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

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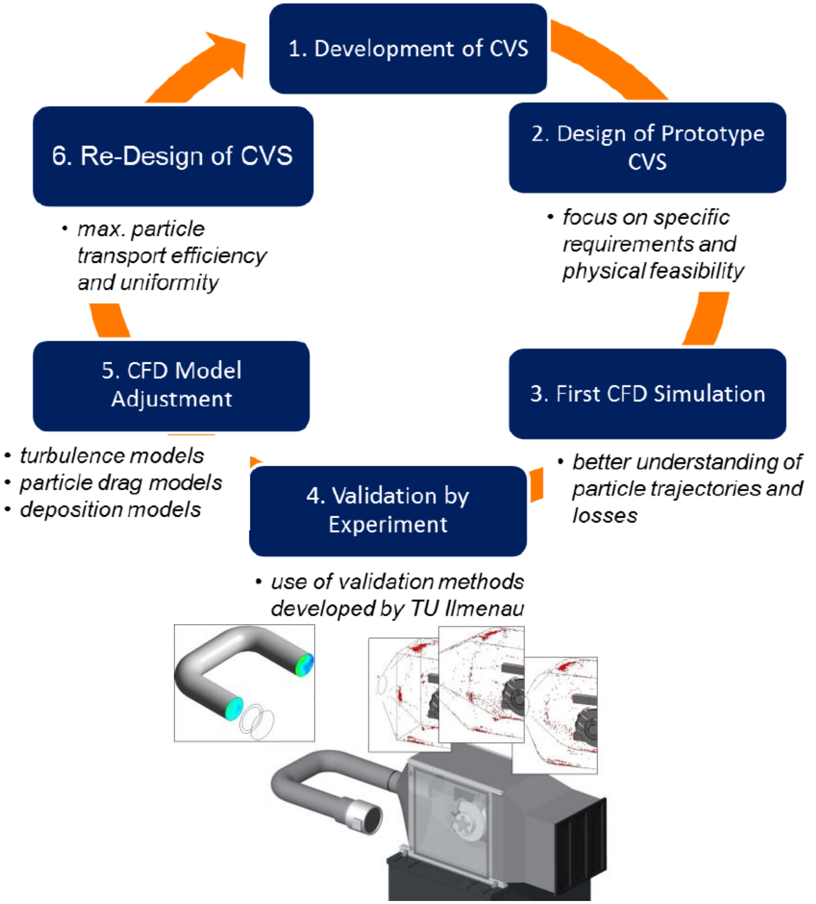
0. Introduction

0.1 Developement of a sampling system

Main function: Providing a representative sample

Requirements for a high-quality measurement / methodology:

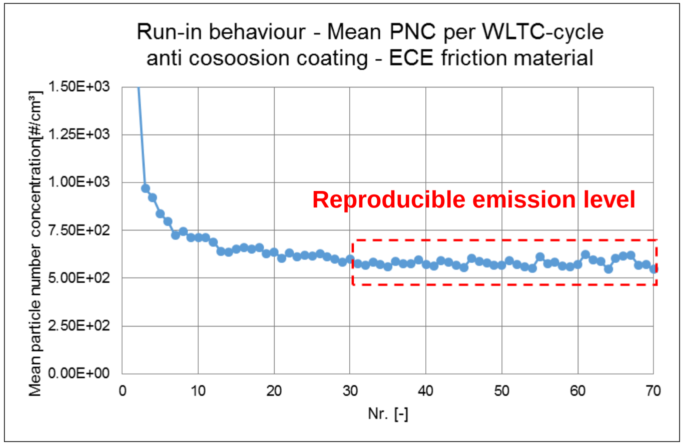
Requirements	Physical Basis
• high measurement efficiency	• function of transport- and sampling efficiency
• high reproducibility	• well premixed and constant aerosol flow
• minimized background concentration	• decoupling from the environment
• multi-device-measurement	• particle number and mass measurement

