Karlsruher Institut für Technologie

Tire wear and tire-road wear particle measurements at inner drum test benches of KIT

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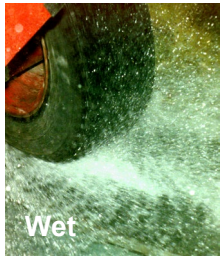
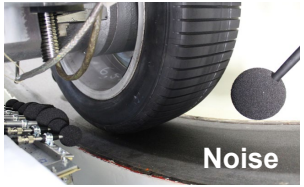
Content

- Test rig
- Test setup
- Test tracks
- Third body material
- Test procedure
- RAMUS
- Test Rig GRIPS
- Relevant publications

Inner Drum Test Bench
for passenger car tires

Internal drum test bench

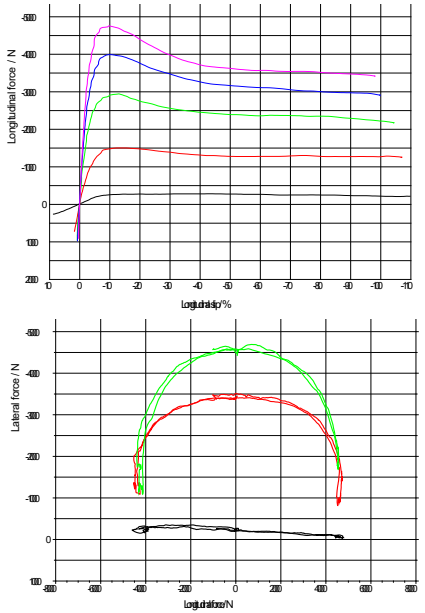




Technical parameter	Value
Drum inner diameter	3.8 m
Ambient temperature	-20 ~ 30 ℃
Slip angle	-20 ~ 20 deg
Camber angle	-10 ~ 20 deg
Road types	Safety-walk, asphalt, washed concrete, snow, ice, wet
Max. Speed	w/o track segments: 200 km/h w/ track segments: 150 km/h
Max. Fx / Fy / Fz	15 kN
Max. Mx / My	5500 Nm
Max. Mz	1500 Nm

Inner Drum Test Bench
for passenger car tires: Test types

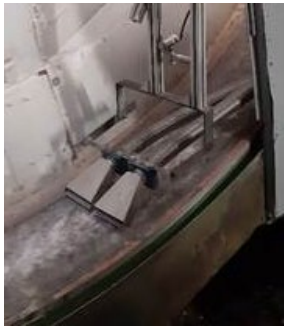
- Tire Characteristic
  - Force & Moment Measurements
  - Rolling Resistance
  - Power loss
  - Dynamic Response (rolling over cleats)
  - Model parametrization measurements
  - Noise emission
- Track influence
  - Dry road at asphalt, concrete or sand paper
  - Wet, icy, snowy road
  - Special tracks (e.g. grooved concrete track)
- Long-term tests
  - TRWP
  - Behavior under extrem operation conditions (pressure loss)
- …



[Link for more details]

Test set up
for particle collection and online analysis

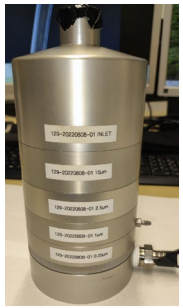
Tire rolling on endless road



Suction funel types

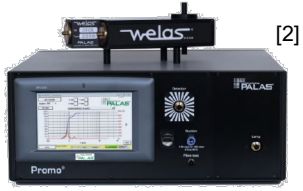
vacuum cleaner

Dust extractor



Impactor (Particle Filter)

Electrical Low Pressure Impactor [3]



[2]

Aerosol Spectrometer

Source left picture: [1] Foitzik M J, Unrau H J, Gauterin F, et al. Investigation of ultra fine particulate matter emission of rubber tires[J]. Wear, 2018, 394: 87-95.

