

Test Equipment with focus on tire

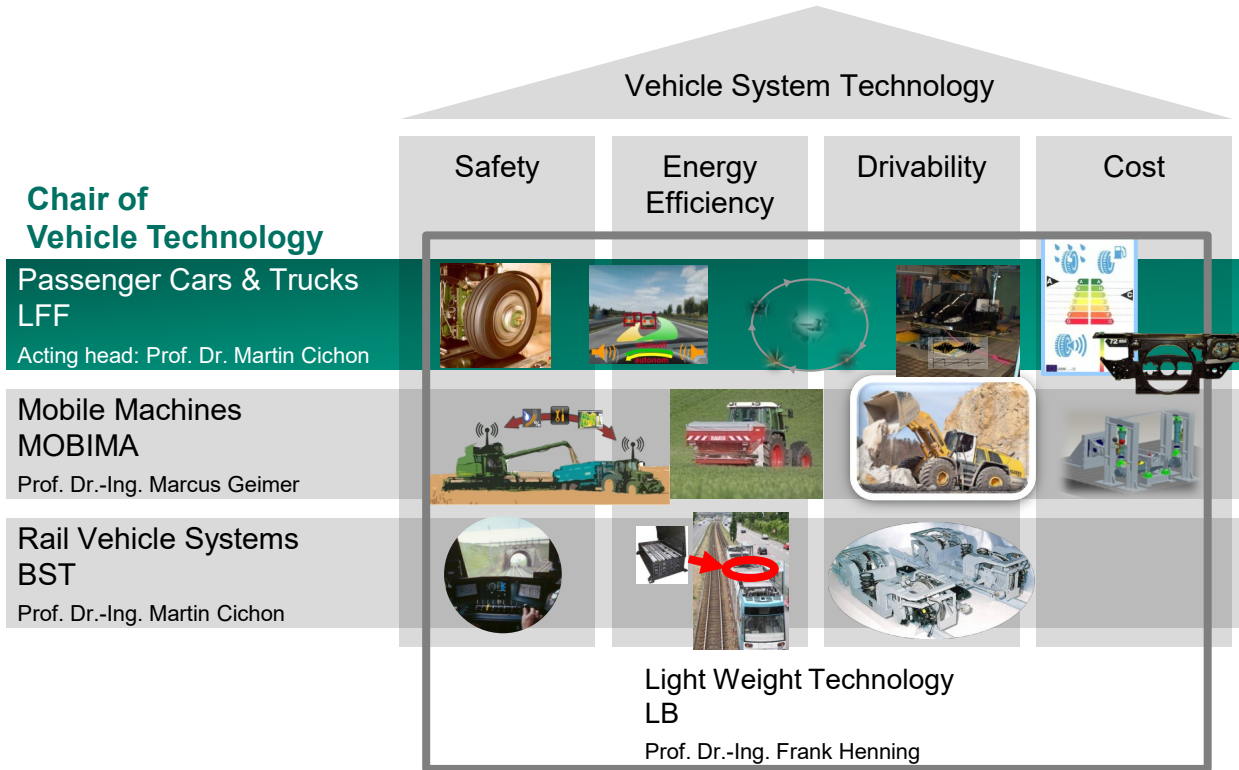
Acting head of Institute:	Prof. Dr.-Ing. Martin Cichon
Research Group Wheel,	
Tire & Road:	Dr.-Ing. Martin Gießler

Content

- Institute Structure & Facilities
- IPS - Inner Drum Test Bench
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- Grip- and Abrasion Teststand (GAT)
- VIL - Vehicle in the Loop Test Bench
- AARPS Acoustic 4WD Chassis Dyno
- Special Equipment
 - Determination of Tire Envelopes
 - NVH Test Equipment

