

Test Equipment for tire related research

Institute of Vehicle System Technology
Chair of Vehicle Science

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Content

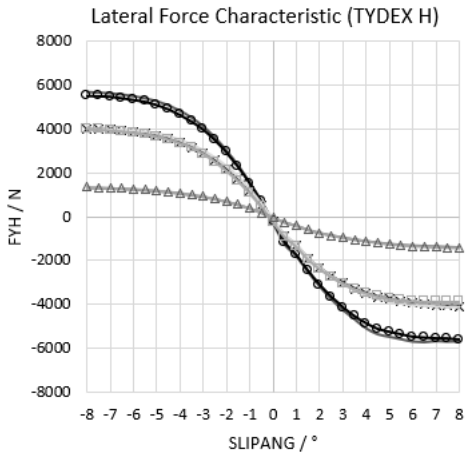
- Research Group Tire, Wheel and Road Surface
- Internal drum Test Bench (IPS)
- Large-Scale internal drum test bench for dynamic tests of PLT and truck tires (GRIPS)
- Grip- and Abrasion Teststand (GAT)
- Vehicle test benches
  - Vehicle in the Loop Test Bench (ViL)
  - Acoustic 4WD Chassis Dyno (AARP)
- Special Equipment

Chair of Vehicle Science
Research Group Tire, Wheel and Road Surface

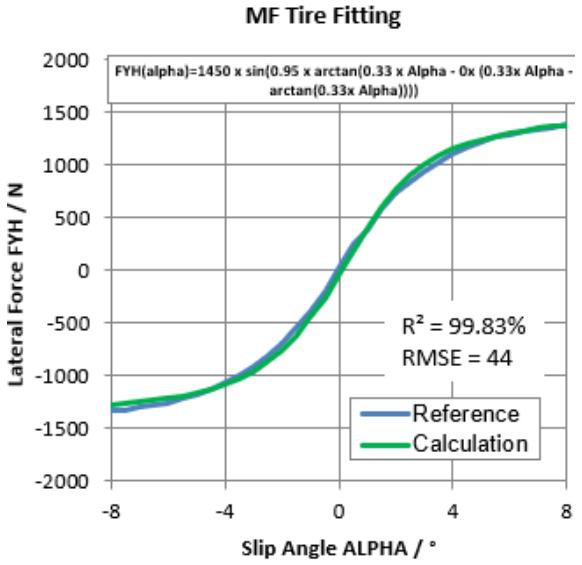
Tool chain of research group:



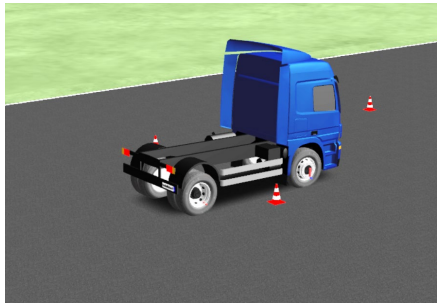
Tire and rubber sample tests



Data Analysis



Model Parametrization



Vehicle Simulation

From data generation to vehicle simulation

Fotos: KIT, FAST

Tire and rubber sample tests
Overview: Tire Test Benches

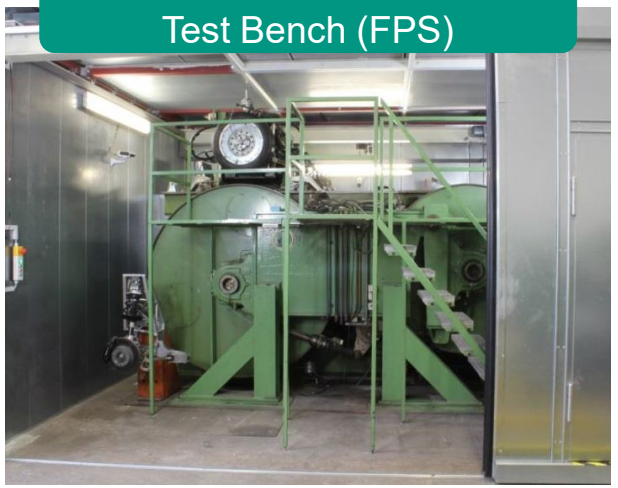
Internal Drum Test Bench (IPS)



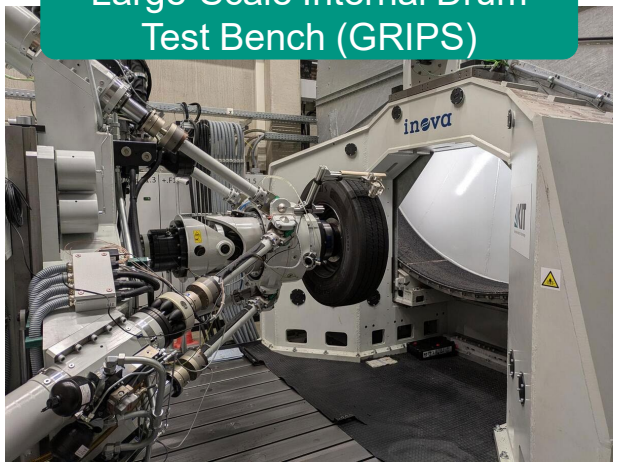




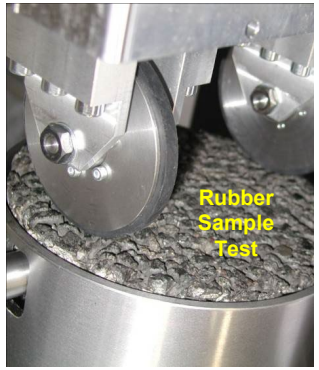
Flat Track and Outer Drum Test Bench (FPS)



Large-Scale Internal Drum Test Bench (GRIPS)





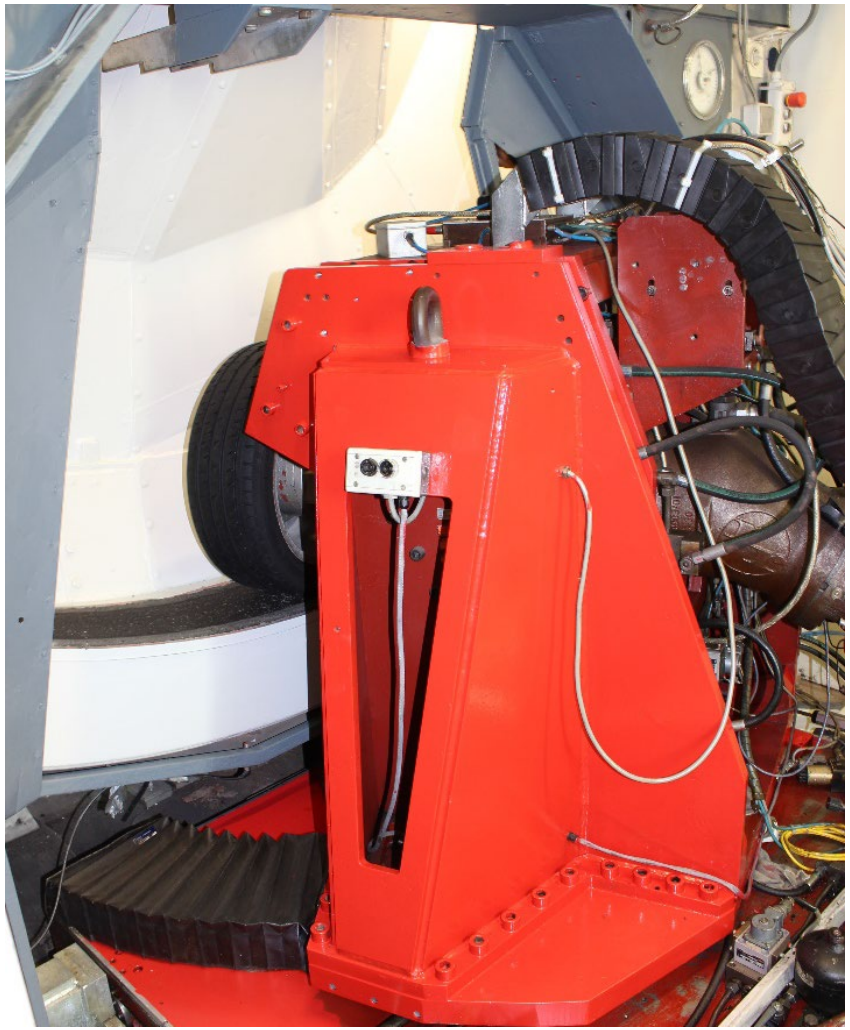


Grip- and Abrasion Teststand (GAT)



Internal Drum Test Bench (IPS)

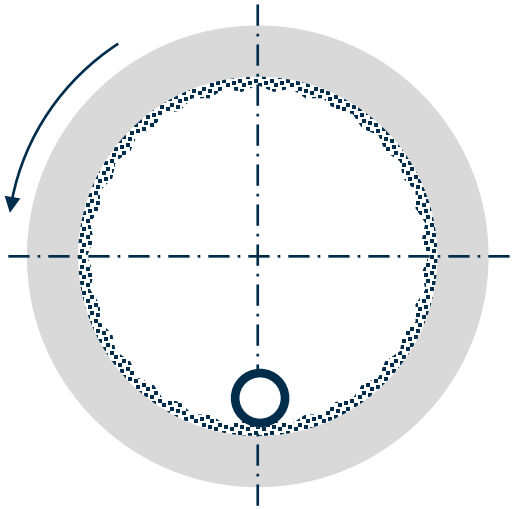
Internal Drum Test Bench (IPS)
Technical Specification

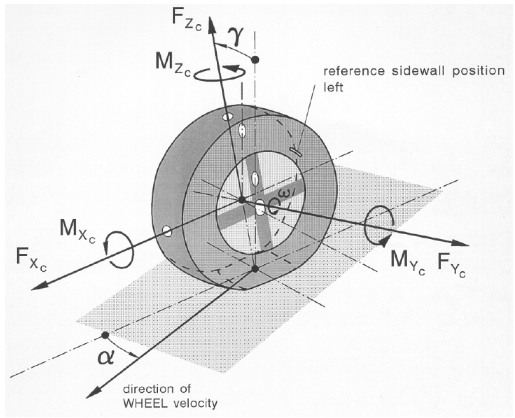


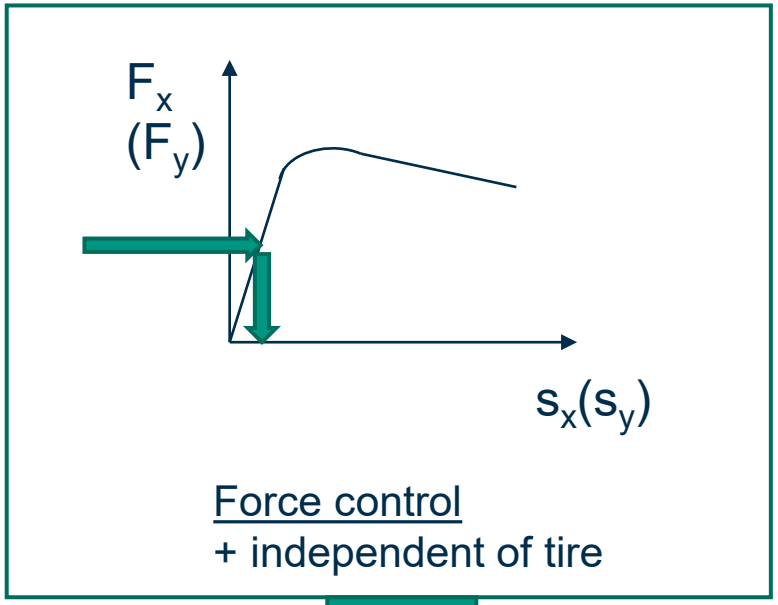
Parameter	Value
Drum inner diameter	3.8 m
Track types	Safety-Walk, Concrete, Asphalt (AC11 oder SMA)
Special track conditions	wet road, hard packed snow layer, icy road
Max. Speed	200 km/h (without track) 150 km/h (with installed track)
Max. Tire dimensions	max. Radius: 450 mm max. width: 310 mm
max. load	max. wheel load: 15 kN; max. aligning torque: 1.5 kNm max. drive torque: 1.6 kNm; max. brake torque: 1.8 kNm
Slip angle	-20° ... +20°
Camber angle	-10° ... +20° (+20° ... +45°)
Ambient temperature	-20 ... +30 °C

