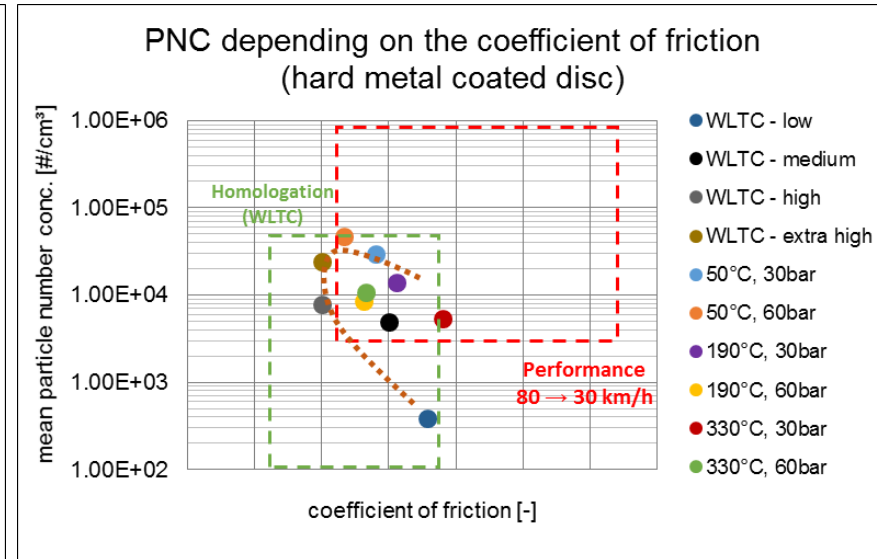
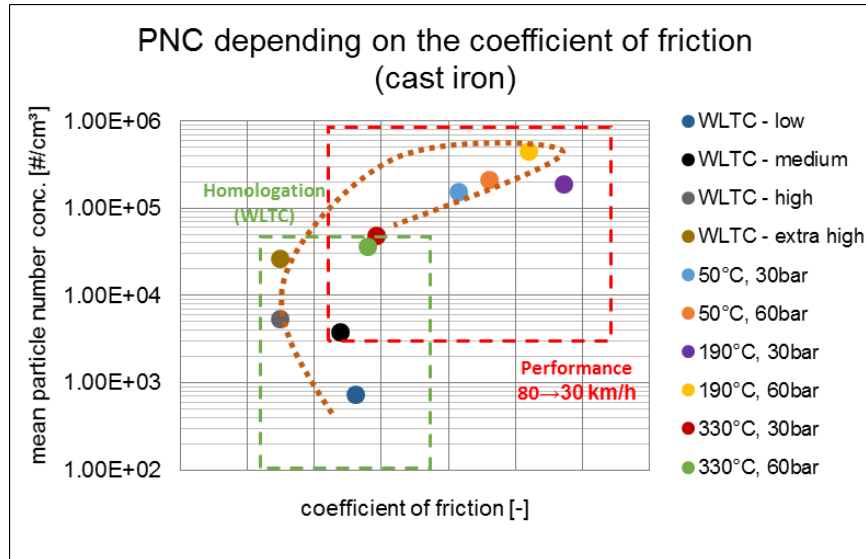
- Tested concepts show a different dependence on the intensity of load
- Cast iron: increase in mecha. and thermal load (friction energy) results in an increase in emission intensity – max. at 190°C and 60bar (non-linear dependence - reversal point)
- Coated disc: High resistance to mechanical and thermal load (performance conditions); Highest intensity at 50°C and 60bar; Reduction of intensity at highest load (330°C)
 - Potential of the coated disc: between 70% - >95% of PN reduction (for particles $\leq 2,5\mu\text{m}$)