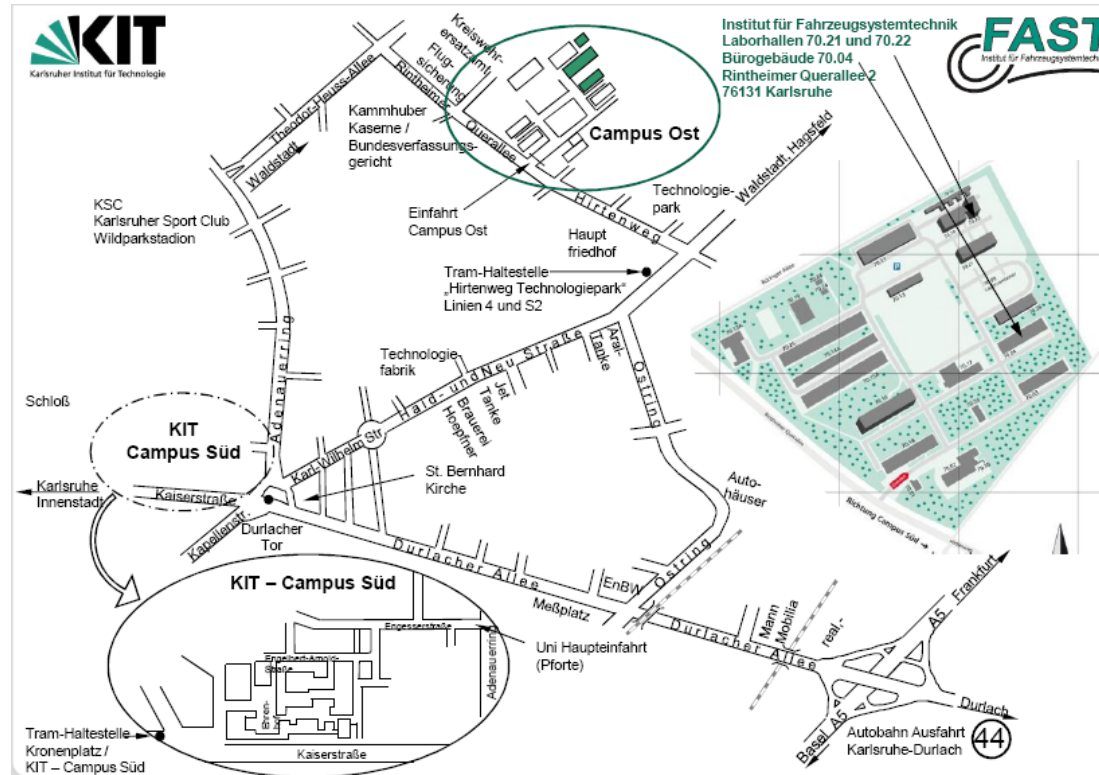
Institute of Vehicle System Technology - FAST

Structure



Facilities of FAST

Campus South – Campus East

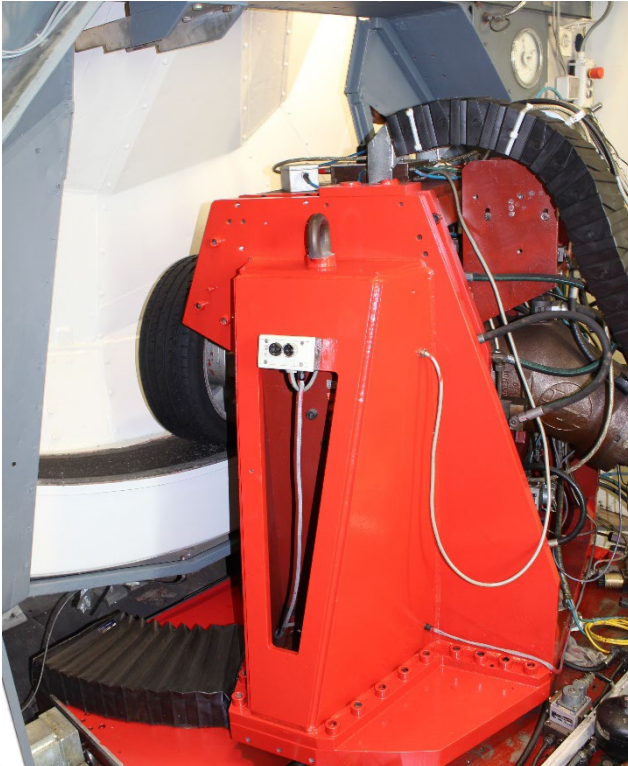


Test facilities @ Campus East:
<https://maps.app.goo.gl/MS9ggmdxAXqfJerR7>

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

IPS - Inner Drum Test Bench

Technical Specification



Inside diameter of the drum	3.80 m
Track surfaces	Safety Walk Diverse concrete surfaces Diverse asphalt surfaces
Top speed	
- on Safety Walk	200 km/h
- on asphalt / concrete	150 km/h
Water film depth	0 ... 3 mm
Ambient temperature	-15 ... +30 °C
Slip angle	-20° ... +20°
Camber angle	-10° ... +20° (+30° ... +45°)