Link to Website

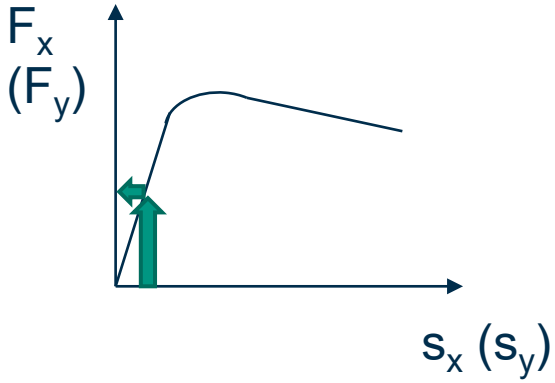
Control method: Force Control



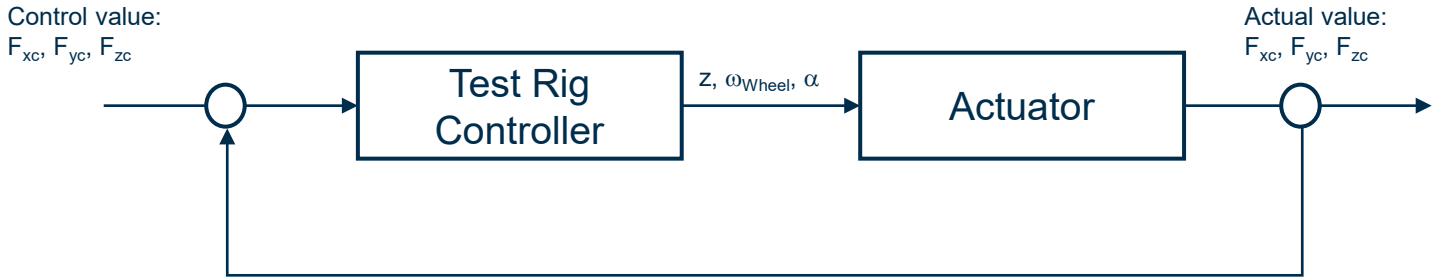




Force control
+ independent of tire



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



Internal Drum Test Bench (IPS)
Test tracks



Asphalt AC 11



Washed
concrete track



Concrete track



Safety Walk

Internal Drum Test Bench (IPS)
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

Internal Drum Test Bench (IPS)
Special track conditions

Wet road



Snow

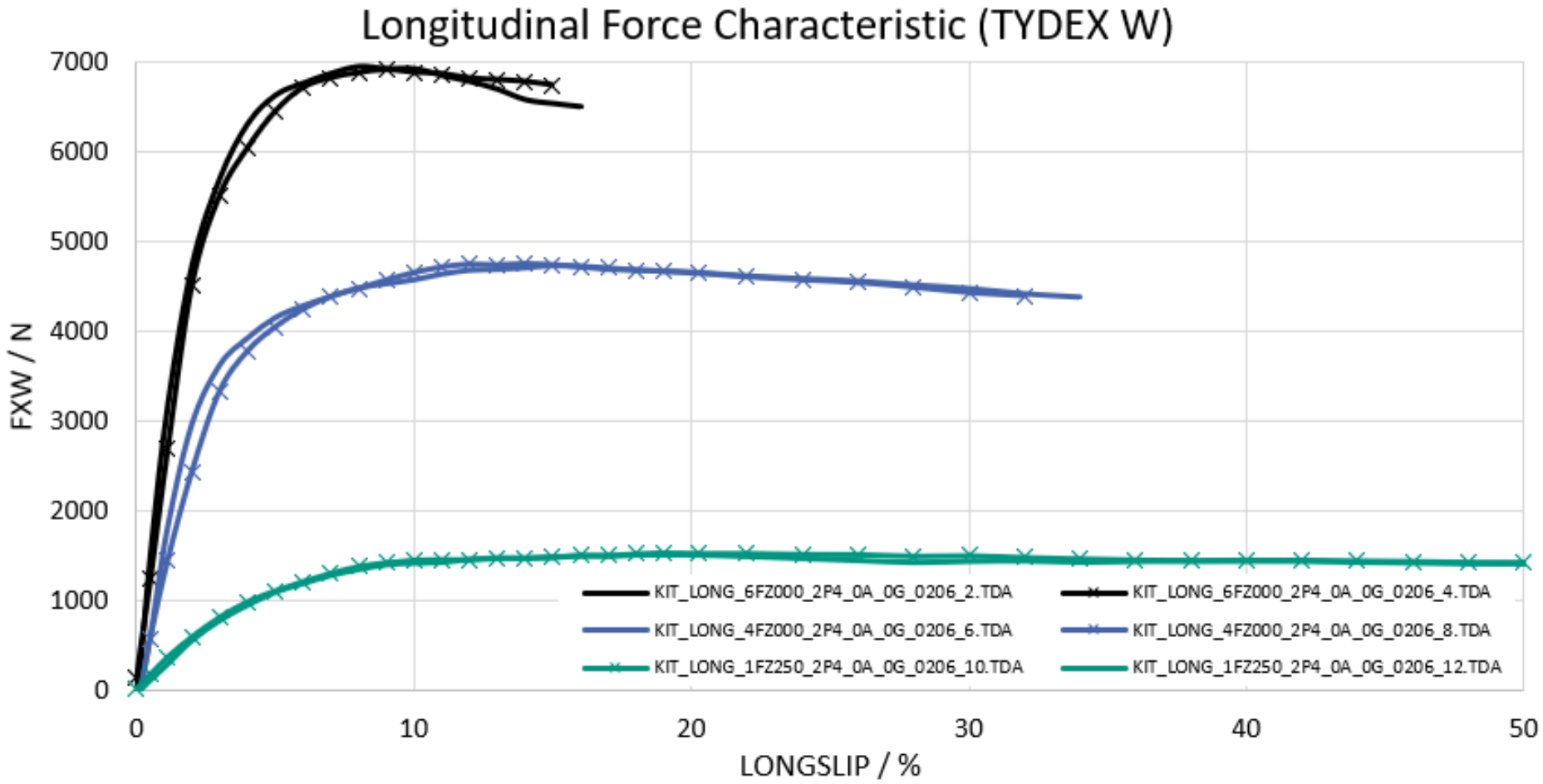


Ice



Literature:
Phd Thesis M. Gießler: Mechanismen der Kraftübertragung des Reifens auf Schnee und Eis, 2011
Phd Thesis H. Fischlein: Untersuchung des Fahrbahnoberflächeneinflusses auf das Kraftschlußverhalten von Pkw-Reifen, 2000

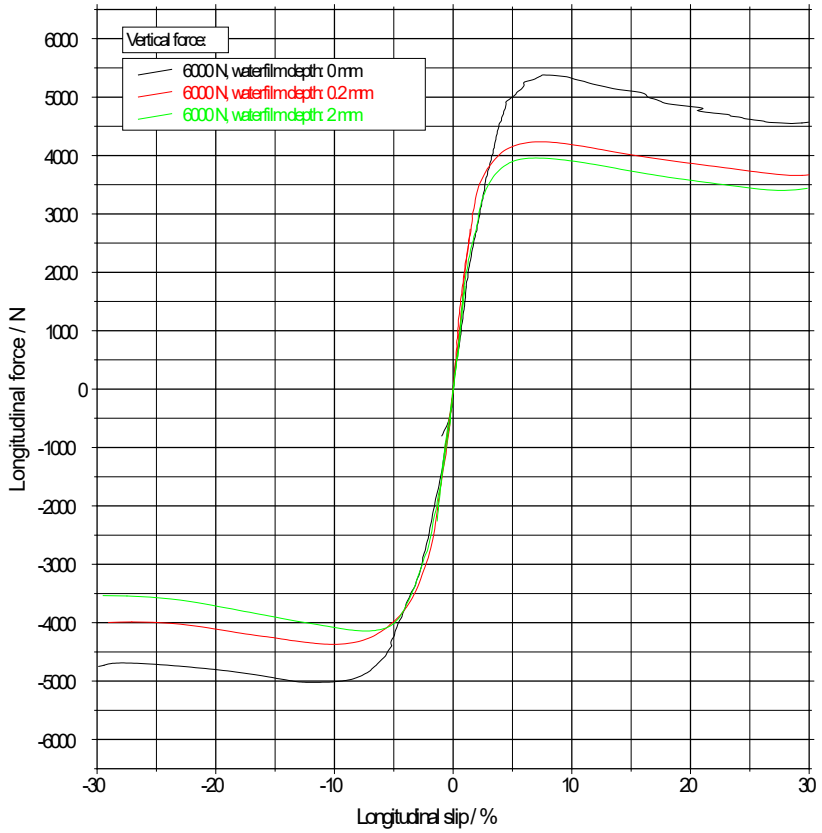
Internal Drum Test Bench
Longitudinal Force Measurements



Source: Dataset of Various Road Measurements on Concrete Surfaces

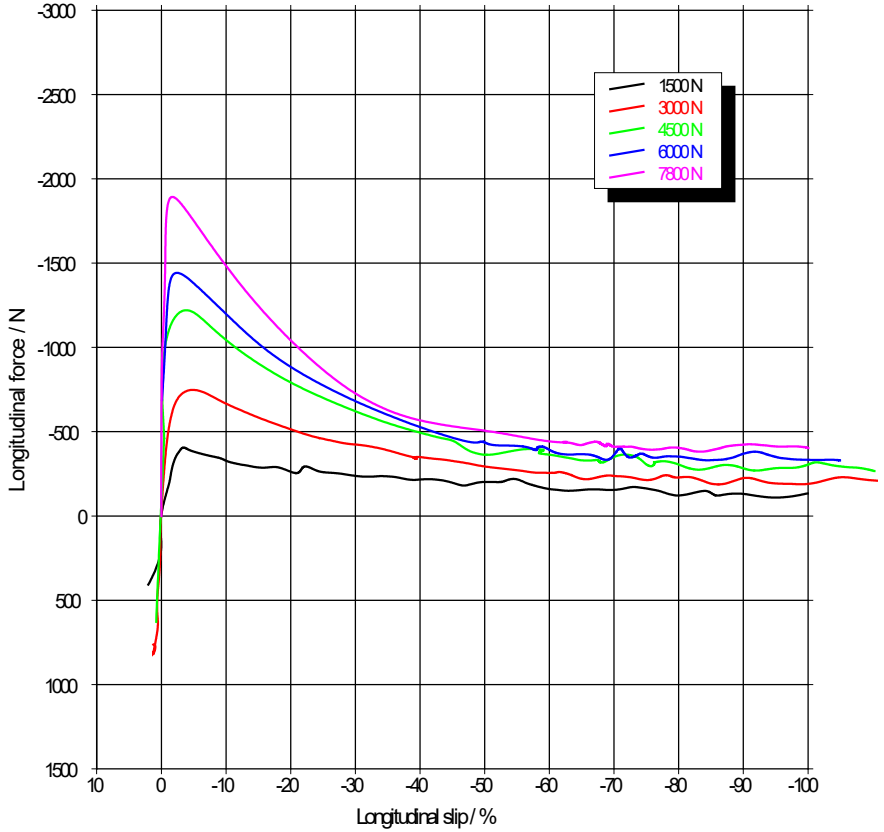
Internal Drum Test Bench (IPS)
Measurements on Wet Track Surface

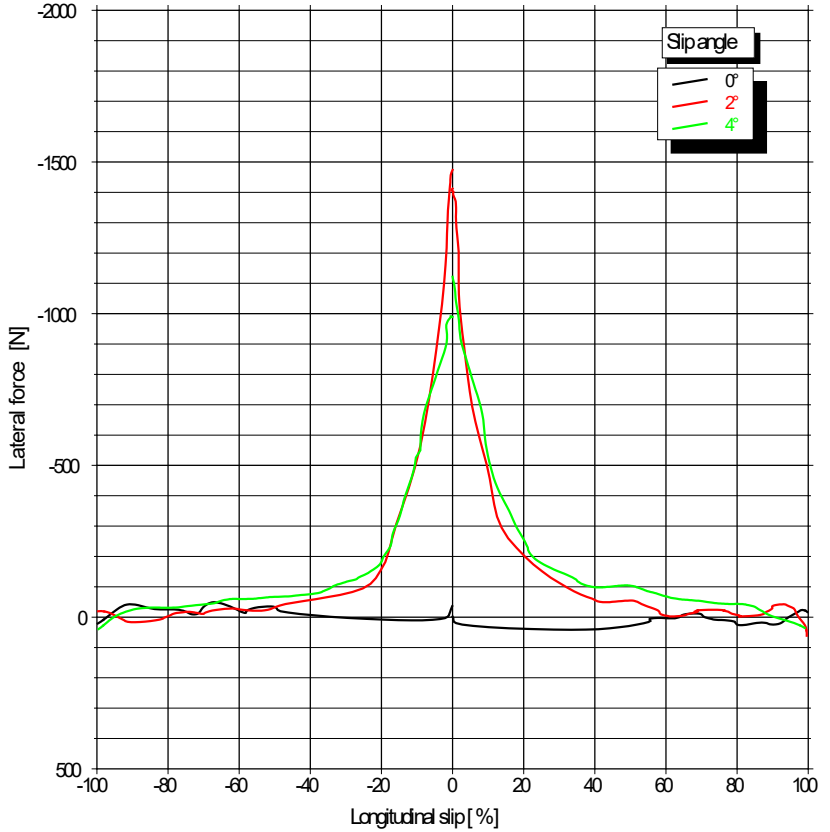




Manufacturer	:	Velocity	: 80 km/h
Tyre size	:	Inflation pressure	: 2,6 bar
Rim size	: 6,0 x 15	Slip angle	: 0°
		Waterfilm depth	: 0 / 0.2 / 2 mm
		Vertical force	: var.