Test set up
Test tracks

Asphalt AC 11

Washed
concrete track

Concrete track

Safety Walk

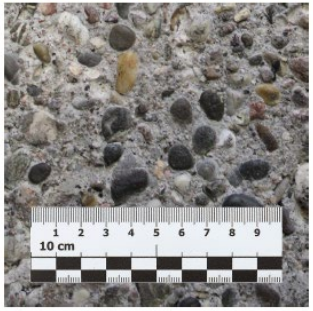
Test set up
Test tracks

(a) Safety-Walk
MPD = 0.15 mm, α = 0.1%

(b) Asphalt 0/5
MPD = 0.37 mm, α = 2.7%

(c) Asphalt 0/11
MPD = 1.15 mm, α = 2.3%

(d) SMA 0/8
MPD = 1.19 mm, α = 12.2%

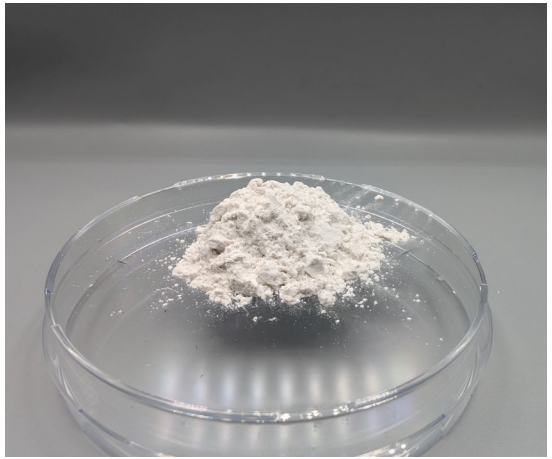


(e) Concrete 0/16
MPD = 1.44 mm, α = 1.0%

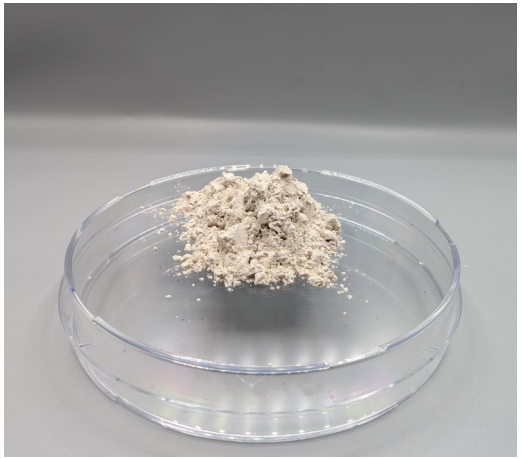
MPD Mean profile depth

Source: [4] Pinay, J. et al.:Understanding the contribution of groove resonance to tire-road noise on different surfaces under various operating conditions. Acta Acustica, 4(2):6, 2020

Test set up
Third body material



Arizona Dust



Miled stones from asphalt track

talc

For inner drum tests:
~30 g / 60 min @ 80 km/h av. speed

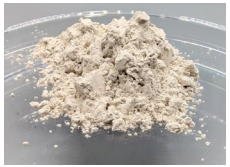
Smears at inner drum tests
→ not suitable

Track treatment

Each Day: Track resharpening with studded tire running under alternating slip angle

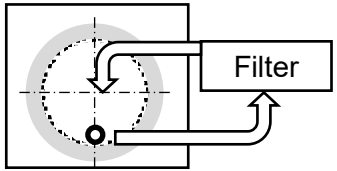
Before each test:

Insert of third body on rotating drum

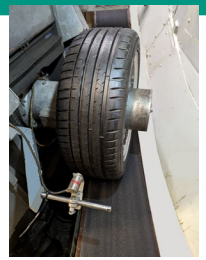


Tire rolls in the drum for 5 min

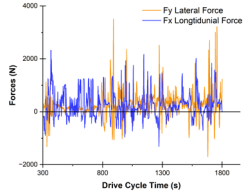
Air stream activated



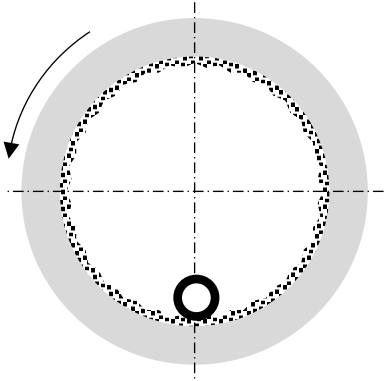
Tire rolls in the drum for 5 min

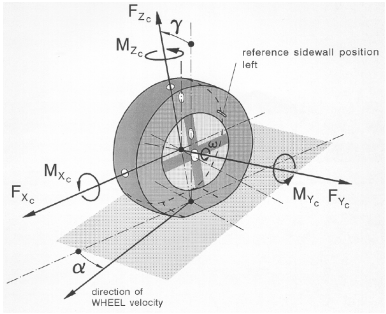


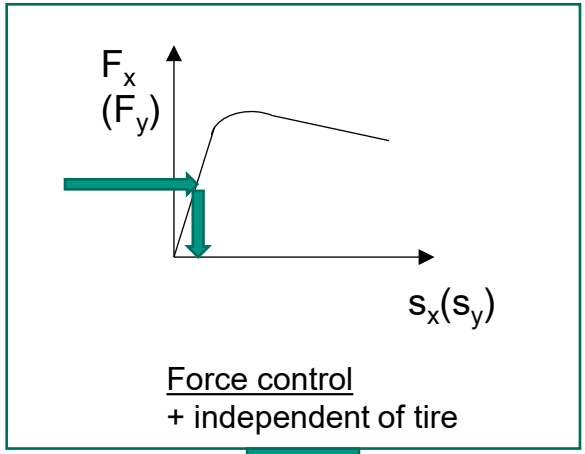
Start of test programm



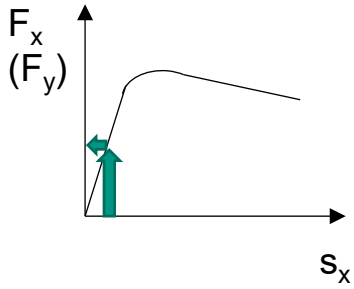
Test procedure
Control method: Force Control