2. Influence of the conditioning / preconditioning

2.4 Performance conditions

Correlation between particle number concentration and coefficient of friction



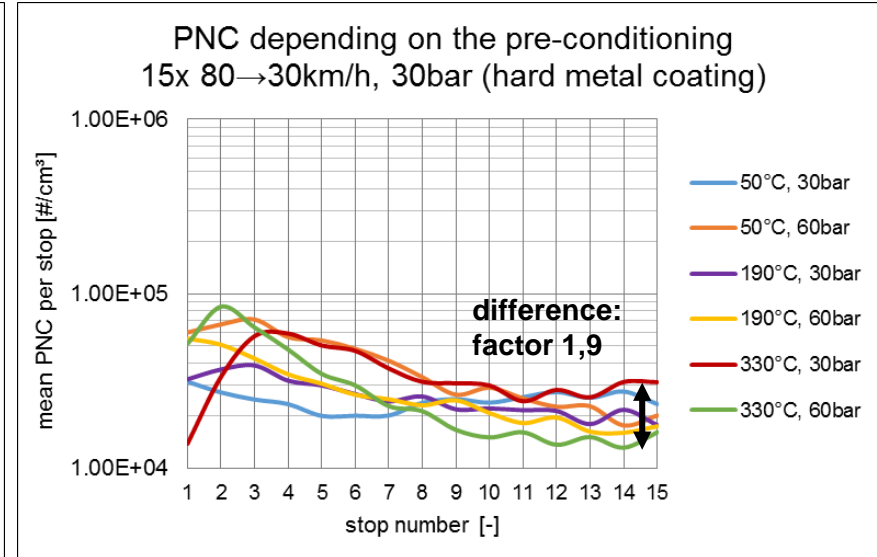
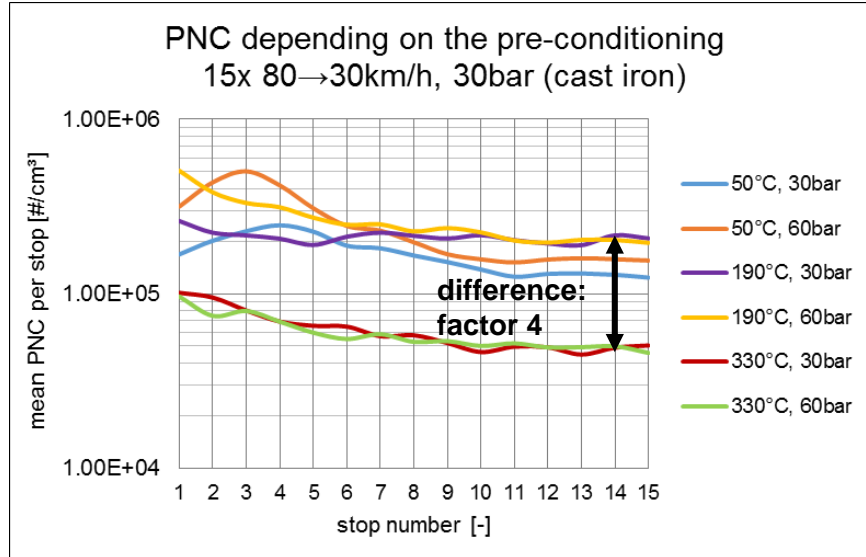
- Tested concepts show a different behavior of the coefficient of friction
- Cast iron: increase of the coefficient of friction and the intensity of the number concentration up to a reversal point (from 330°C reduction of the coefficient of friction and the emission intensity)
- Coated disc: lower coefficient of friction compared to cast iron under performance conditions, but higher resistance (max. friction coefficient at 330°C and 30bar)



2. Influence of the conditioning / preconditioning

2.4 Performance conditions

Influence of preconditioning on the subsequent emission behavior



- Tested concepts show a different dependencies on pre-conditioning
- Different number of conditioning brakes necessary (recovery of the braking system)
- Cast iron: high thermal load (330°C) results in a low emission level (intermediate conditioning: number of brake events ≥ 75 necessary)
- Coated disc: higher resistance to high mechanical and thermal load (less number of conditioning brakes necessary)



3. Conclusions

- Different friction concepts show different dependence on the intensity of load
- Coefficient of friction and friction energy are not used to verify the emission level
- Cast iron shows higher potential with regard to friction behavior under high loads, but disadvantages with regard to particle emissions (high dynamic)
- Hard metal coated disc shows potential in terms of particle emissions (resistance to mechanical and thermal load)
- In order to carry out comparative measurements, the type of preconditioning and the number of brake events are of great importance
 - Direct influence on the emission level of subsequent cycles
 - Preconditioning with high mechanical load for cast iron and hard metal coating possible (reduction of duration and number of brake events)
 - Preconditioning before the actual test can only be carried out with comparable intensity of the target load



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**Thank You for Your
Attention!**