Internal Drum Test Bench (IPS)
Measurements on Snow and Ice Surfaces





Manufacturer	:	Velocity	: 80 km/h	Manufacturer	:	Velocity	: 80 km/h
Tyre size	:	Slip angle	: 0°	Tyre size	:	Slip angle	: variabel
Rim size	: 6,5 x 15	Track surface	: Ice	Rim size	: 6,5 x 15	Track surface	: ice
Inflation pressure	: 2,4 bar	Ambient temperature	: -10 °C	Inflation pressure	: 2,4 bar	Ambient temperature	: -10 °C
		Vertical force	: variabel			Vertical force	: 6000 N

Internal Drum Test Bench (IPS)
Measurements for Tire Comfort Models

- **Rolling over Cleats**



Changeable Pavement

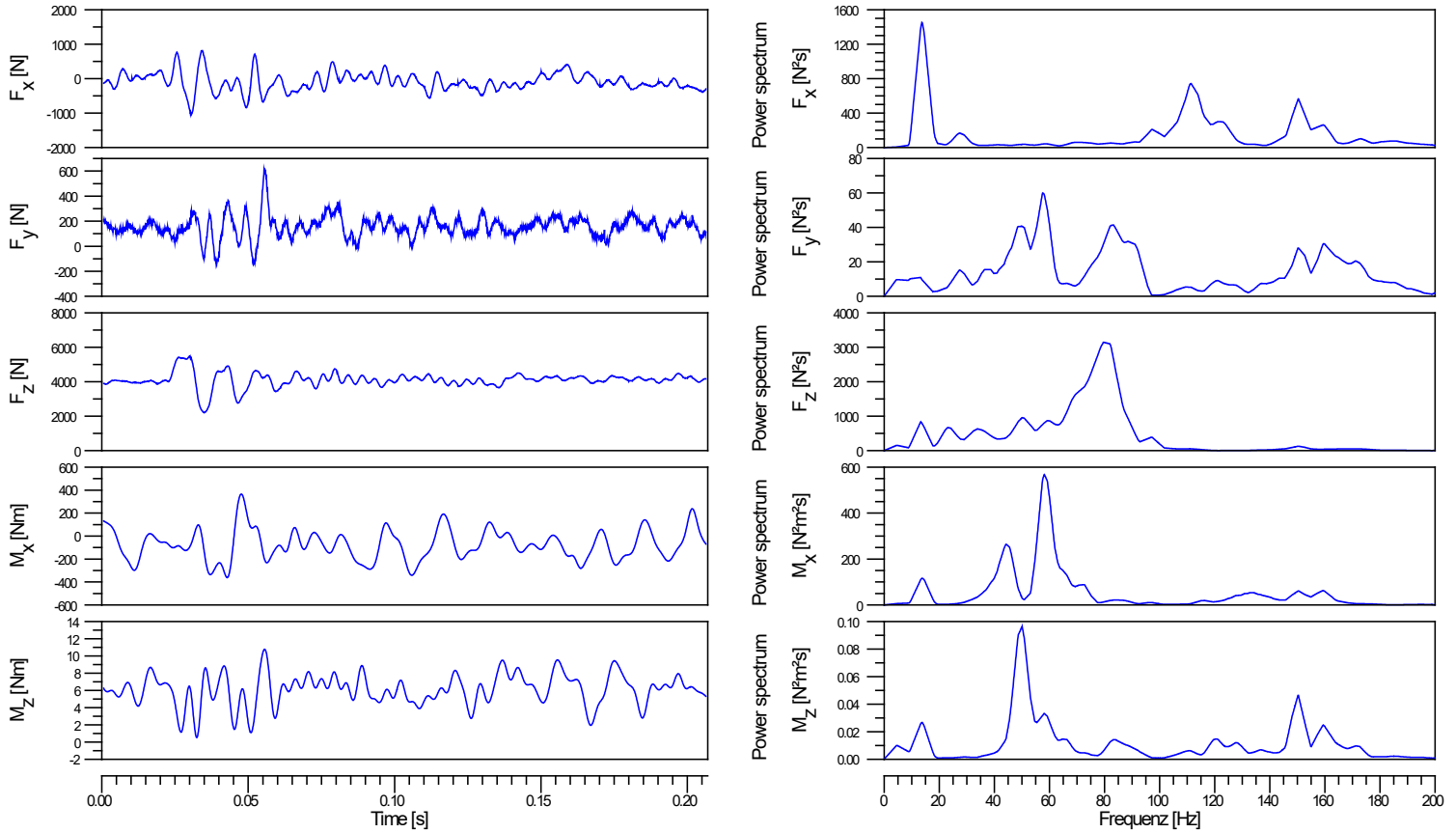
and

changeable cleats



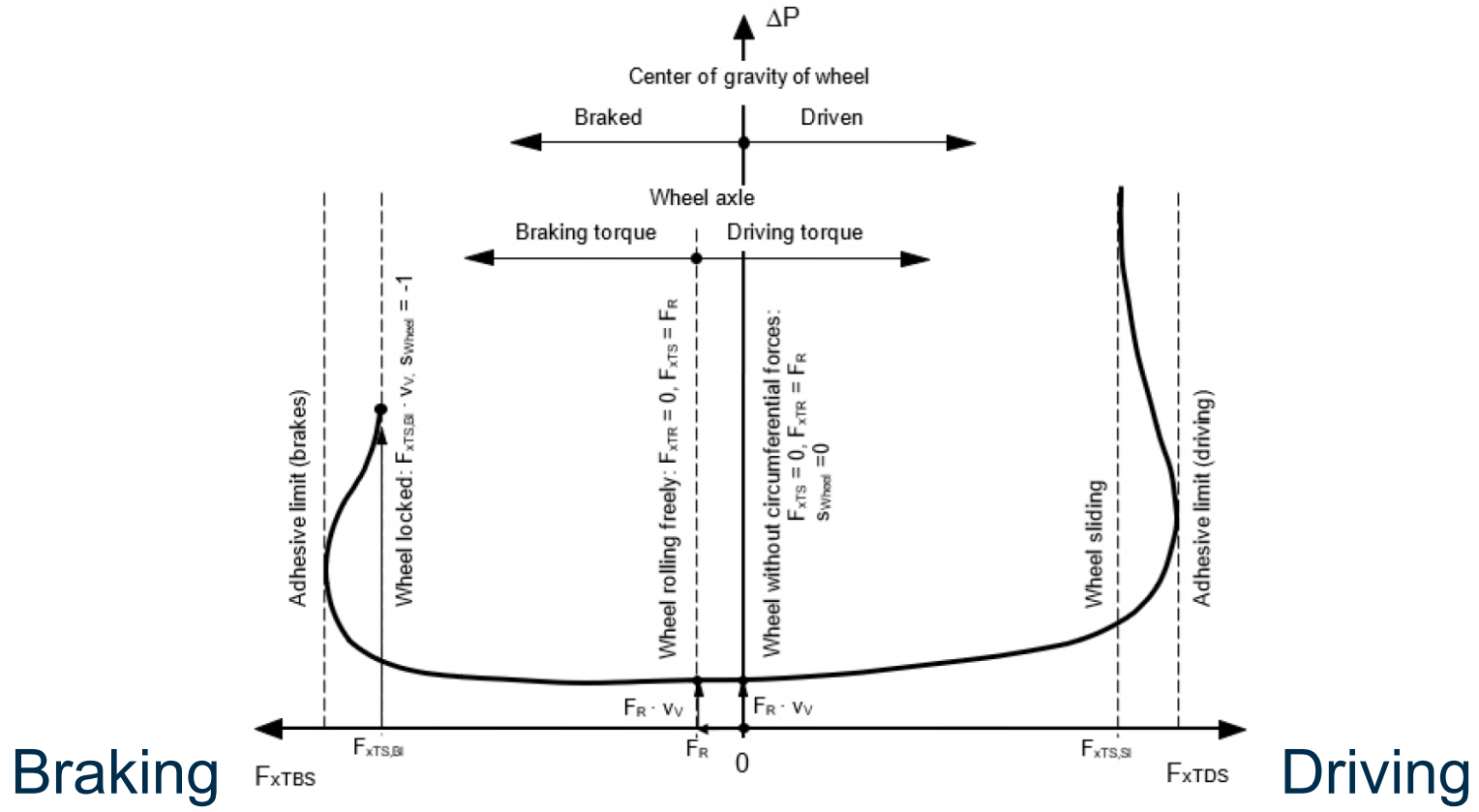
Internal Drum Test Bench (IPS)
Measurements for Tire Comfort Models

- **Rolling over cleats: Measurement of Forces and Moments**



Manufacturer	:	Vertical force	: 4.000 N
Tyre size	:	Velocity	: 100 km/h
Form of cleat	: Batten	Inflation pressure	: 2.2 bar
		Slip angle	: 0°

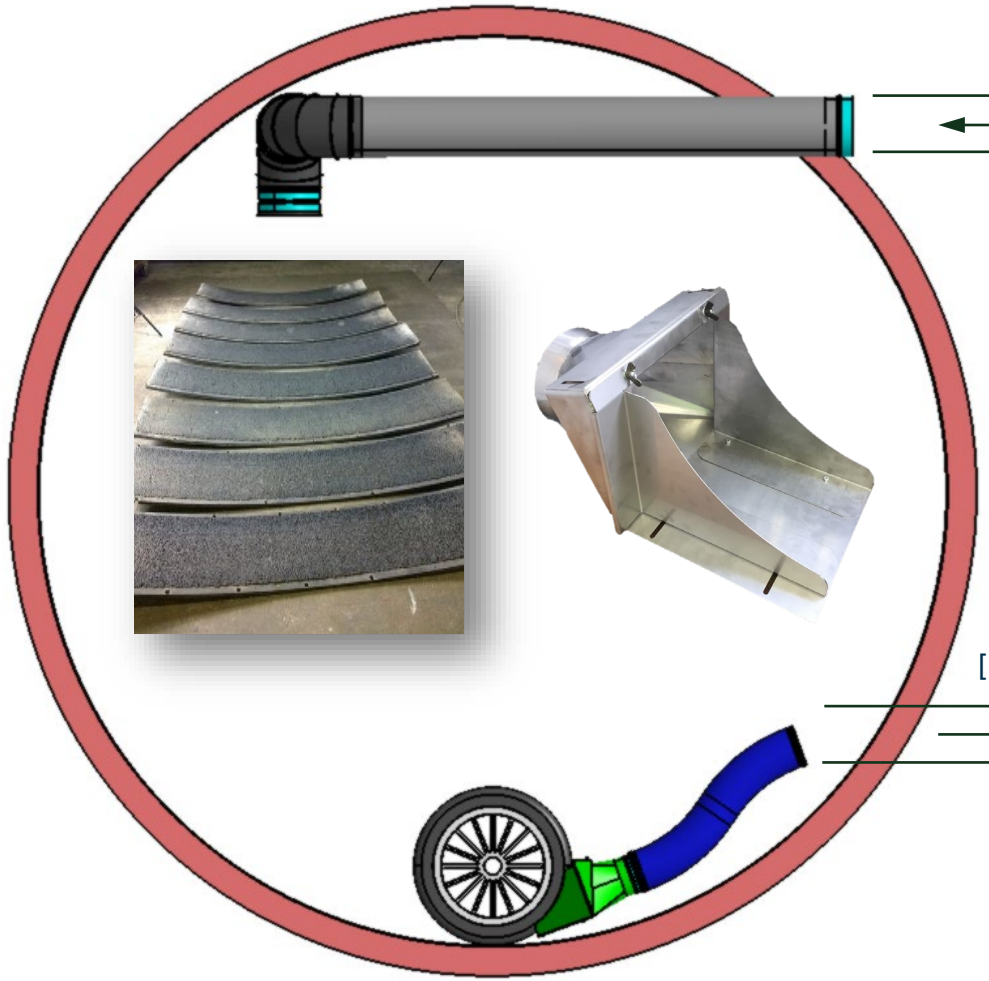
Internal Drum Test Bench
Power loss



$$\Delta P = [F_R \cdot (1 + s_{wheel}) + F_{xTS} \cdot s_{wheel}] \cdot v_v$$

with F_R Rolling Resistance; Longitudinal Drive/Brake Force F_{XTS}

Internal Drum Test Bench (IPS)
Setup for tire emission measurement





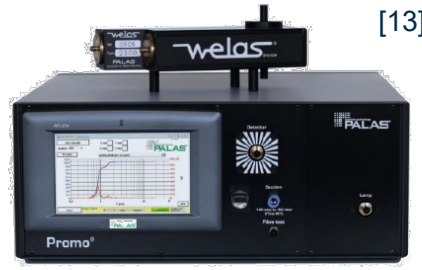
[14]

[12]



Aerosol spectrometer	
Particle number, size and distribution	
Rate	1 Hz
Range	0,2 – 100 µm

[13]