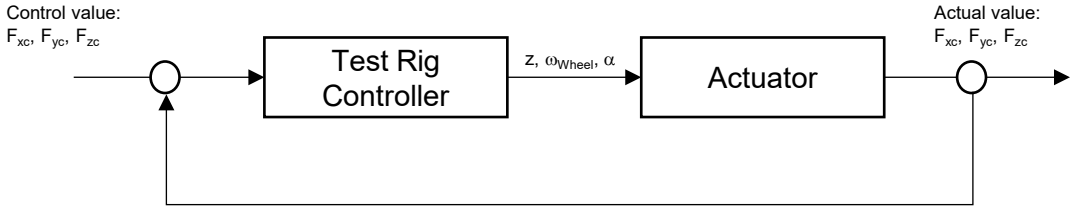




Force control
+ independent of tire

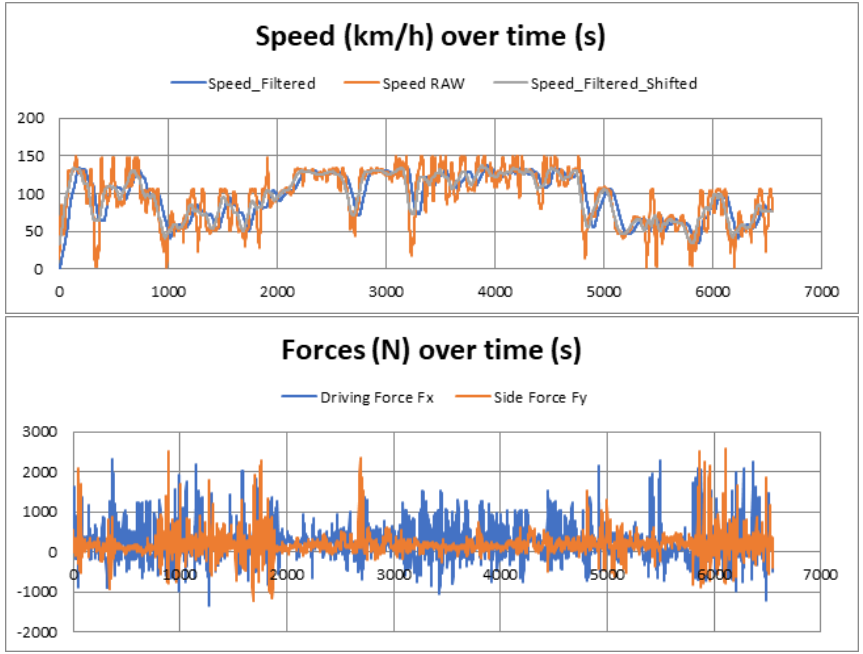


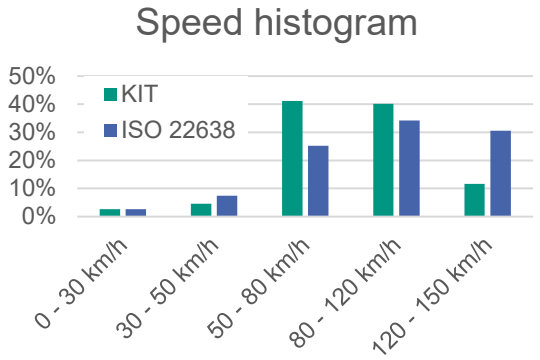
Deflection or Slip control
- force depend on tire‘s stiffness