Measuring system for frictional force behaviour

Rotating 6 component measuring system:

vertical force, lateral force, longitudinal force

max. **15 kN**, durability tests 12 kN

Max. tire radius: 450 mm

Max. tire width: 310 mm

Internal Drum Test Bench

Installable Tracks



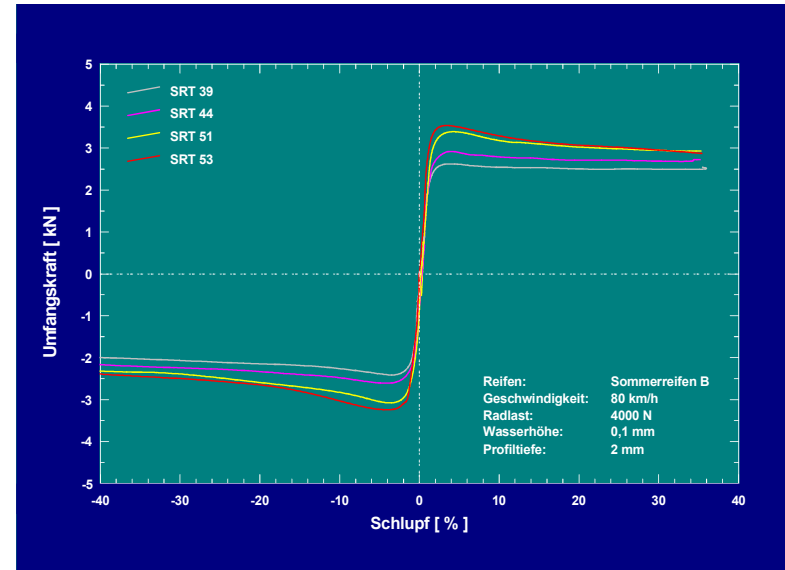
Analysis of the influence of

- different composites of the track
- different textures of track surface

for example:

- Safety-Walk
- asphalt
- concrete

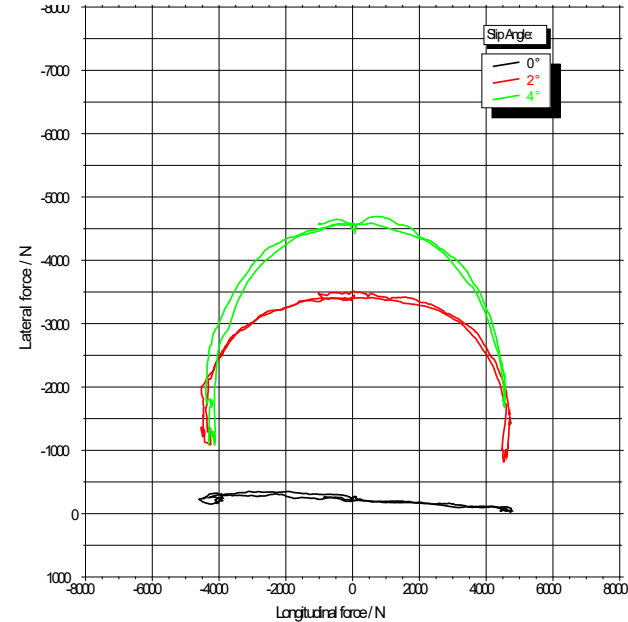
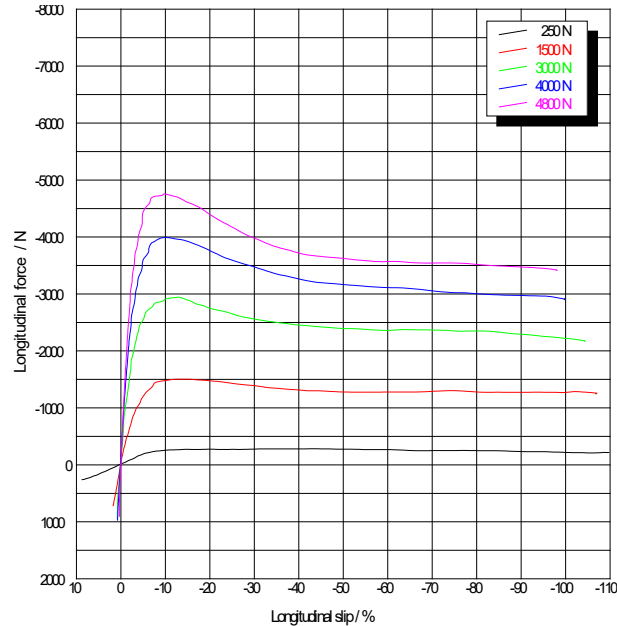
on the frictional behavior of tires on wet and dry roadway.