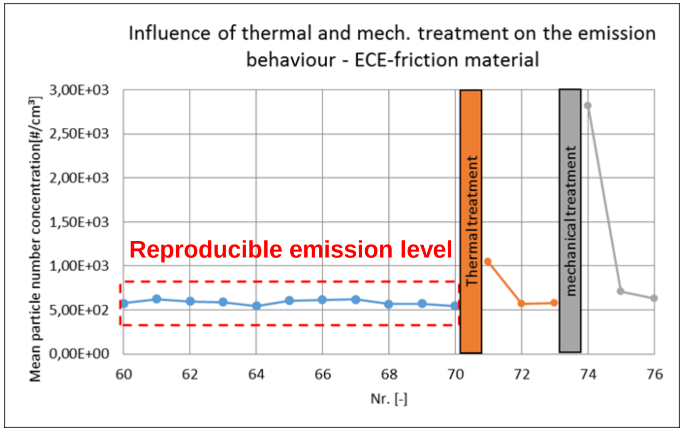


0. Introduction
0.2 Influence of the run-in and conditioning procedure

Previous results

- A number of 30 WLTC-cycles in total are need to achieve a reproducible emission level for cast iron discs (anti corrosion coating)
- The preconditioning of brake pads have 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

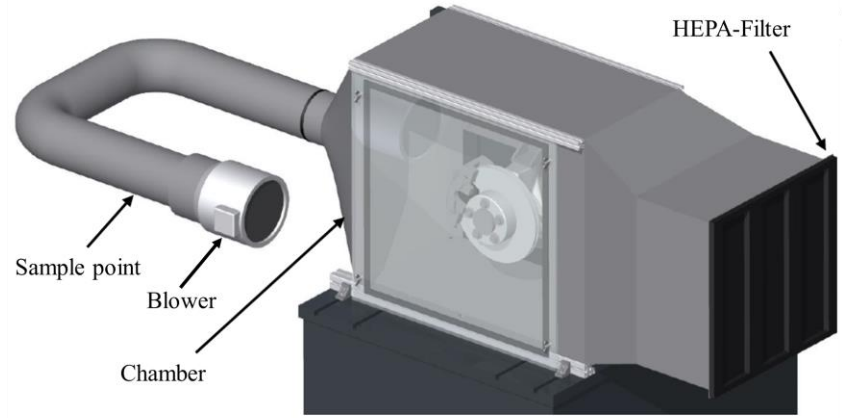
Measurement devices

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 ≤2.5µm (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

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

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

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

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

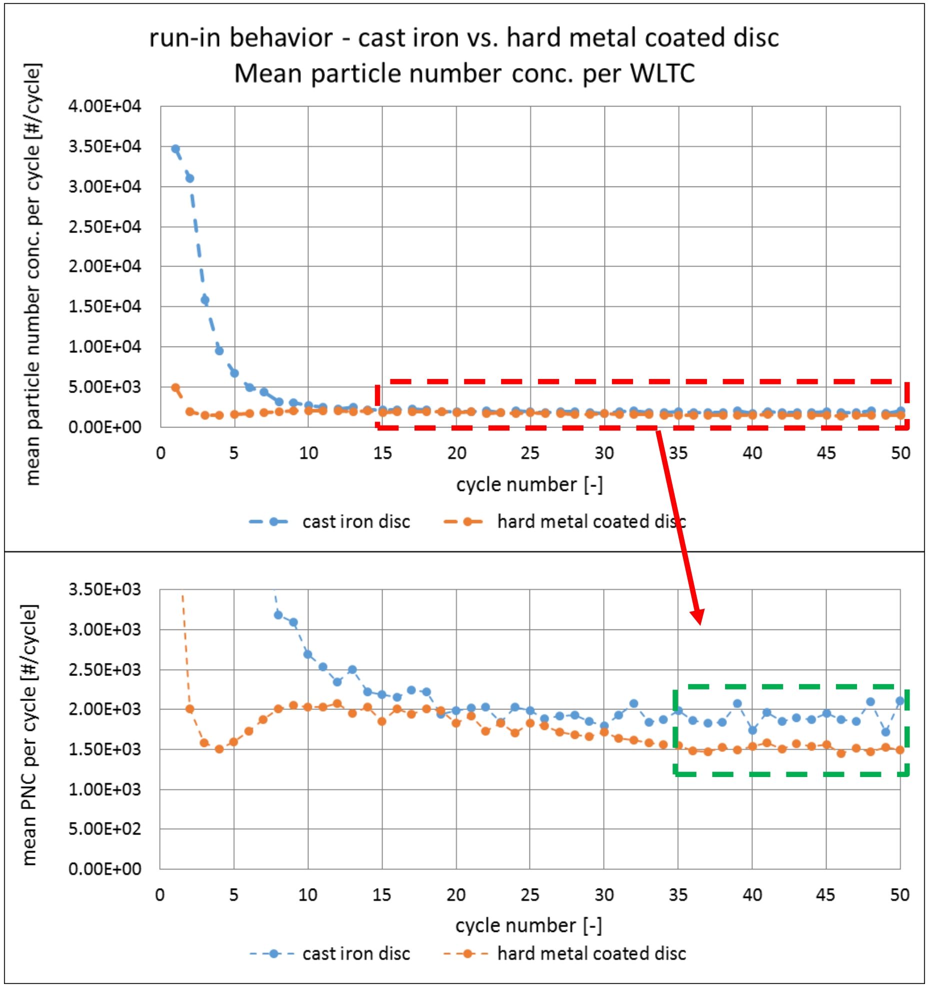
- Parameter variation under performance conditions (temperature and brake pressure)
- Intermediate conditioning (IC) to ensure reproducible initial conditions
- Measuring of particle number concentration (10 - 2,500nm) across all sections