Test procedure
Realistic load profile

Time series data of the driving cycle

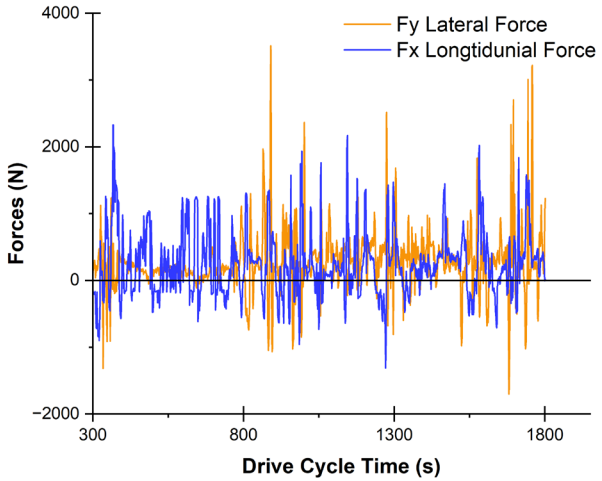


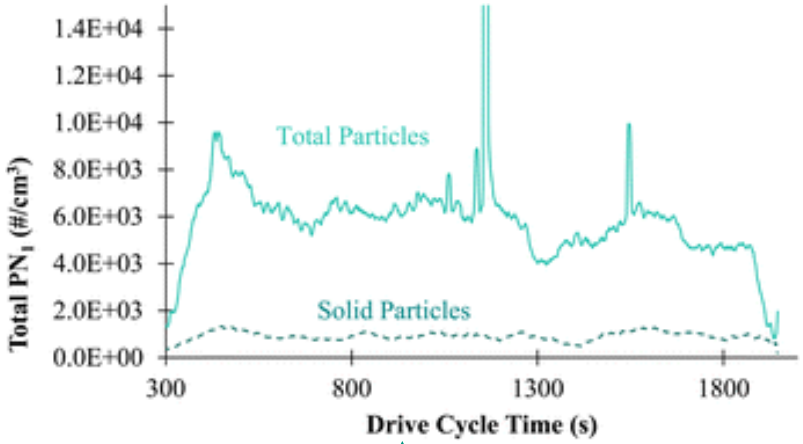


Drum drive power and inertia limits max. achieveable speed to 130 km/h and max. acceleration.

BUT: Wear depends on mechanical and thermal load → Friction power = f(Slip) less depend on absolute speed, than on relative speed

Test procedure
Realistic load profile – Example: Nano Particle Collection





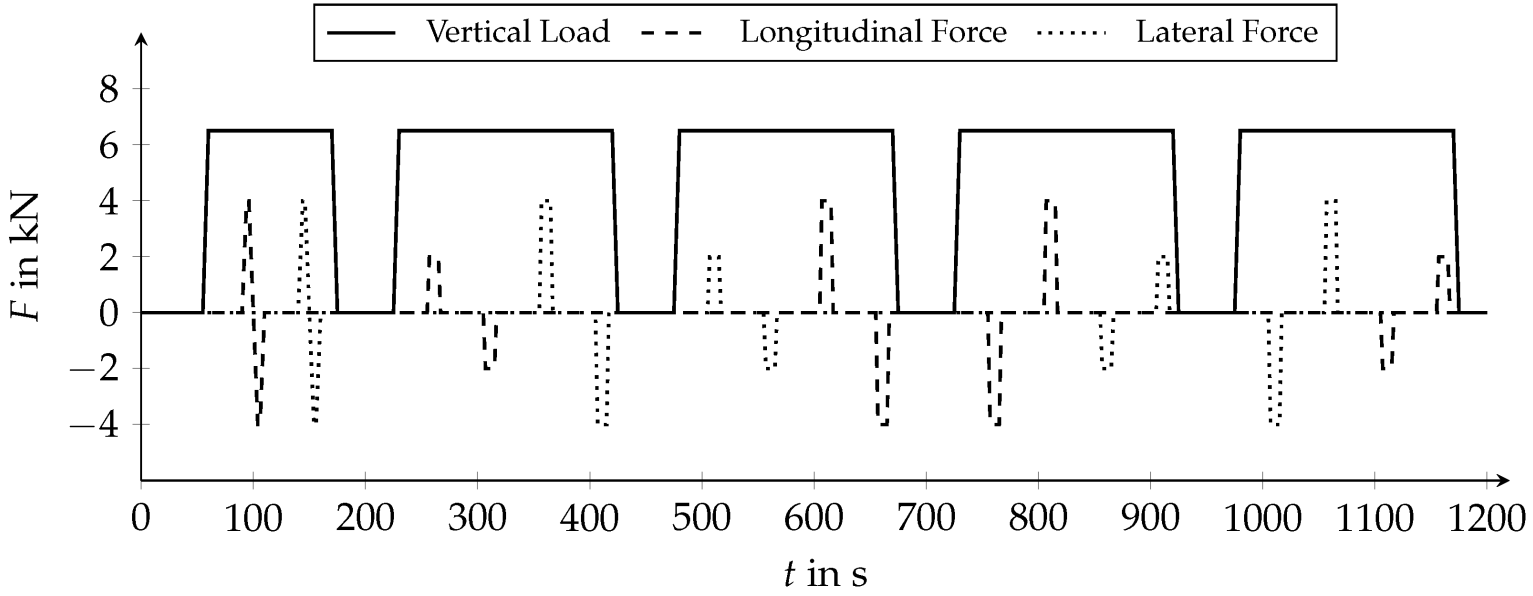
Force events result in peaks in particulate emissions

Source right figure:
[5] Haugen, M. et al.: Method development and analysis of nanoparticle size fractions from tire-wear emissions Environmental Science: Atmospheres. 2024 doi:10.1039/D4EA00048J

Test procedure
Realistic load profile - Video

Gießler, M.; Bühler, P.: Tire wear and tire-road wear particle measurements at inner drum test benches of KIT. **Tire Technology Expo Conference in March 2025 - Hannover**