Variation of skid resistance,
tests on humid track surface

Internal Drum Test Bench

Longitudinal Force Measurements



Manufacturer :
Tiresize :
Rimsizes : 5,5x15

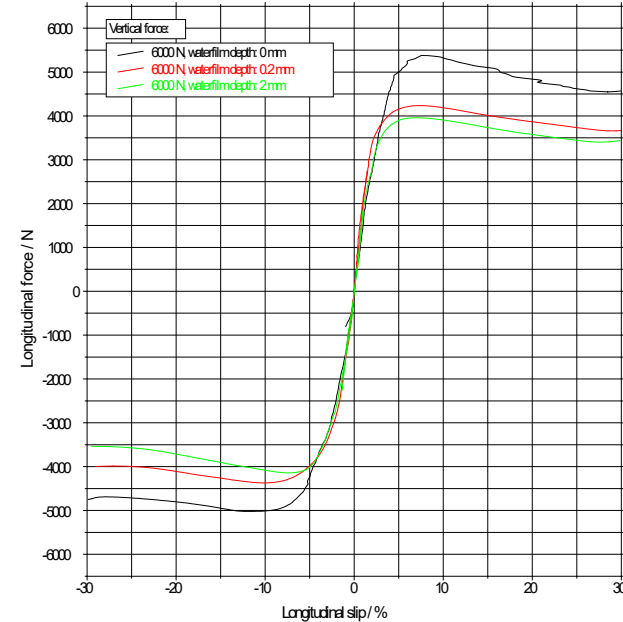
Velocity : 100 km/h
Inflation pressure : 2,1 bar
Slip angle : 0°
Waterfilm depth : 0 mm
Vertical force : var.

Manufacturer :
Tiresize :
Rimsizes : 7,5x16

Velocity : 40 km/h
Inflation pressure : 2,2 bar
Camber angle : 0°
Waterfilm depth : 0 mm
Vertical force : 4800 N

Internal Drum Test Bench

Measurements on Wet Track Surface



Manufacturer :
Tyre size : 6.0 x 15
Rim size :

Velocity : 80 km/h
Inflation pressure : 2.6 bar
Slip angle : 0°
Water film depth : 0 / 0.2 / 2 mm
Vertical force : var.

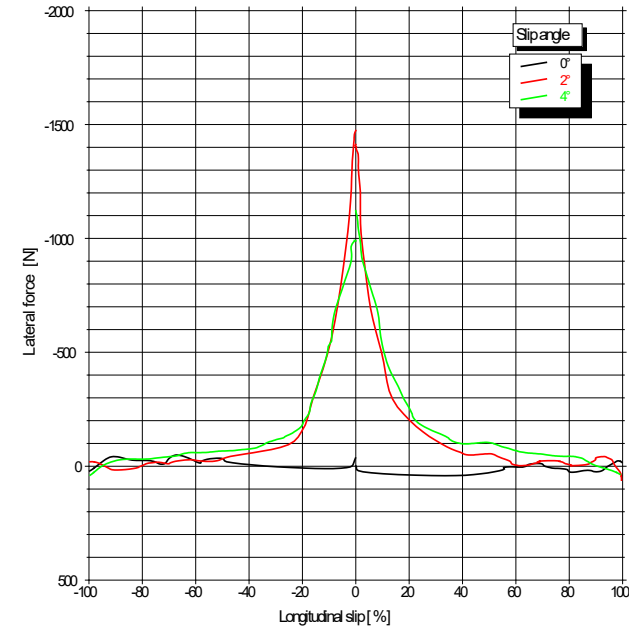
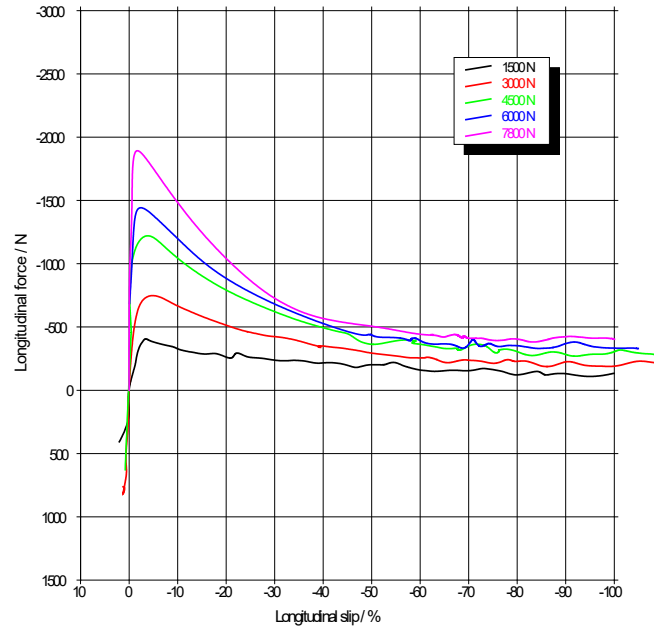
Internal Drum Test Bench