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

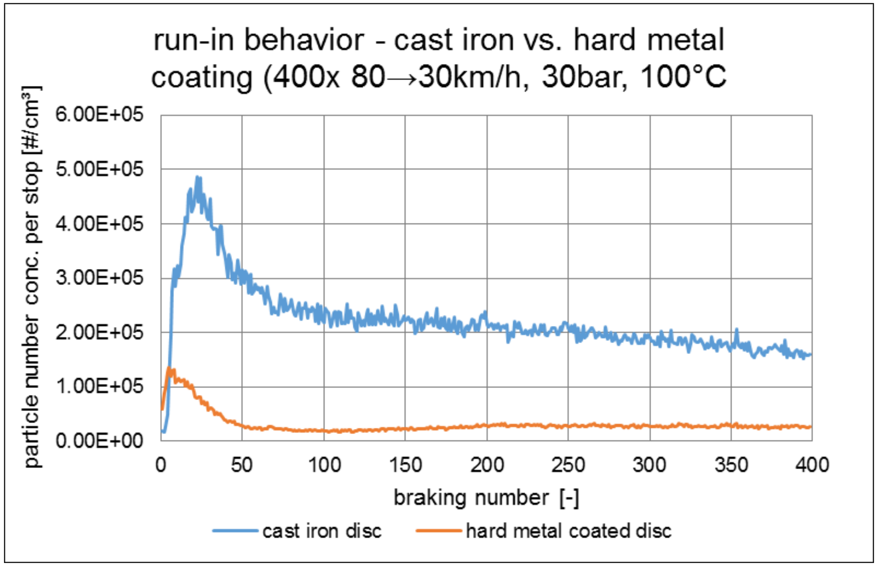
Mean particle number concentration per WLTC-cycle