Suction System

Incl. integrated filter

Secundary air

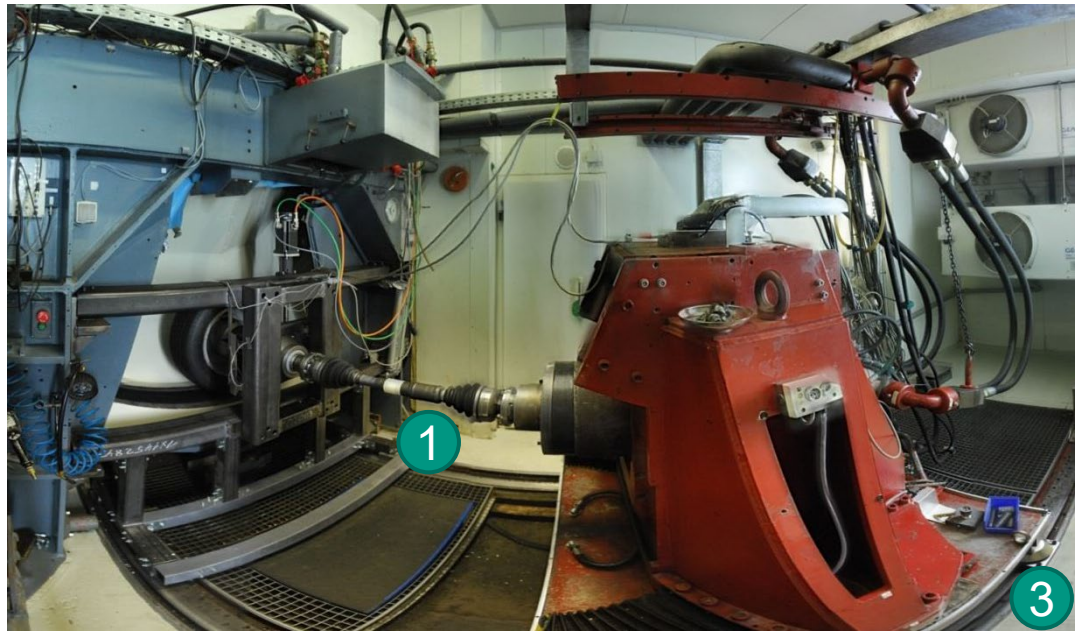
Sample collection

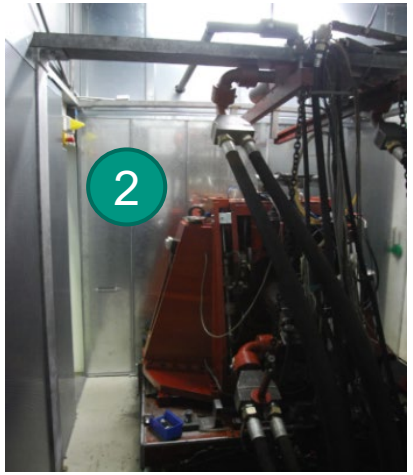
Particle Measurement

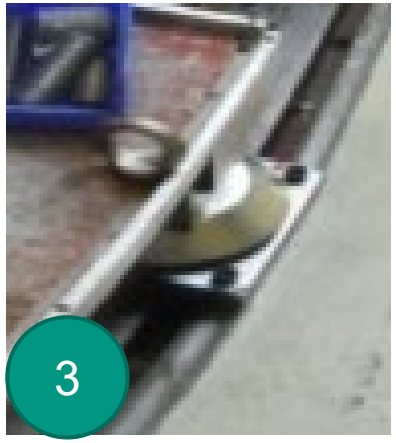


Schläfle, S. et al.: Experimentelle Untersuchung der Reifen-Fahrbahn-Feinstaubemission von Premium-Sommerreifen am Innentrommelprüfstand

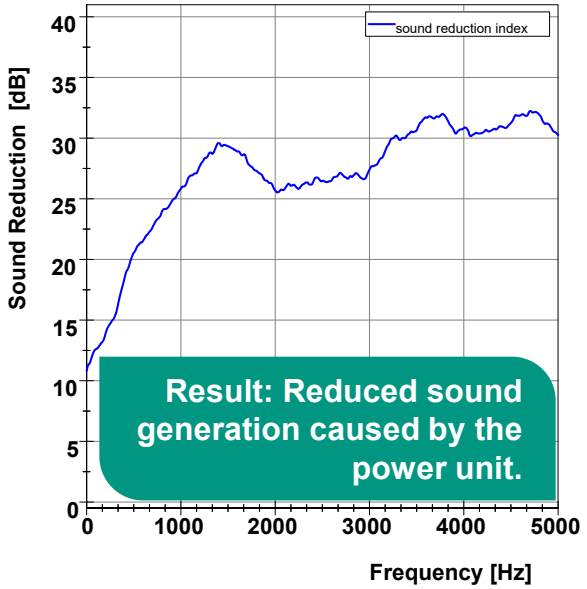
Internal Drum Test Bench (IPS)
Setup for Acoustic Tests





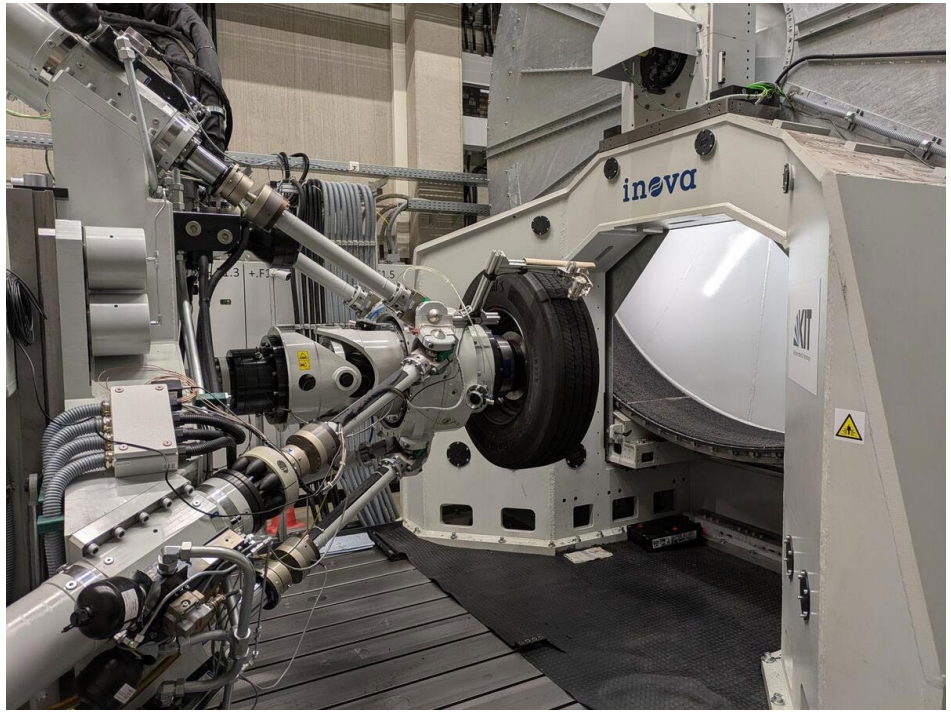


1. Drive shaft is decoupled mechanically by elastic flexible disc.
2. Acoustic dividing wall: Subdivision of the test rig into a measuring cabin and a cabin for the power unit.
3. Solid-borne sound reduction: wheelhouse with the hydraulic motor is placed onto dampening mounting feet
4. Applying the wheel force through an electrically driven ball screw
5. Absorption modules ensuring a semi-anechoic space



Large-scale internal drum test bench (GRIPS)

Large-scale internal drum test bench (GRIPS) for dynamic tests of PLT and truck tires

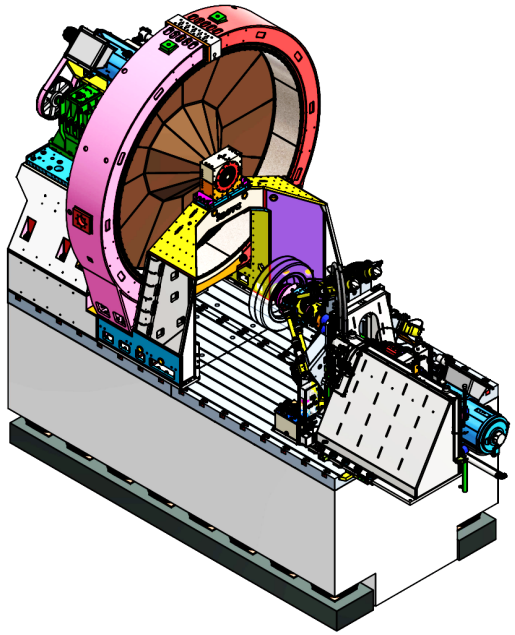


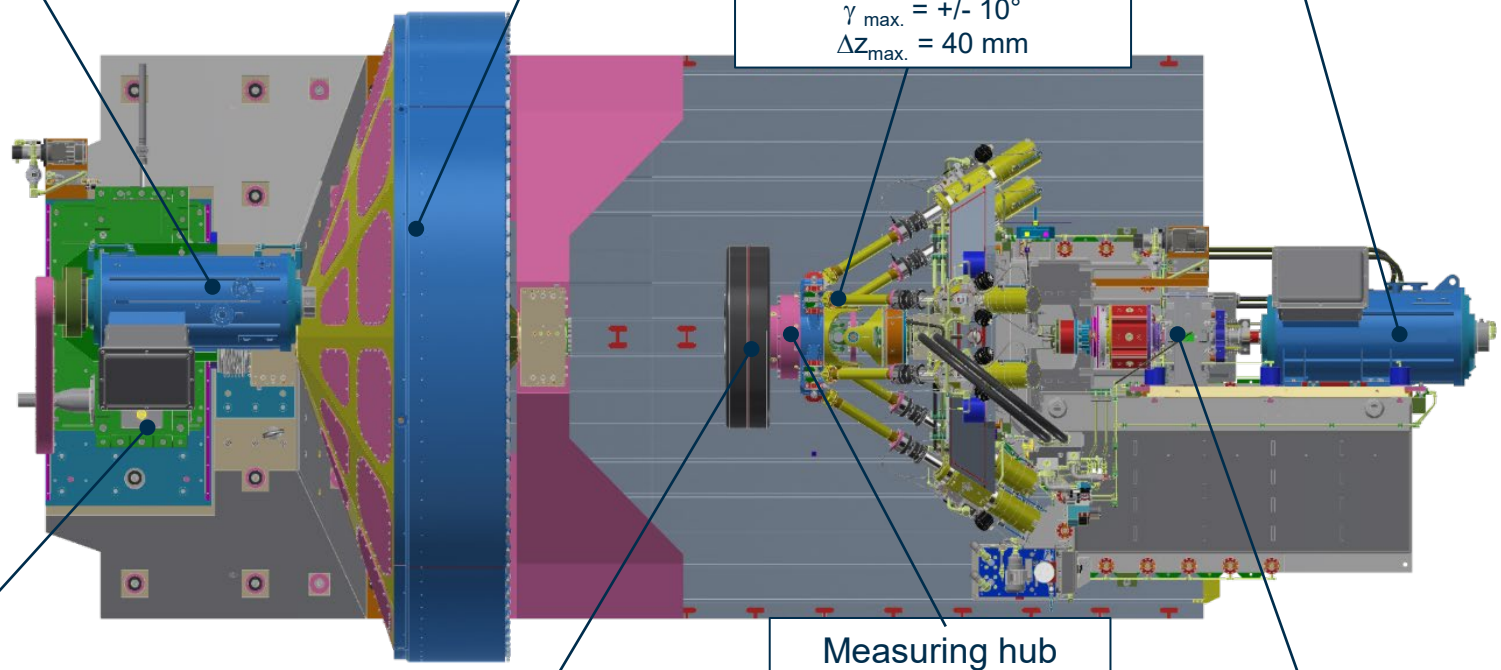


Large-scale research equipment funded by the German Research Foundation (DFG)

Link to Website

Large-scale internal drum test bench (GRIPS) Technical Specification





d = Inner diameter of drum
b = width of track

Large-scale research equipment funded by the German Research Foundation (DFG)

Large-scale internal drum test bench (GRIPS) Technical Specification



Parameter	Value
Drum inner diameter	4.5 m
Track types	Safety-Walk, Asphalt (AC11 oder AC8)
Max. Speed	250 km/h (without track)
Max. Tire dimensions	max. radius: 538 mm max. width: 600 mm
max. load	max. wheel load: 60 kN; max. longitudinal force: 26 kN max lateral force: 40 kN
Slip angle	-15° ... +15°
Camber angle	-10° ... +10°
Ambient temperature	+20 ... +30 °C

Link to Website

Flat Track and Outer Drum Test Bench (FPS)