Measurements on Snow and Ice Surfaces



Internal Drum Test Bench

Measurements on Snow and Ice Surfaces



Manufacturer :
Tyre size :
Rim size : 6.5 x 15
Inflation pressure : 2.4 bar

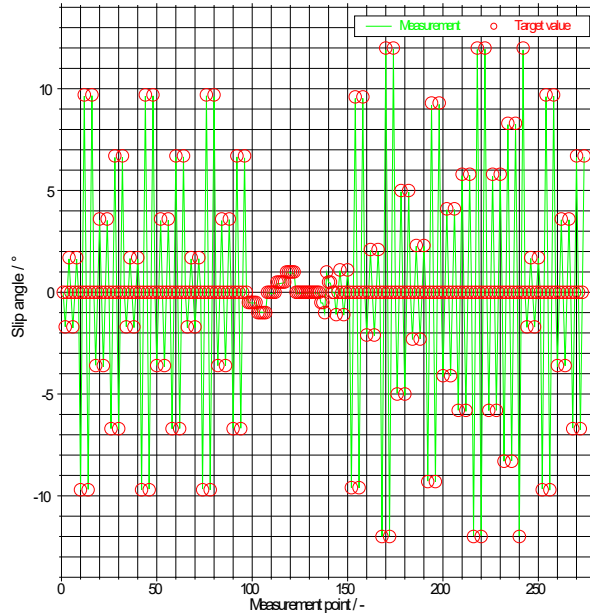
Velocity : 80 km/h
Slip angle : 0°
Track surface : ice
Ambient temperature : -10 °C
Vertical force : variabel

Manufacturer :
Tyre size :
Rim size : 6.5 x 15
Inflation pressure : 2.4 bar

Velocity : 80 km/h
Slip angle : variabel
Track surface : ice
Ambient temperature : -10 °C
Vertical force : 6000 N

Internal Drum Test Bench

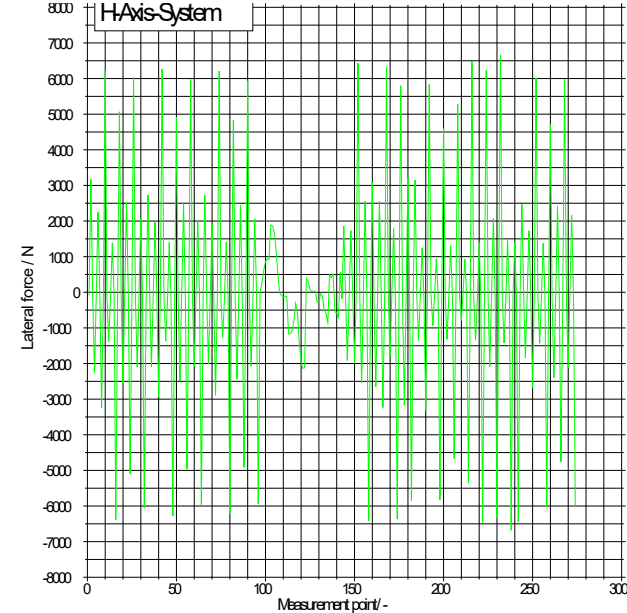
Measurements with the TIME Procedure



Adjustment of certain parameter combinations
(constant for 3 sec)

Manufacturer :
Identity :
Tyre size : 7 x 16
Rims size :

Velocity : 40 km/h
Inflation pressure : 2.4 bar
Indination angle : var.
Waterfilm depth : 0 mm
Vertical force : var.



Measurement of tire forces
at adjusted parameter combinations

Manufacturer :
Identity :
Tyre size : 7 x 16
Rims size :

Velocity : 40 km/h
Inflation pressure : 2.4 bar
Indination angle : var.
Waterfilm depth : 0 mm
Vertical force : var.