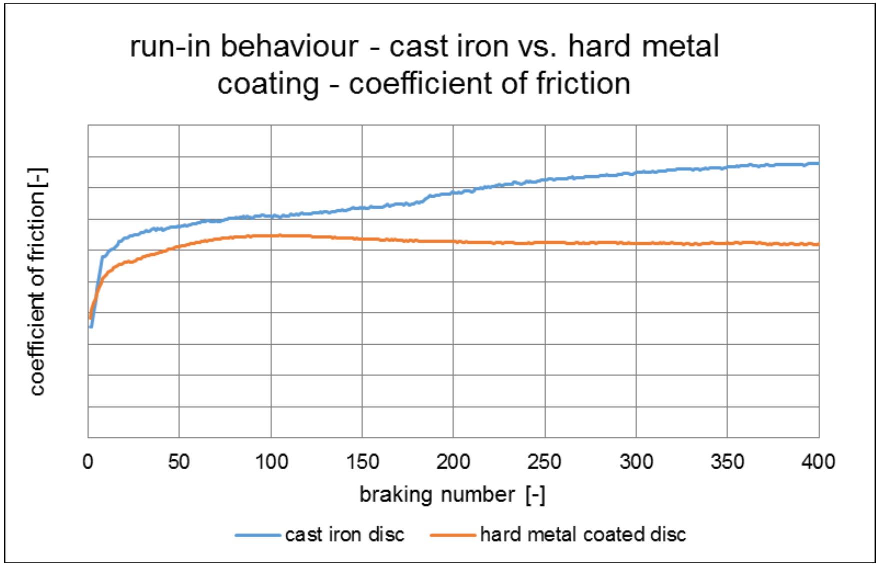


- 50xWLTC: 1163km / 2400 brake events
- Cast iron: high emission level over cycles 1 - 10 (corrosion coating)
- Coated disc: significantly lower emission level over all cycles (green / run-in state)
- Coated disc: Significantly higher reproducibility of the mean number concentration over the analyzed cycles
- Reproducible emission level from WLTC cycle 35
- Potential of the coated disc: approx. 20% PN reduction (based on cycles 35 - 50 for particles ≤2,5µm)
  - ➢ 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, initialtemperature: 100°C