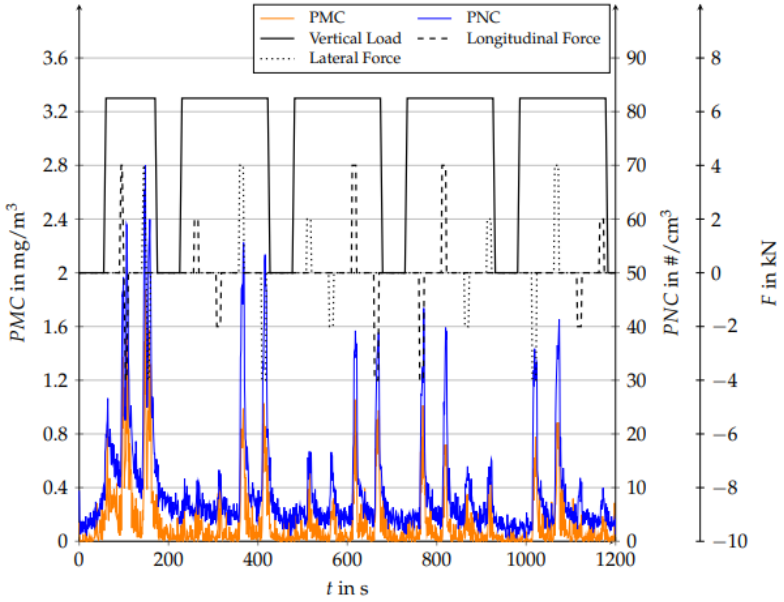
Test procedure
Single load points



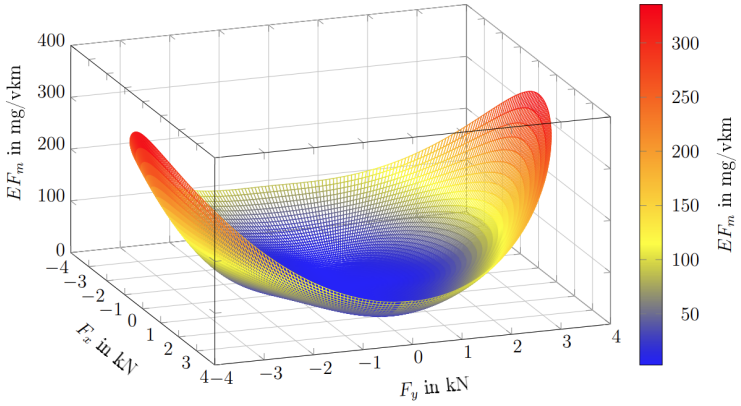
Source: [6] Schläfle, S. et al.: Influence of Longitudinal and Lateral Forces on the Emission of Tire–Road Particulate Matter and Its Size Distribution[J]. Atmosphere, 2023, 14(12): 1780