Internal Drum Test Bench

Measurements for Tire Comfort Models

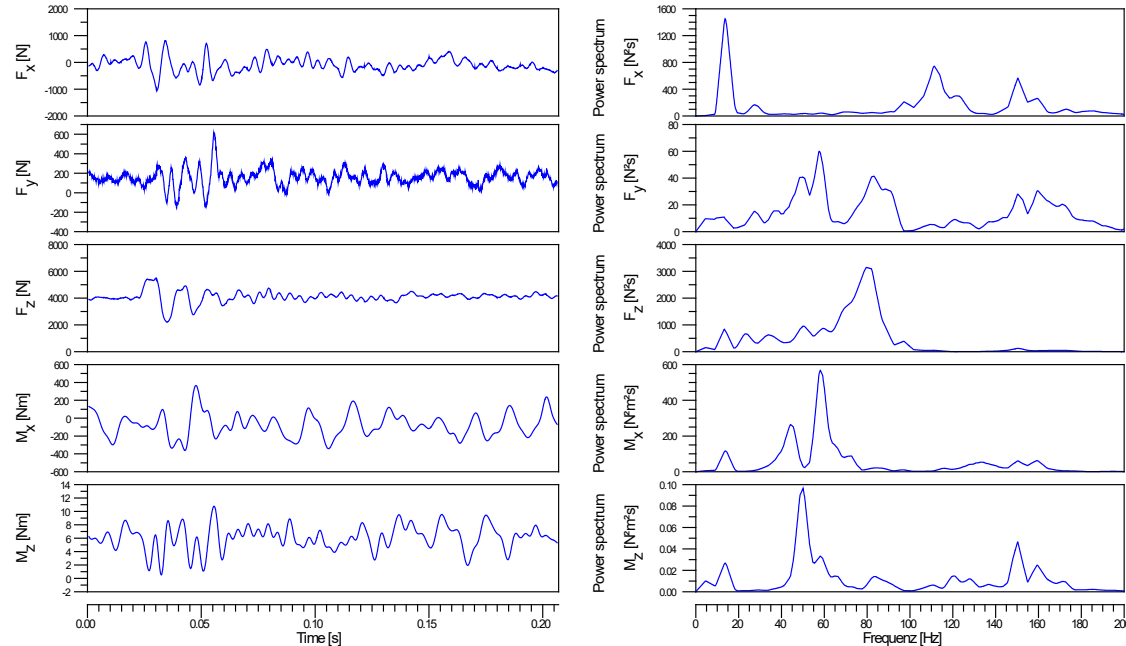
- Rolling over Cleats



Internal Drum Test Bench

Measurements for Tire Comfort Models

Rolling over cleats: Measurement of Forces and Moments

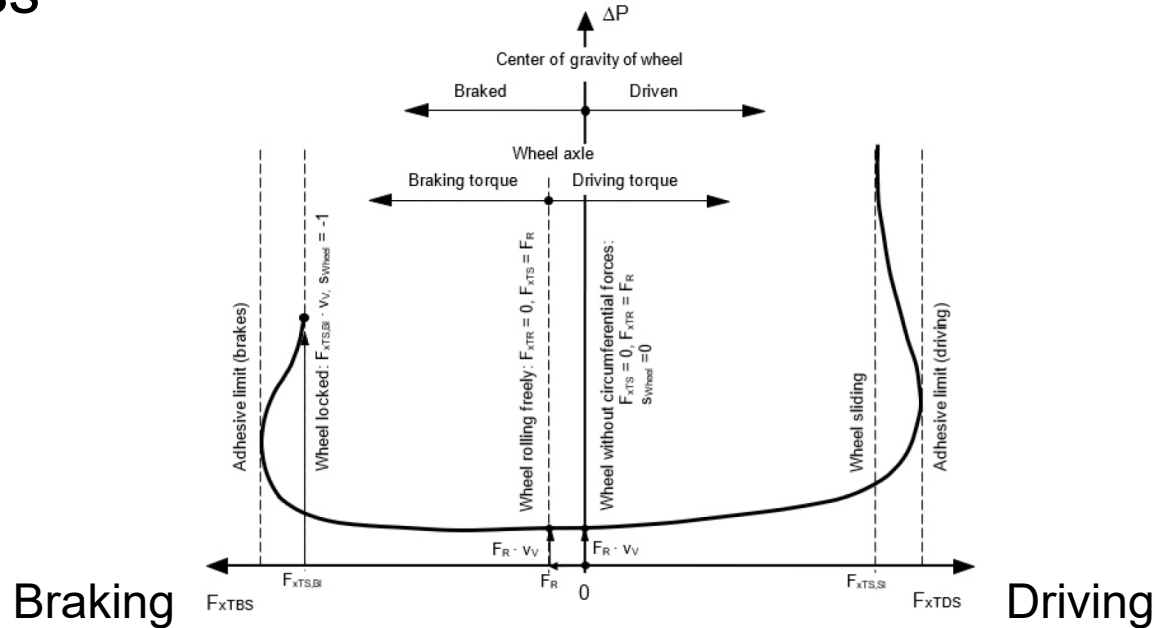


Manufacturer :
Tyre size :
Form of cleat : Batten

Vertical force : 4.000 N
Velocity : 100 km/h
Inflation pressure : 2.2 bar
Slip angle : 0°