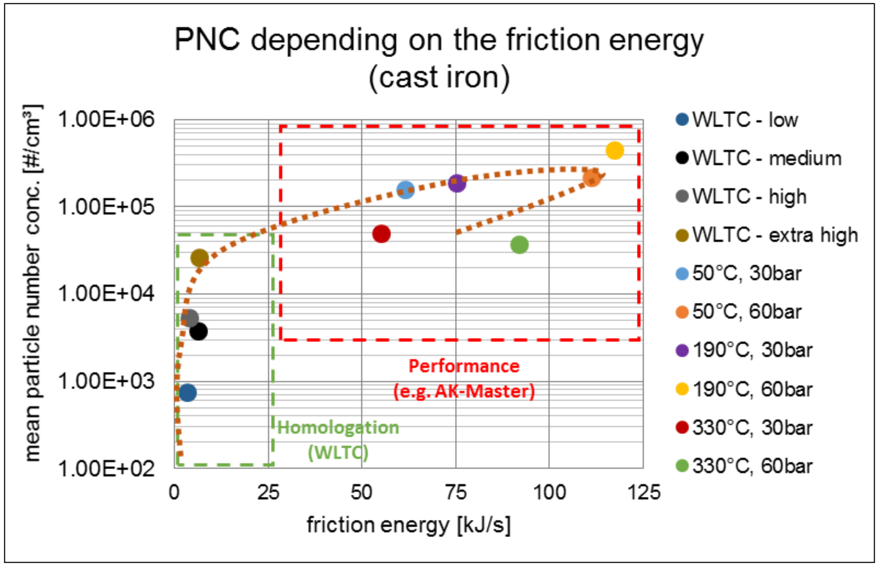


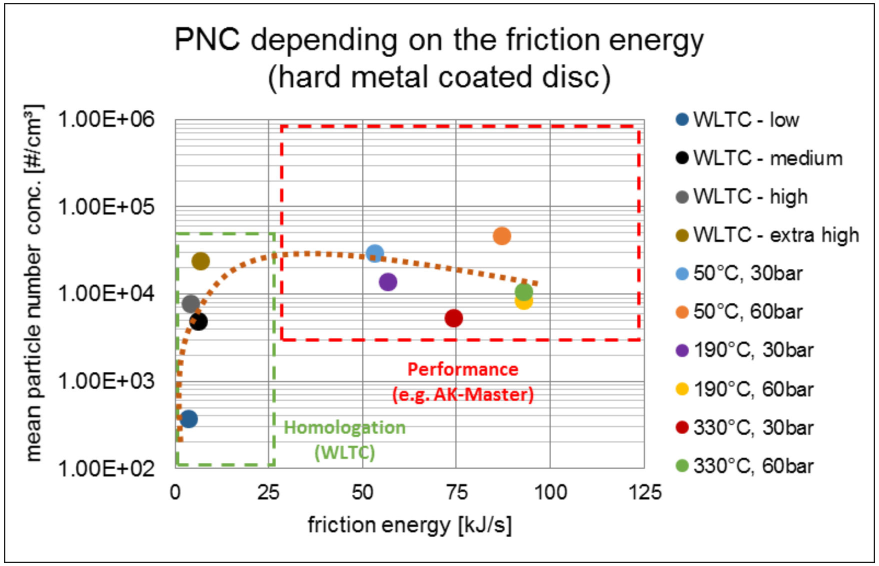


- Initial conditions: unconditioned state of the discs (cast iron: anti corrosion coating)
- Correlation between coefficient of friction and emission characteristic
- Cast iron: higher emission level compared to hard metal coated disc and WLTC
- Cast iron: run-in period >400 brake events to achieve a 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

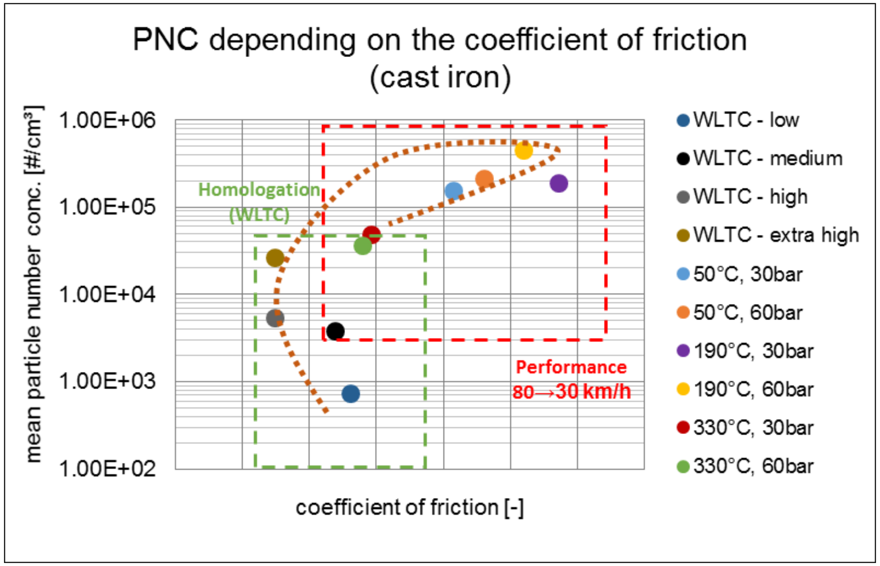


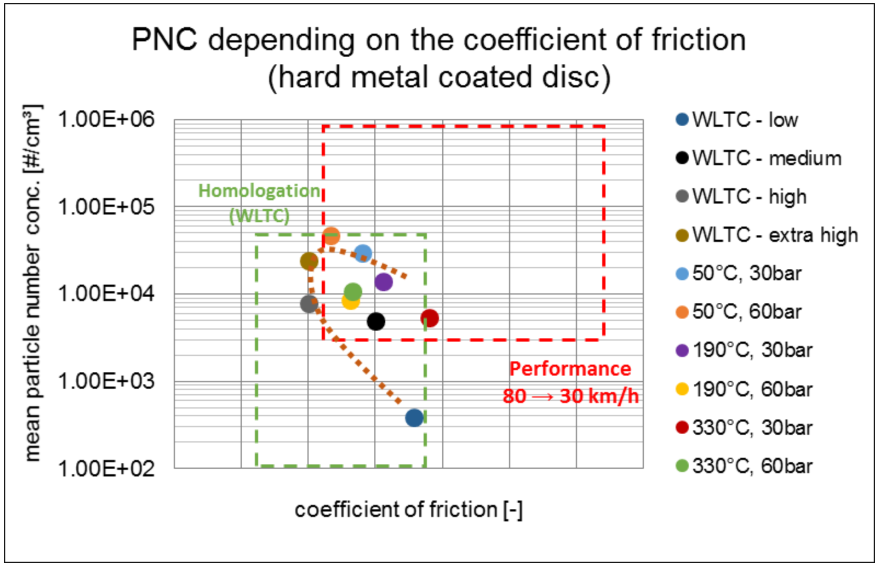


- Tested concepts show a different dependence on the intensity of load
- Cast iron: increase in mecha. and thermal load (friction energy) results in an increase in emission intensity – max. at 190°C and 60bar (non-linear dependence - reversal point)
- Coated disc: High resistance to mechanical and thermal 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 ≤2,5µm)