Flat Track and Outer Drum Test Bench (FPS)
Technical Specification

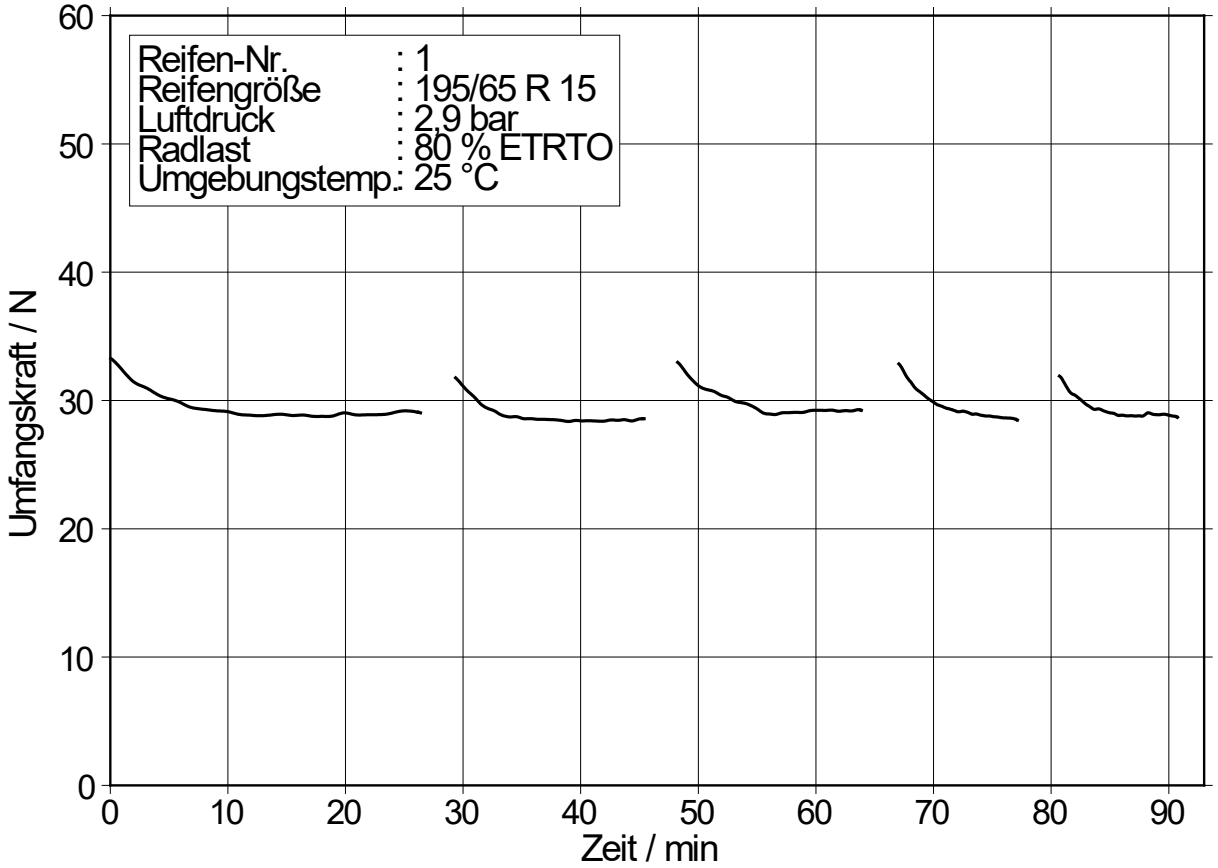






Parameter	Value
Outer diameter of drums	2 and 1.71 m
Max. Speed	300 km/h 250 km/h (flat steel belt)
Max. Tire dimensions	max. Radius: 400 mm max. width: 350 mm
max. load	max. wheel load: 10 kN; max. lateral and longitudinal force: 1 kN max. drive torque: 30 Nm; max. aligning torque: 300 Nm; max. camber torque: 1.2 kNm
Slip angle	-5° ... +5°
Camber angle	-10° ... +10°
Ambient temperature	+7 ... +40 °C

Flat Track and Outer Drum Test Bench (FPS)
Test result: Rolling Resistance Measurement - Repeatability

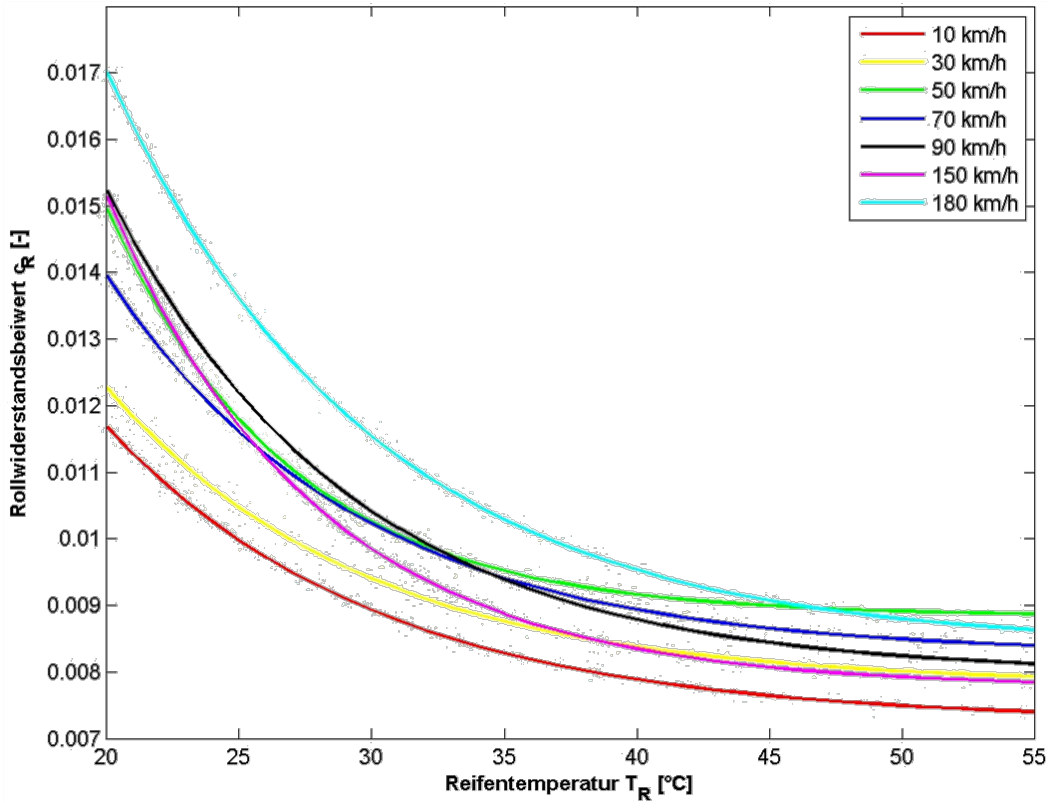


Flat Track and Outer Drum Test Bench (FPS)
Rolling Resistance Measurement – Dependencies

- Rolling resistance depends on
  - speed,
  - temperature,
  - road surface,
  - drive torque,
  - side slip,
  - weather condition, …

- Real life conditions differ from standardized test conditions (ISO 28580).

Developed method: Test method to predict tire temperature and rolling resistance in real drive cycles.



Literature:
Phd Thesis M. Greiner: Verfahren zur Prädiktion des Rollwiderstands bei variablen Betriebsparametern auf Basis standardisierter Rollwiderstandsmessungen

Phd Thesis H.-J. Unrau: Der Einfluss der Fahrbahnoberfläche auf den Rollwiderstand, die Cornering Stiffness und die Aligning Stiffness von Pkw-Reifen

Grip- and Abrasion Teststand (GAT)

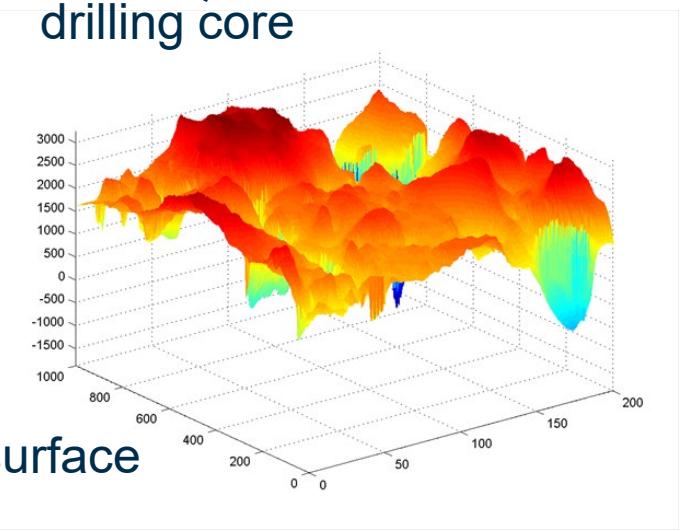
Grip- and Abrasion Teststand (GAT)

Rubber road friction test stand

- sliding and rolling samples
- adjustable side slip angle
- real and artificial road surfaces
- controlled speed
- controlled normal force
- vibration damping
- adjustable water flow & temperature
- measurement
  - lateral force
  - normal force



drilling core



3d profile of road surface



Grip- and Abrasion Teststand (GAT)

pneumatic cylinder, vertical load adjustment

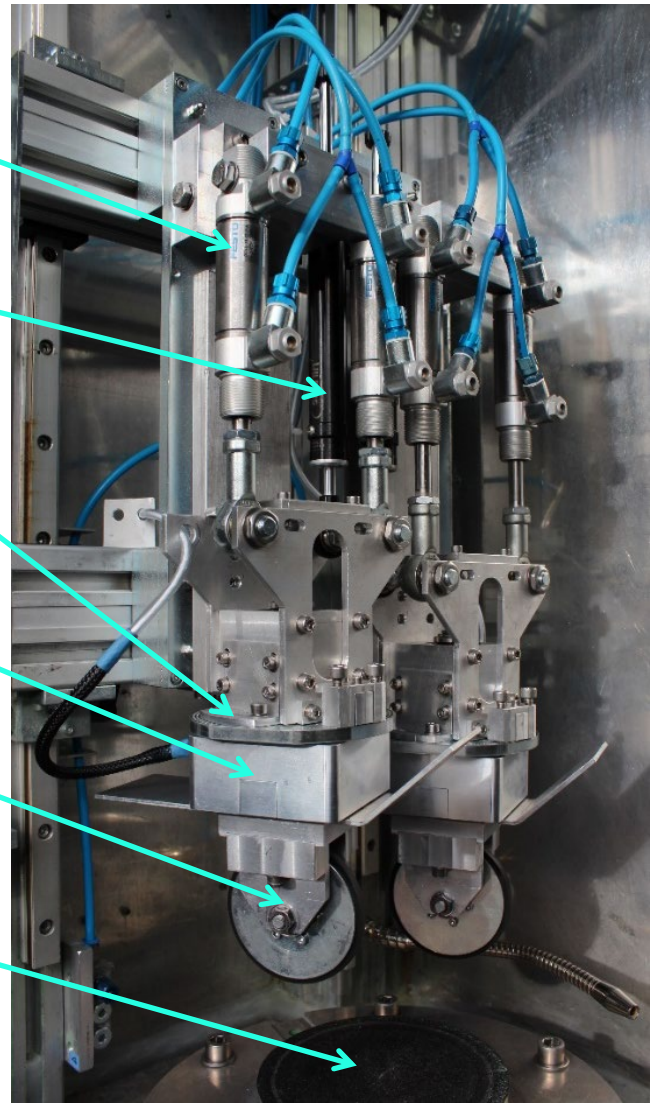
shock absorber

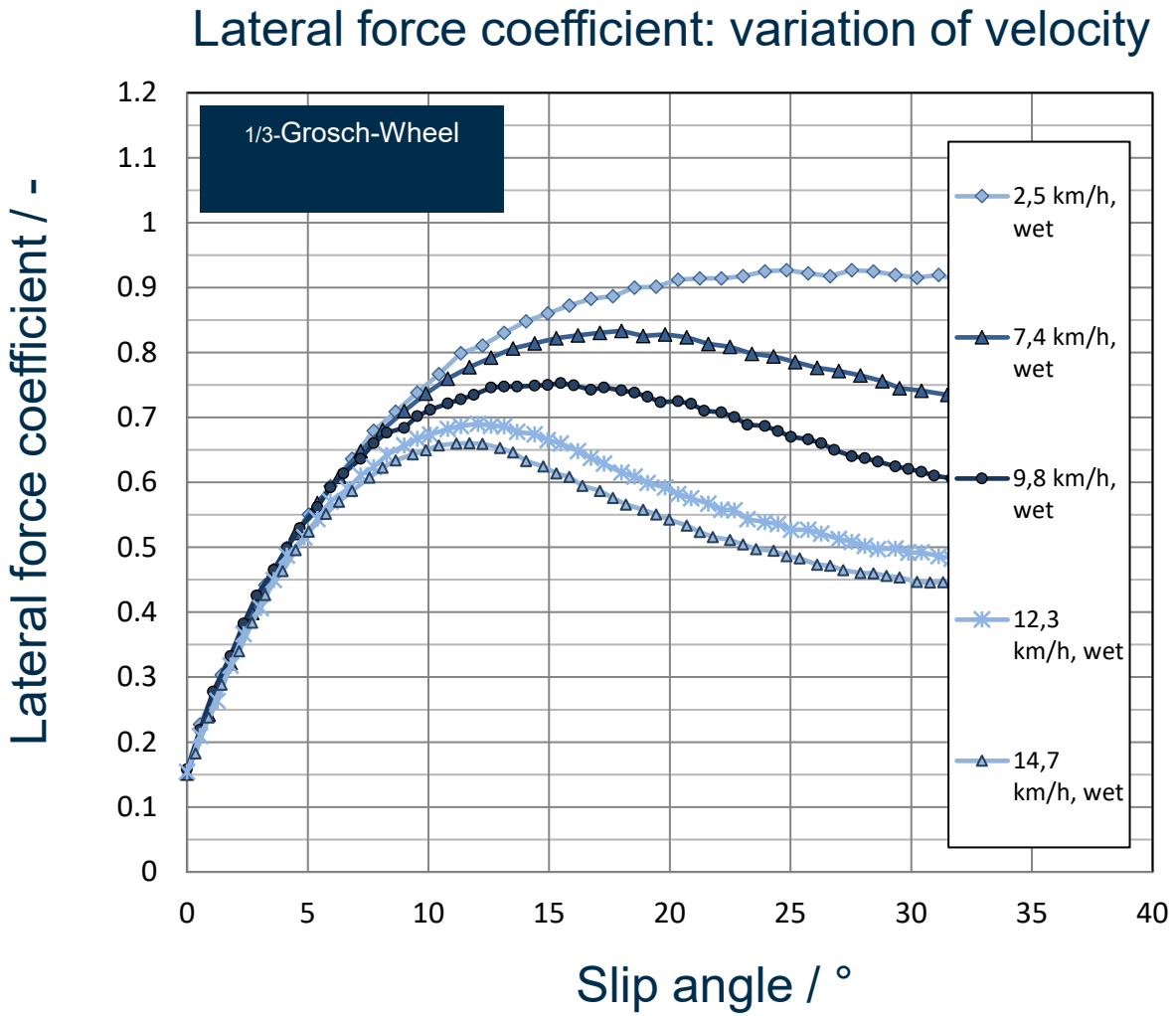
side slip angle adjustment

load cell

rubber sample fixation

rotating surface sample





Vehicle test benches

Vehicle in the Loop Test Bench (VIL)
Technical Specification



ViL with load engines (1), Aligning torque simulator (2), fan (3), inverter (4)