Internal Drum Test Bench

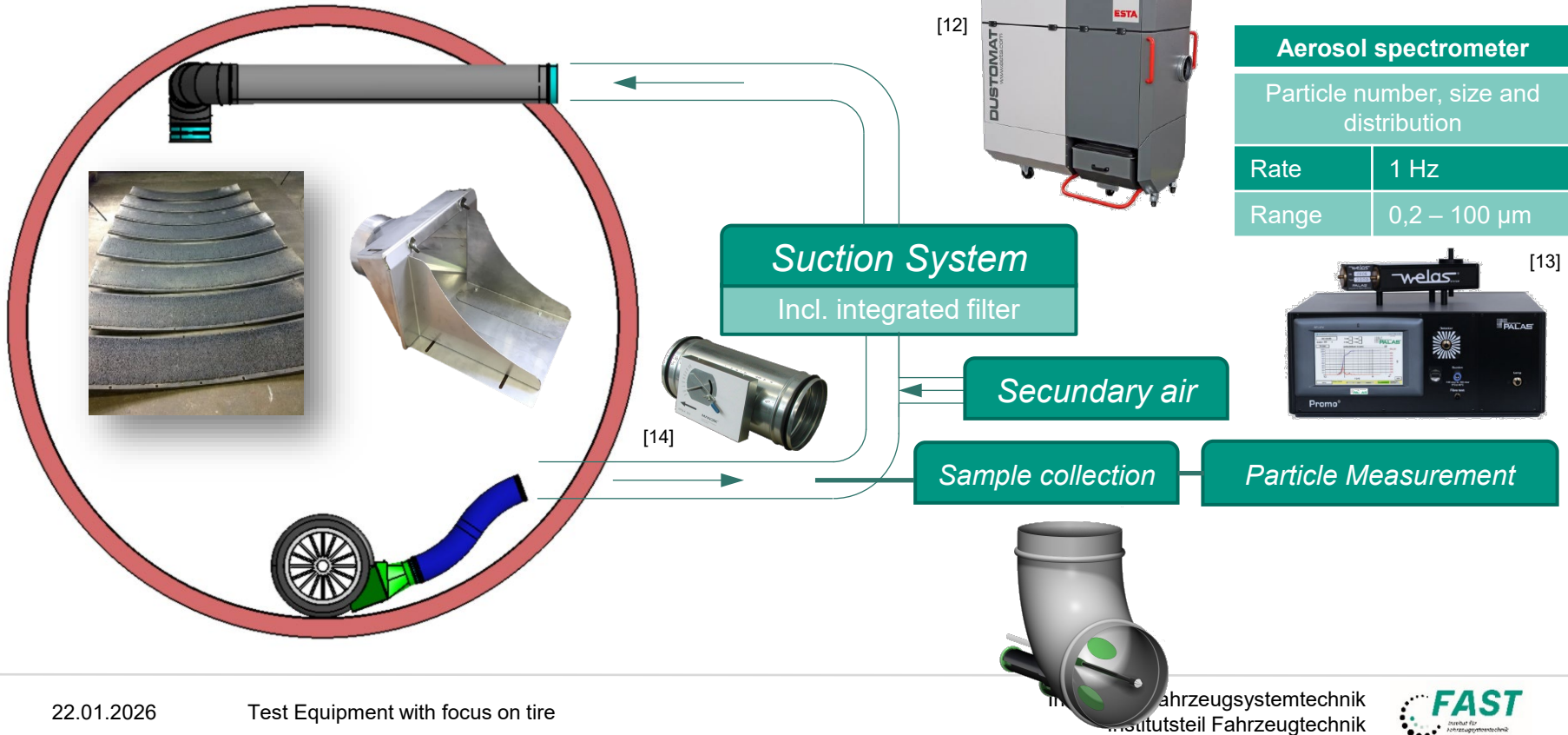
Power loss



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

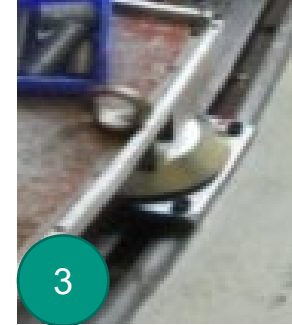
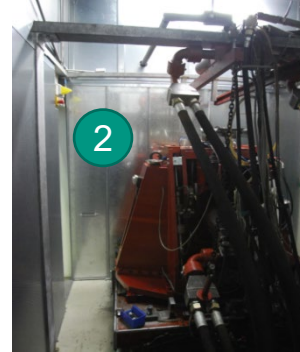
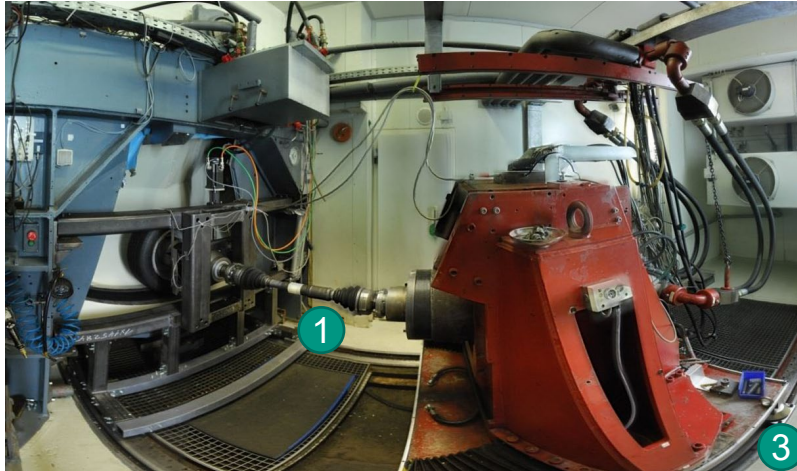