2. Influence of the conditioning / preconditioning
2.4 Performance conditions

Correlation between particle number concentration and coefficient of friction

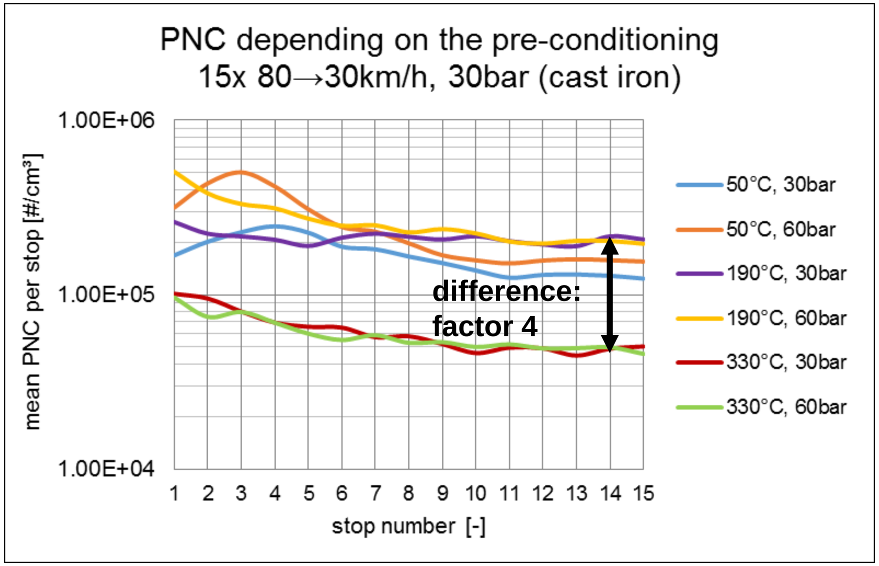


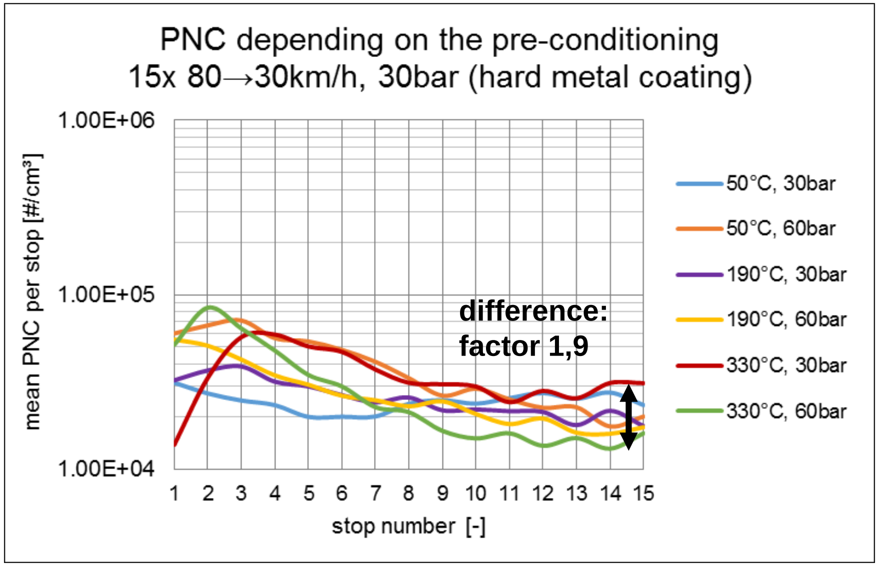


- Tested concepts show a different behavior of the coefficient of friction
- Cast iron: increase of the coefficient of friction and the intensity of the number concentration up to a reversal point (from 330°C reduction of the coefficient of friction and the emission intensity)
- Coated disc: lower coefficient 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

Acknowledgement

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Thank You for Your Attention!