Parameter	Value
Max. Vehicle Weight	12 t
Max. Wheel Load	3 t
Wheel base	1.8 – 4.9 m
Track width	1.2 – 3.9 m
Max. wheel speed	2,000 min-1 (200...260 km/h)
Max. wheel load torque	2.5 kNm
Max. wheel load power	209 kW
Max. steering angle front wheels	+/- 20°
Max. aligning load torque front wheels	1 kNm
Max. fan speed	135 km/h

Link to Website

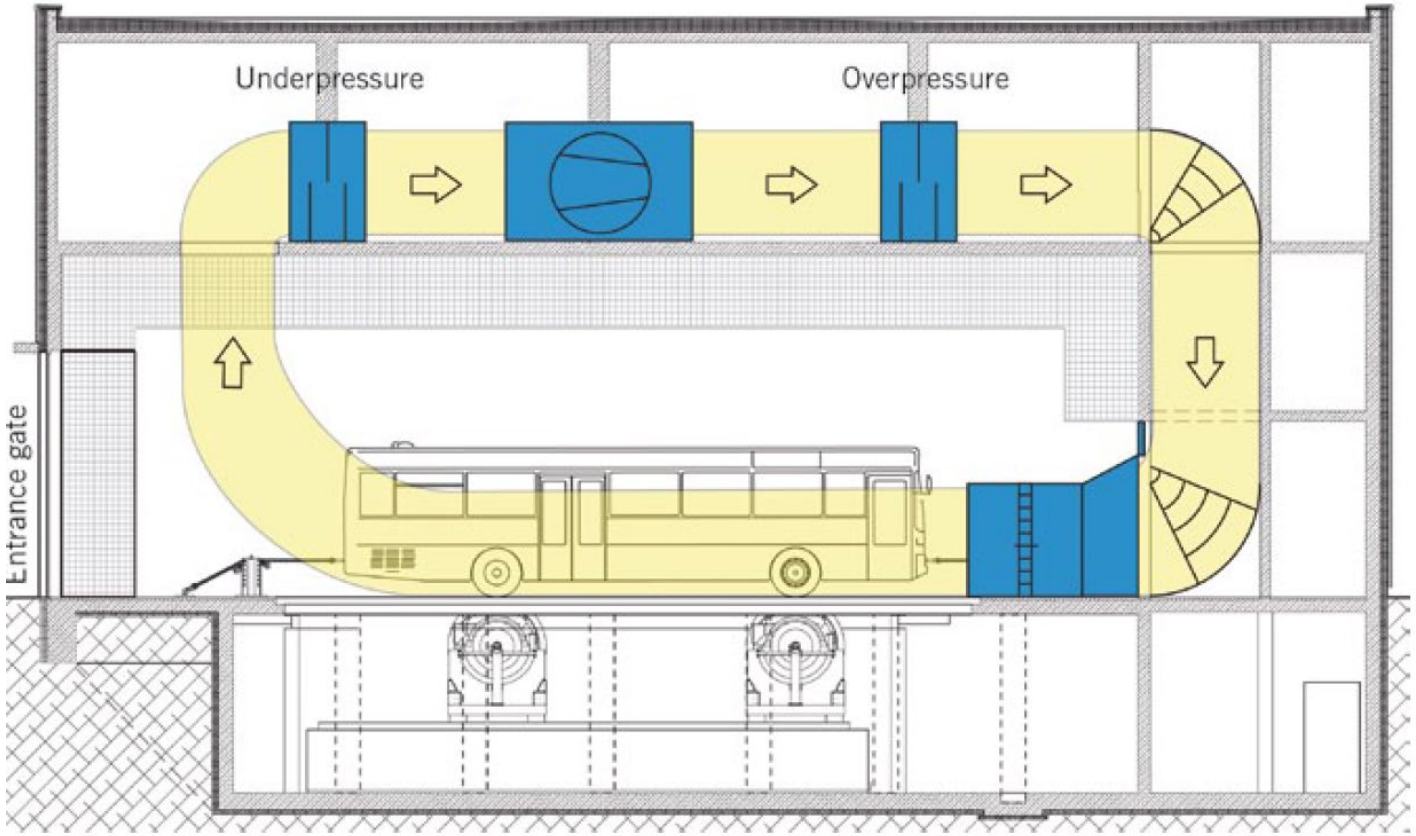
Acoustic 4WD Chassis Dyno (AARP)
Technical Specification



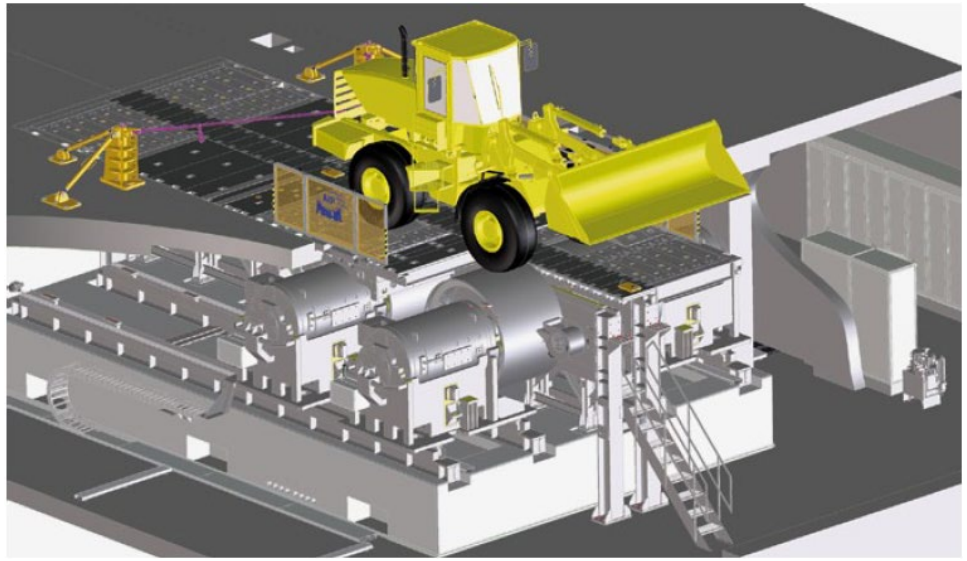
Parameter	Value
Drum outer diameter	2 m
Max. Speed	160 km/h
Max. vehicle weight	40 t
Axle load	28 t
Wheel base	2.05 – 8 m
Max. traction force per wheel	110 kN
Cooling air flow	Up to 180,000 m³/h
Acoustic Cut-off frequency	63 – 17,000 Hz