Test procedure
Single load points

Real-time PM emission analysis



Post processing

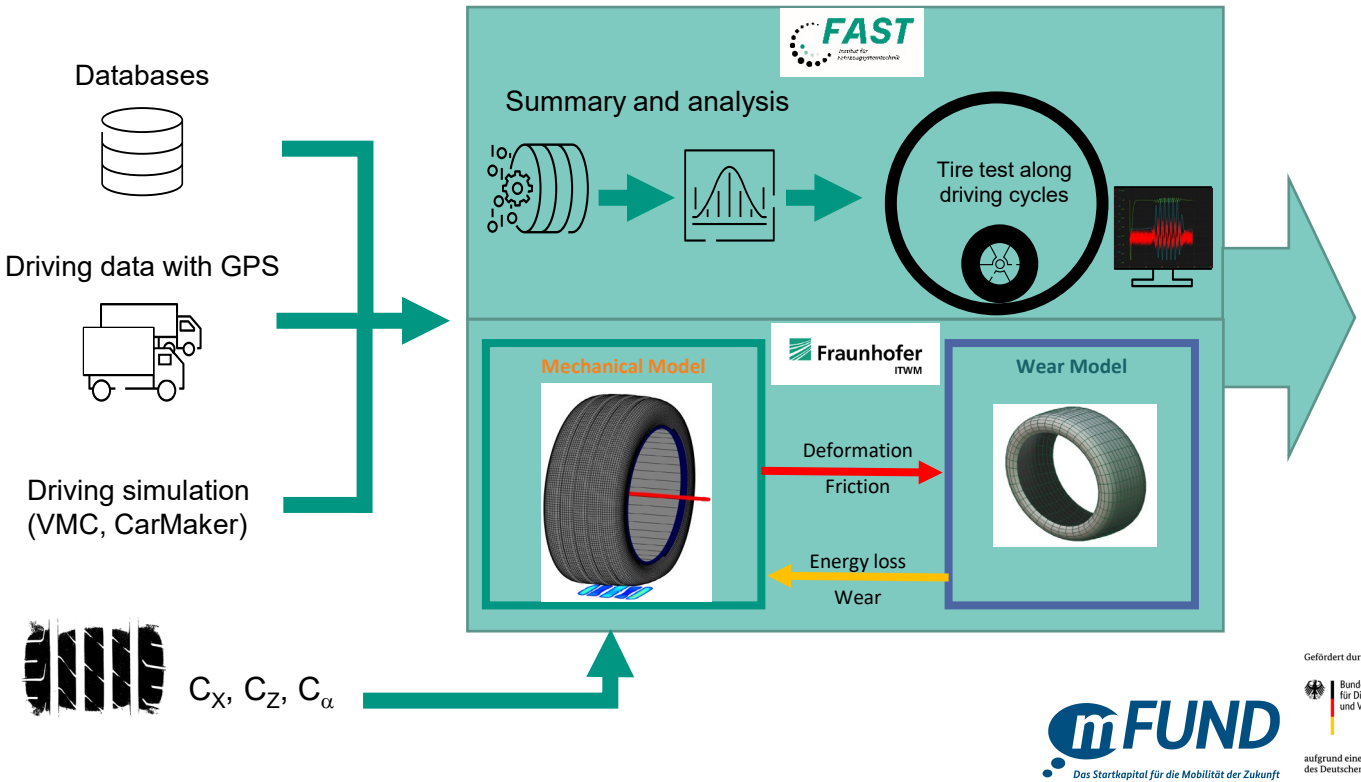


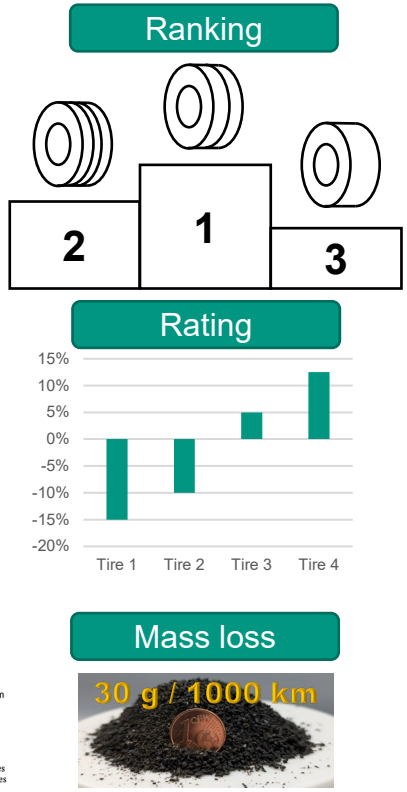
PMC : In mass PNC : In number

Source: [6] Schläfle et al.: Influence of Longitudinal and Lateral Forces on the Emission of Tire–Road Particulate Matter and Its Size Distribution. *Atmosphere*, *14*(12), 1780. https://doi.org/10.3390/atmos14121780

RAMUS

Prediction of tire abrasion in condensed operating cycles by combination of tests and simulation





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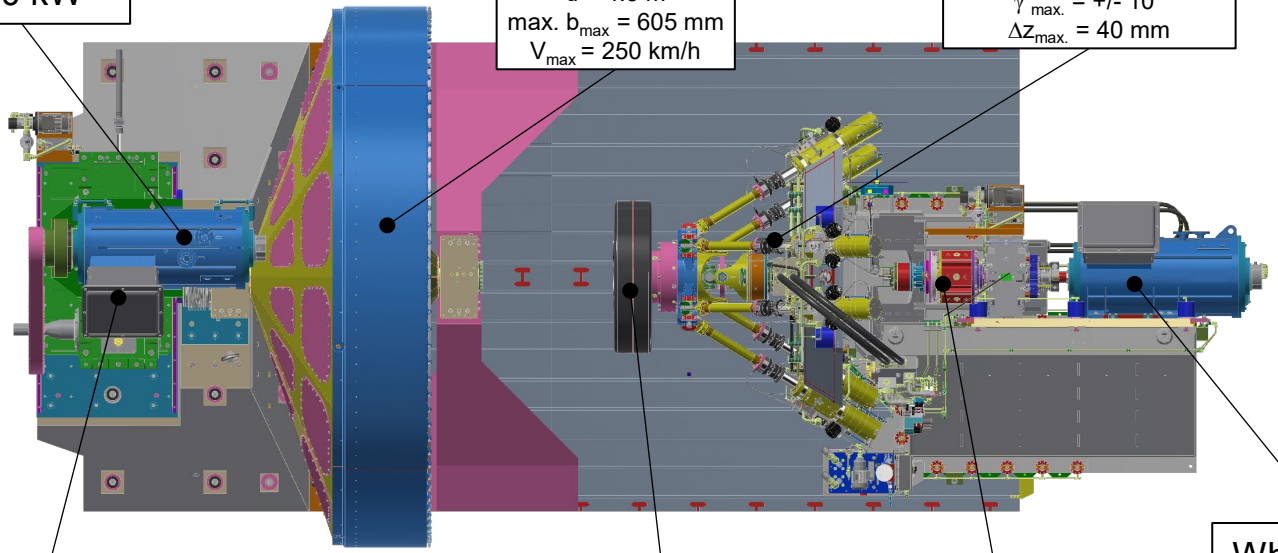
Das Startkapital für die Mobilität der Zukunft