Link to Website

Acoustic 4WD Chassis Dyno (AARP)
Sectional and 3D view



Source: Dömges Architekten, Dreher

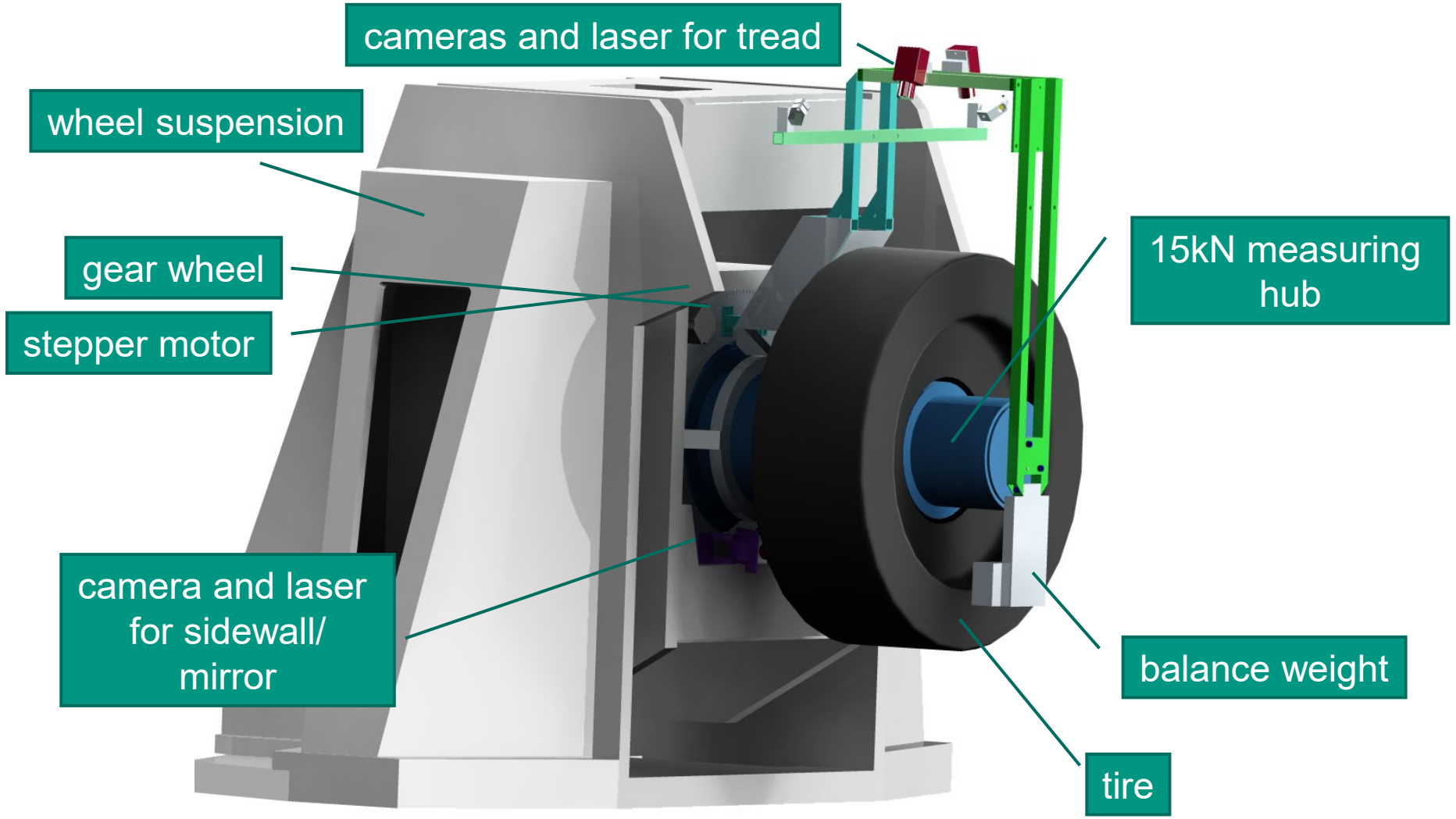


Source: Maha-Aip

Link to Website

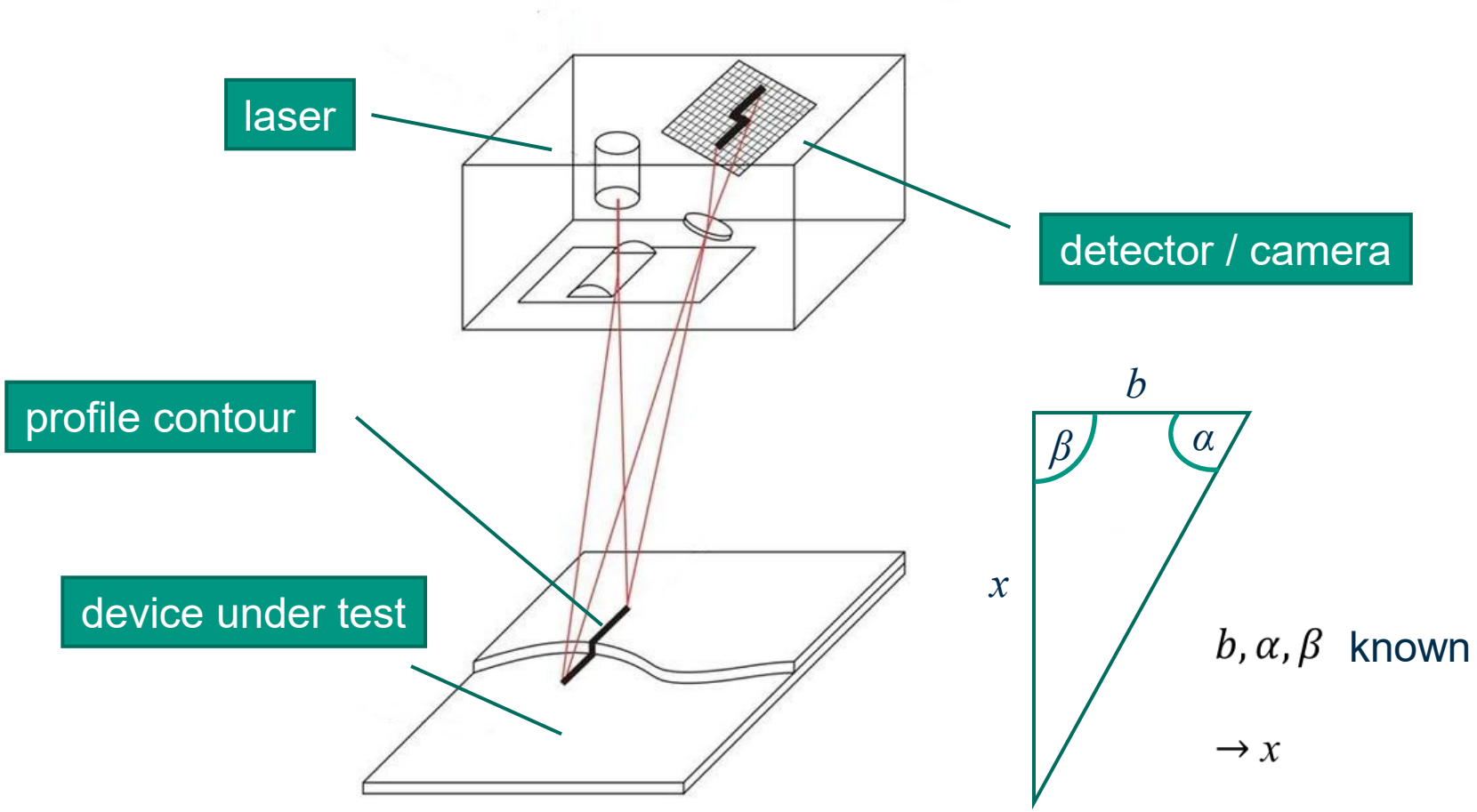
Special equipment
(for tire related research)

Special Equipment
Determination of Tire Envelopes



Special Equipment
Determination of Tire Envelopes

- Light Section Triangulation Method



Special Equipment
Determination of Tire Envelopes

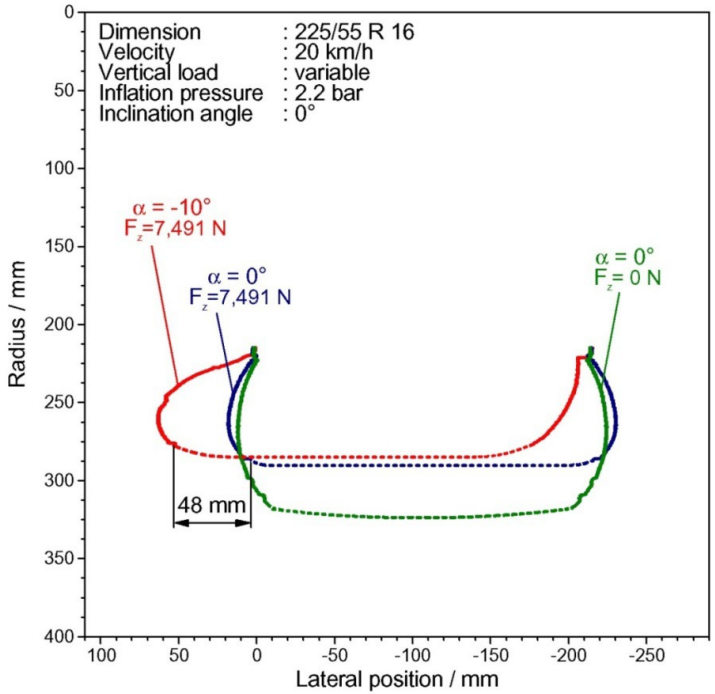
- **Measurement under Real Driving Conditions at Internal Drum Test Bench**

  Non-contact measurement of tire contour

  - under real (even extreme) driving conditions
  - on real track surfaces

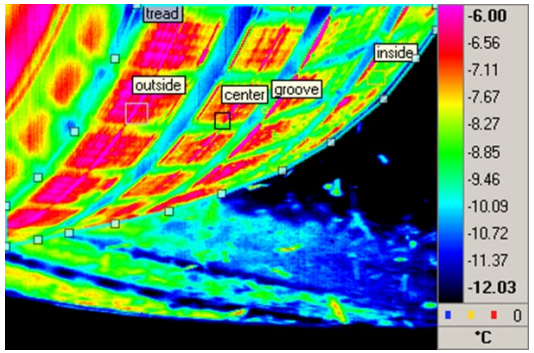
  with measurement of tire forces and moments at the same time.

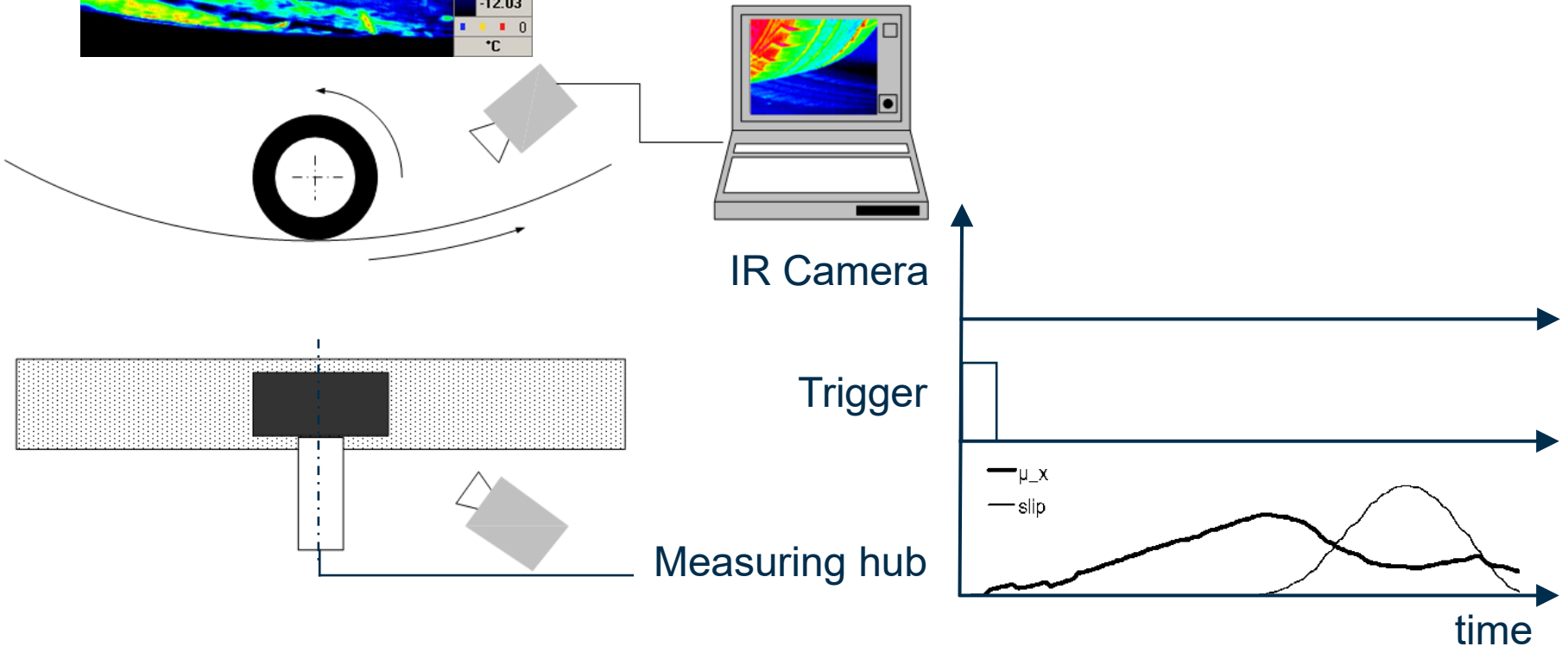




Measured tire contour for several load and slip angle conditions

Special Equipment
High Speed Infrared Camera



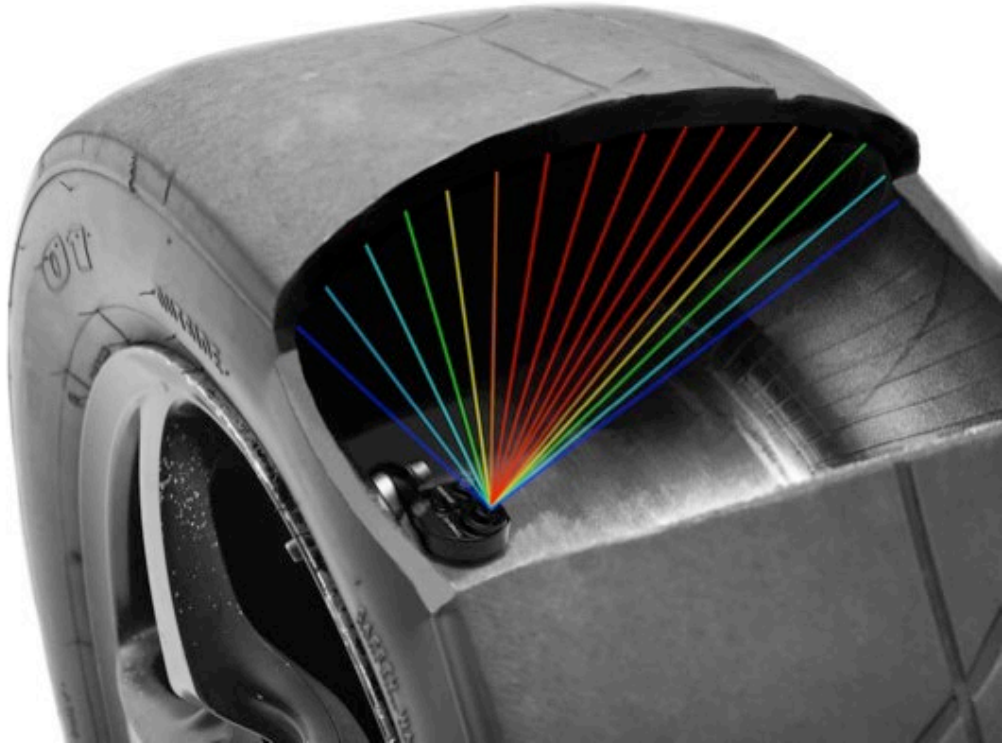




Technical Specification:

- Detector: 320 x 256 elements (30 µm pixel)
- Spectral sensitivity: 3.7 – 5.1 µm Wave length
- Integration time: 10 µs – 10 ms
- Stirling Cooler
- Thermal Sensitivt: @25°C <25mK
- Snap Shot with definable integration time of 3µs to 20 ms
- Trigger Input and Output: 0-3 V,
- Jitter <250ns,
- Analog video output: CCIR (50 Hz) or RS 170 (60Hz)
- 14 Bit dgital output USB-2
- measurement ranges:
  - -20°C to 50°C
  - 5 to 300°C

Special Equipment
TTPMS – Tire pressure & Temperature Measurement



SPECIFICATIONS – TTPMS SENSOR

Pressure, Range (Absolute)	0 to 5000 mBar
Pressure, Resolution	1 mBar
Pressure, FS Accuracy (typ)	±5 mBar
Internal Temperature, Range	-40 to 150˚C
Internal Temperature, Resolution	0.1˚C
Internal Temperature, FS Accuracy	±0.25˚C
IR Temperature, Range	-20 to 300˚C
IR Temperature, Resolution	0.1˚C
IR Temperature, Accuracy (typ)	±0.5˚C
Sampling Period at Speed	1.25 seconds
Operating Temperature Range*	0 to 135˚C
Battery Life (typ)	1.5 million transmissions
Encryption	AES-128
RF Frequency	868, 915, 920 MHz
RF Output Power	1mW
Wireless Range, Open Space	> 100m

*Will survive brief temperature excursions < 150˚C

Source: https://www.izzeracing.com/products/tire-temperature-pressure-monitoring-system.html

Special Equipment
Infrared Sensor for Surface Temperature Measurement



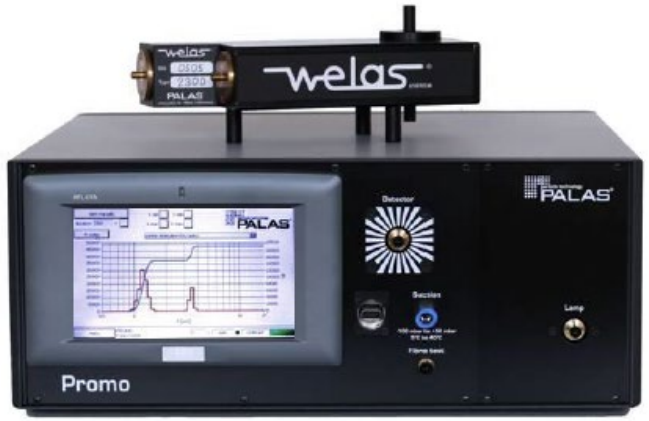
Technical Parameter:

- Temperature range: -50°C ... 975°C
- Spectral range: 8 … 14 µm

Source: https://www.optris.de/ctlaser-lt-ltf

Particle Measurement

Scattered light aerosol spectrometer system Promo 3000 with welas 2500 (aerosol sensor)



- Resolution (number C_N): < 1 • 106 Particle /cm3
- Chanels: Max. 128 (64/Dekade)
- Measurement range (Size): 0,2 – 10 µm, 0,3 – 17 µm, 0,6 – 40 µm, 2 – 100 µm
- Measurement Principle: Optical Light Scattering
- Flow: 5 l/min
- Resolution Time Scale: ≤ 1 s
- Operation temperature: +10 – +40 °C, -100 – 50 mbar
- DAQ: Digital, 20 MHz Processor, 256 Chanels

Source: Promo® 3000 - Produktlinien - Palas

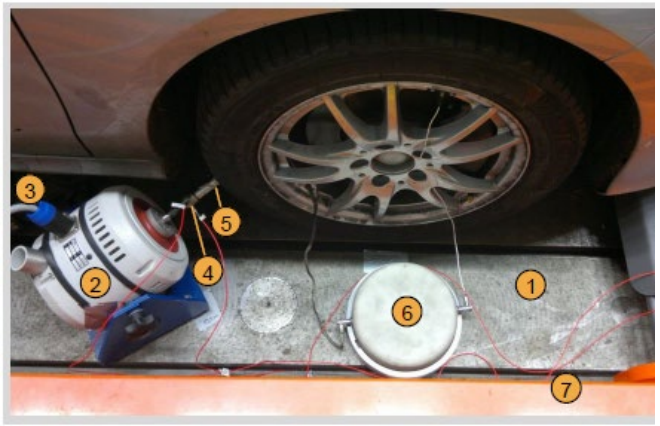
Article:
Atmosphere | Free Full-Text | Influence of Load Condition, Tire Type, and Ambient Temperature on the Emission of Tire–Road Particulate Matter (mdpi.com)

Special Equipment for NVH Tests

Analysis of



Car vibration

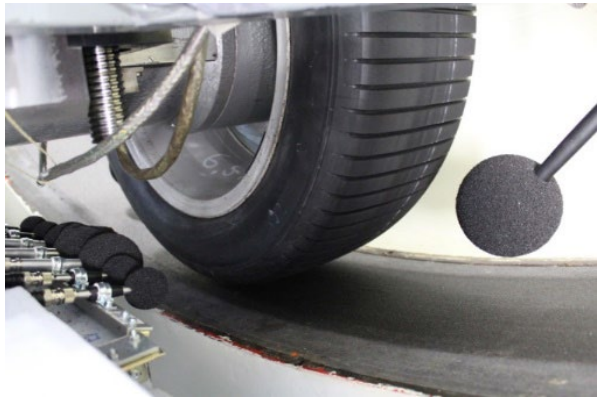


Tire vibration

1. Seismic mass (300t)
2. Shaker
3. Power cable
4. Sensor
5. Adapter
6. Acoustic torus measurement device



Car noise



Tire noise

Special Equipment for NVH Tests





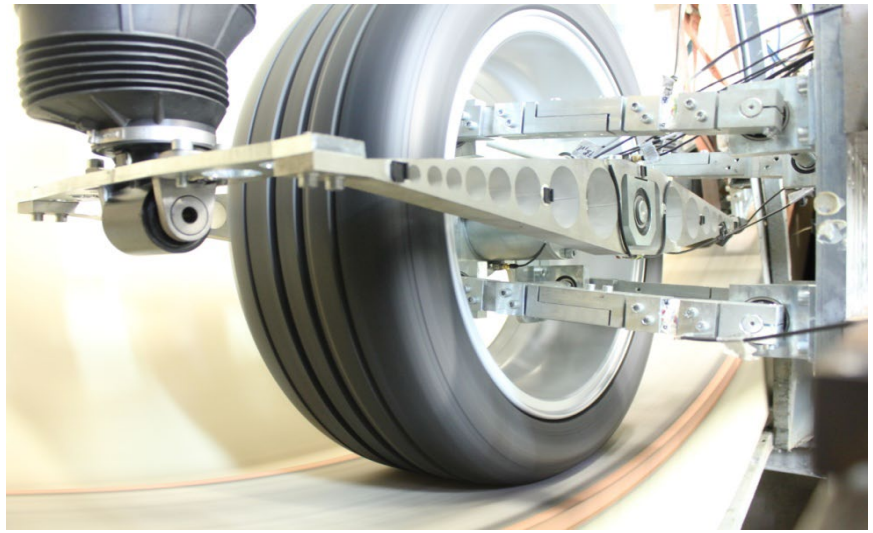
Sensors

Amount	Type	Brand
6	Freefield and Diffuse Microphone 1/2“	B&K
12	Freefield Microphone 1/4“	G.R.A.S.
4	Microphone – pressure type bis 180dB	PCB
1	Acoustic Head Measurement System	Head Acoustics
16	Triaxial Accelerometer	B&K
1	3D-Scanningvibrometer	Polytec

Data Acquisition

No. of input channels	Performance	Brand
96	f_{Mess} 25,6 kHz; 16bit	B&K Pulse
24	f_{Mess} 51,2 kHz; 24bit; ICP	NI PXI
8 (drahtlos)	f_{Mess} 25,6 kHz; 24bit; ICP	NI WLS

Special Equipment
Noise & Vibration analyzed with Elastic Wheel Hub





Noise and vibrations measured by multiple triaxial accelerator sensors, microphones and 3D-Scanningvibrometer (see complete list next slide).

Special Equipment
Visualization of the tire tread deformation

mobile under-floor laboratory



[2] DE102013107018.3

mobile under-floor laboratory installed into a common drain on the street

easy integration



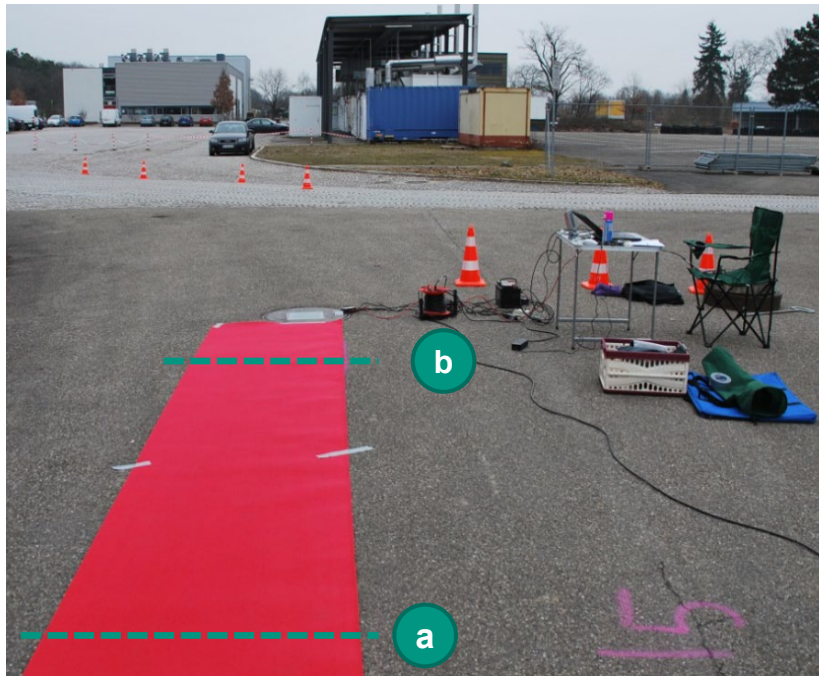
[2] DE102013107018.3

illumination with > 14.000 Lumen
recording of tire crossing > 2,300 fps

simple handling

Special Equipment
Visualization of the tire tread deformation

mobile under-floor laboratory



start-up carpet avoids collecting stones and dust particles by the tire during drive up

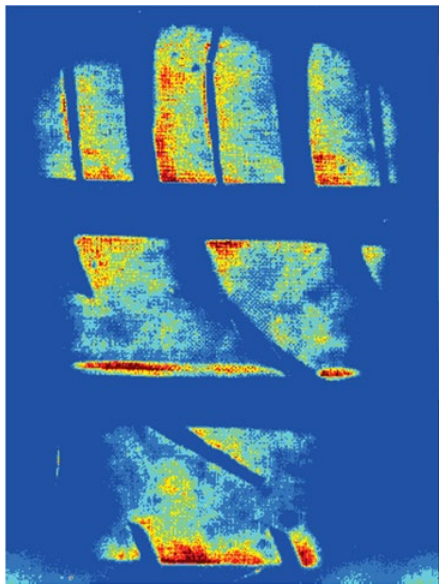
light barrier (a) activates pre-defined torque at electric vehicle automatically
⇨ reproducible tangential forces can be applied

light barrier (b) activates camera recording

fully automated

Special Equipment
High Speed Camera





Aquisition of contact pressure distribution of rolling tire with high speed cam

- Resolution: 1696x1710 @ 500 fps
- Frequence: max. 100.000 fps

Contact

Institut für Fahrzeugsystemtechnik
Institutsteil Fahrzeugtechnik



Prof. Dr.-Ing. Matthias Pfriem

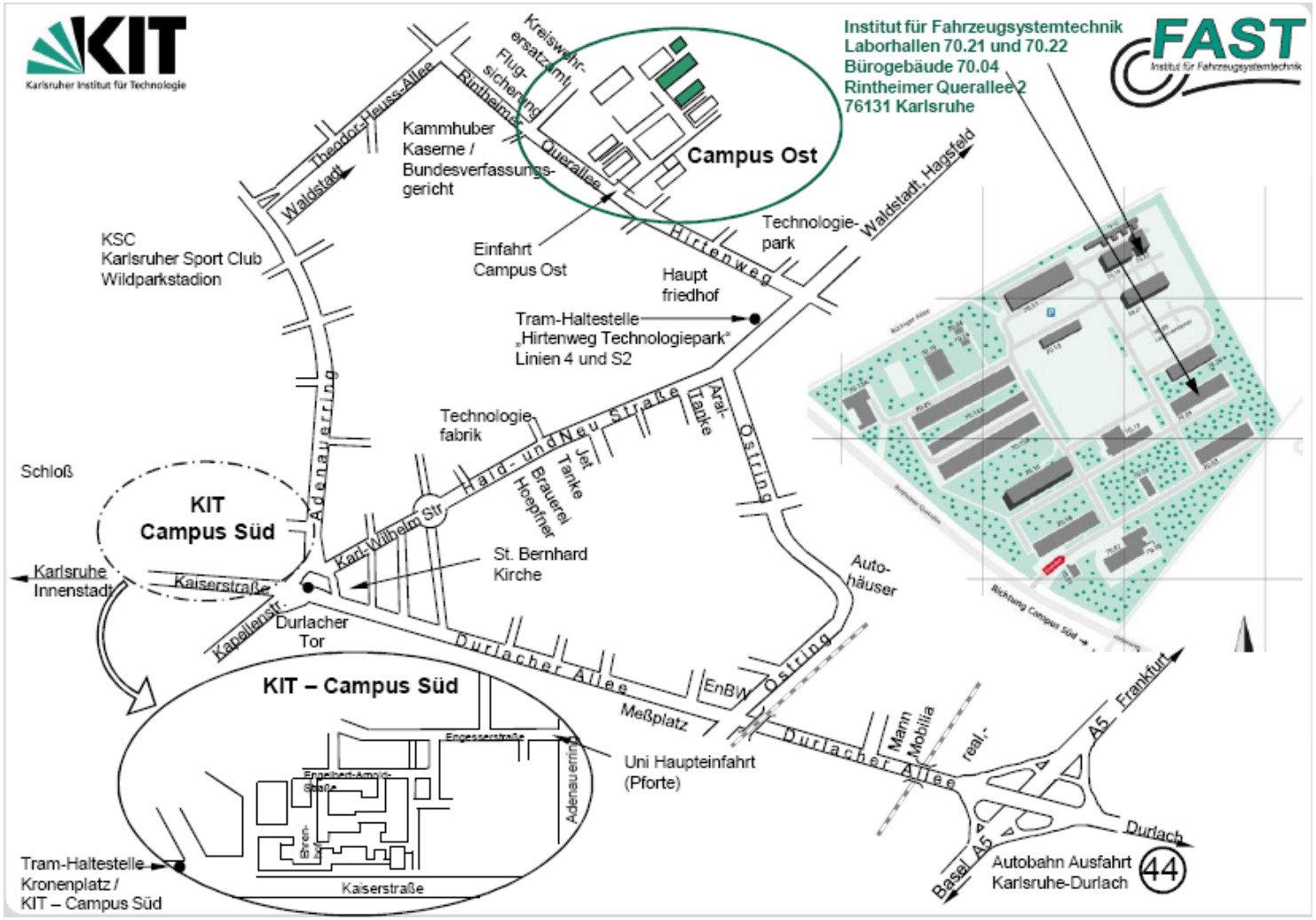
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Facilities of FAST
Campus South – Campus East



Test facilities @ Campus East:
https://maps.app.goo.gl/MS9ggmdxAXqfJerR7

Tire test laboratory @ Campus South:
https://maps.app.goo.gl/XmFNofTjQqXF3DK49