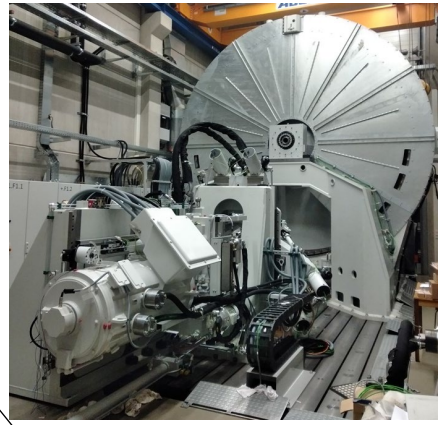
Inner Drum Test Bench
for dynamic actuation and truck tire loads

Drum drive
630 kW

Drum
d = 4.5 m
max. b_{max} = 605 mm
V_{max} = 250 km/h

Hexapod
a_{z_max} = 1.1 m/s²
$f_{max.}$ = 30 Hz
$\alpha_{max.}$ = 15°
$\gamma_{max.}$ = +/- 10°
$\Delta z_{max.}$ = 40 mm





Transmission

Test object:
Truck / PLT Tire
$r_{dyn\ max.}$ = 650 mm

Transmission

Wheel drive
630 kW

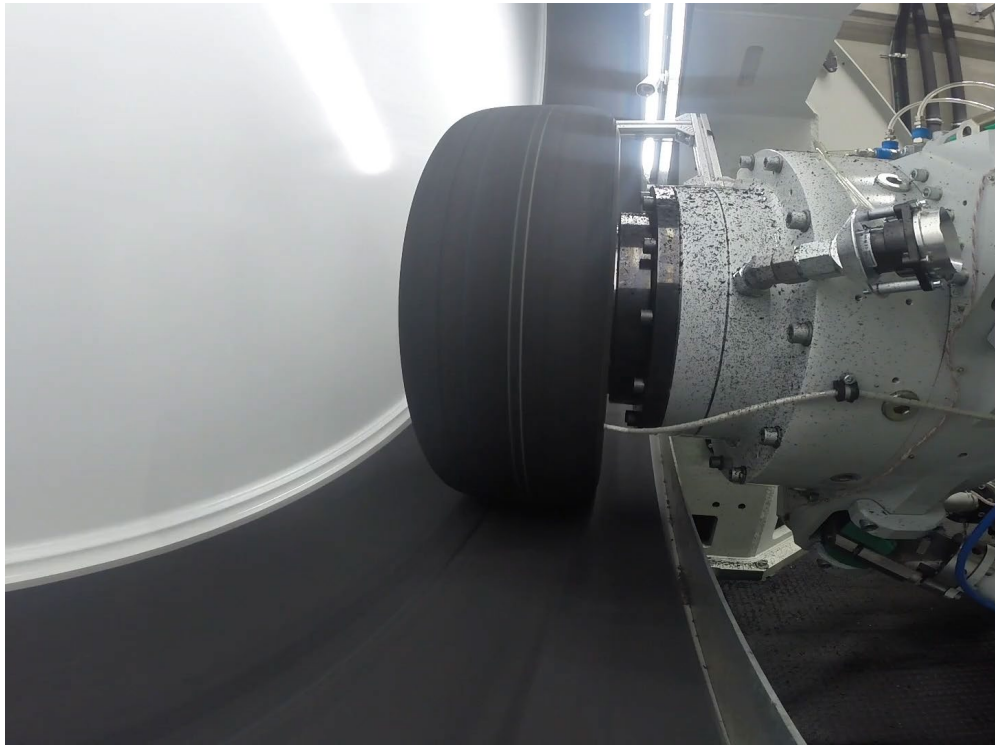
d = inner diameter
b = track width

Source of CAD picture: Inova GmbH.

Gießler, M.; Bühler, P.: Tire wear and tire-road wear particle measurements at inner drum test benches of KIT. **Tire Technology Expo Conference in March 2025 - Hannover**

Institut für Fahrzeugsystemtechnik
Institutsteil Fahrzeugtechnik

Inner Drum Test Bench
for dynamic actuation and truck tire loads



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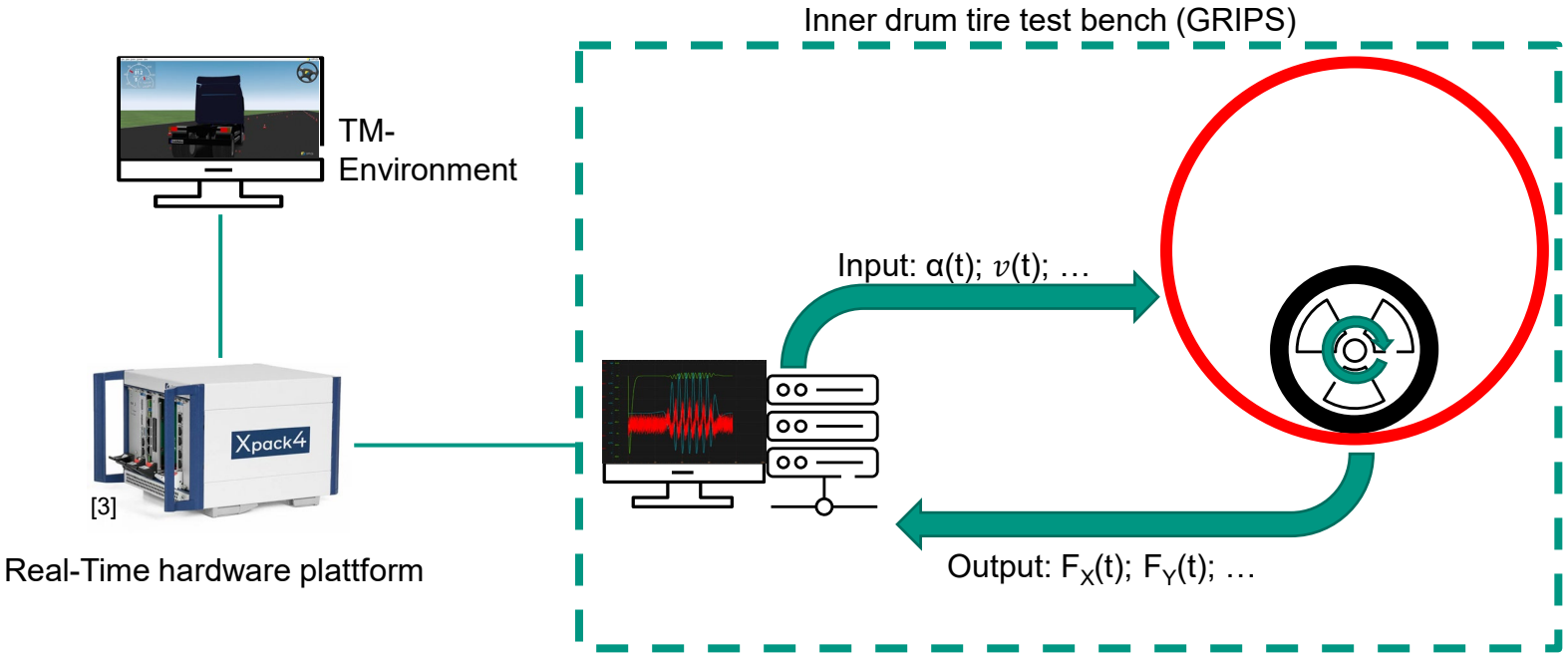
Tire-in-the Loop
Setup



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Conclusion

- Tyre and road wear particles (TRWP) can be generated under reproducable test conditions at KIT‘s inner drum test benches.
- Track type can be selected.
- Different methods to analyse TRWP are available. Selected results had been published.
- Within the project RAMUS a noval method to predict tire wear rate based on simulation and tests will be developed.

Reference

1. Foitzik M J, Unrau H J, Gauterin F, et al. Investigation of ultra fine particulate matter emission of rubber tires[J]. Wear, 2018, 394: 87-95.

2. PALAS GmbH: Promo 2000. https://www.palas.de/product/promo2000 visited 2025-02-03

3. Dekati: Dekati® ELPI®+ (Electrical Low Pressure Impactor) https://dekati.com/products/elpi/ visited 2025-02-03

4. J. Pinay, Y. Saito, C. Mignot, and F. Gauterin. Understanding the contribution of groove resonance to tire-road noise on different surfaces under various operating conditions. Acta Acustica, 4(2):6, 2020.

5. Haugen, M.; Bühler, P.; Schläfle, S.; O'Loughlin, D.; Saladin, S.; Giorio, C.; Boies, A.: Method development and analysis of nanoparticle size fractions from tire-wear emissions Environmental Science: Atmospheres. 2024.

6. Schläfle S, Unrau H J, Gauterin F. Influence of Longitudinal and Lateral Forces on the Emission of Tire–Road Particulate Matter and Its Size Distribution[J]. Atmosphere, 2023, 14(12): 1780.

7. Schläfle S, Unrau H J, Gauterin F. Influence of Load Condition, Tire Type, and Ambient Temperature on the Emission of Tire–Road Particulate Matter[J]. Atmosphere, 2023, 14(7): 1095.

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9. Schläfle S, Zhang M, Unrau H J, et al. Influence of Vertical Load, Inflation Pressure, and Driving Speed on the Emission of Tire–Road Particulate Matter and Its Size Distribution[J]. Atmosphere, 2024, 15(4): 502.

Contact
Tire tests

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