with F_R Rolling Resistance; Longitudinal Drive/Brake Force F_{xTS}

Setup for tire emission measurement

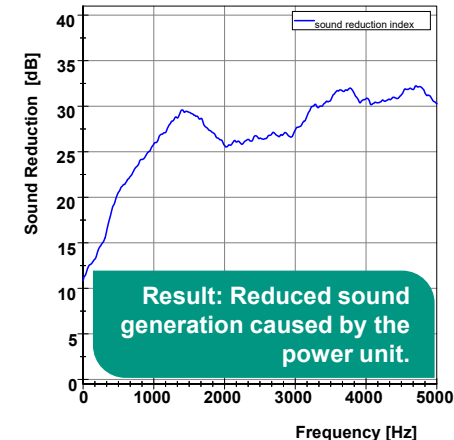


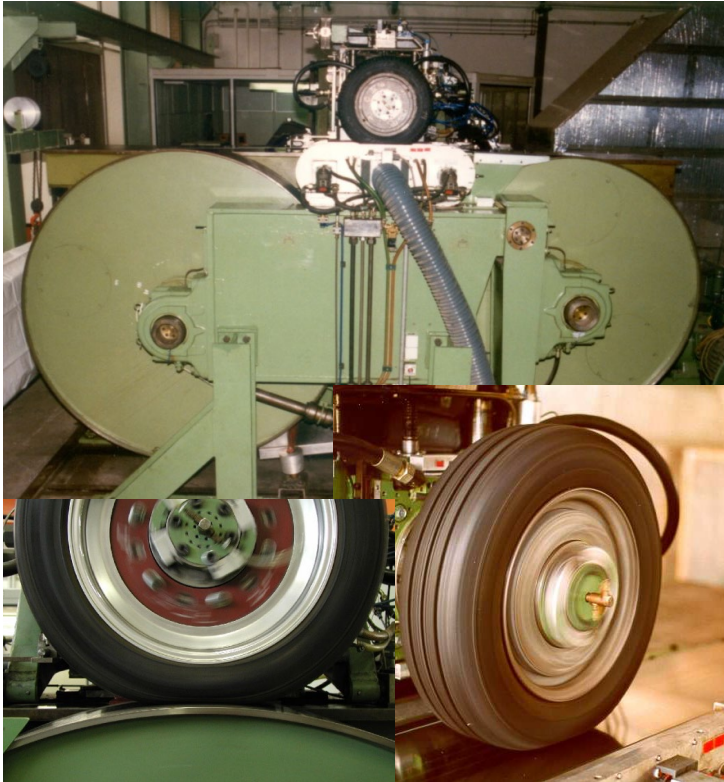
Inner Drum Test Rig

Setup for Acoustic Test



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



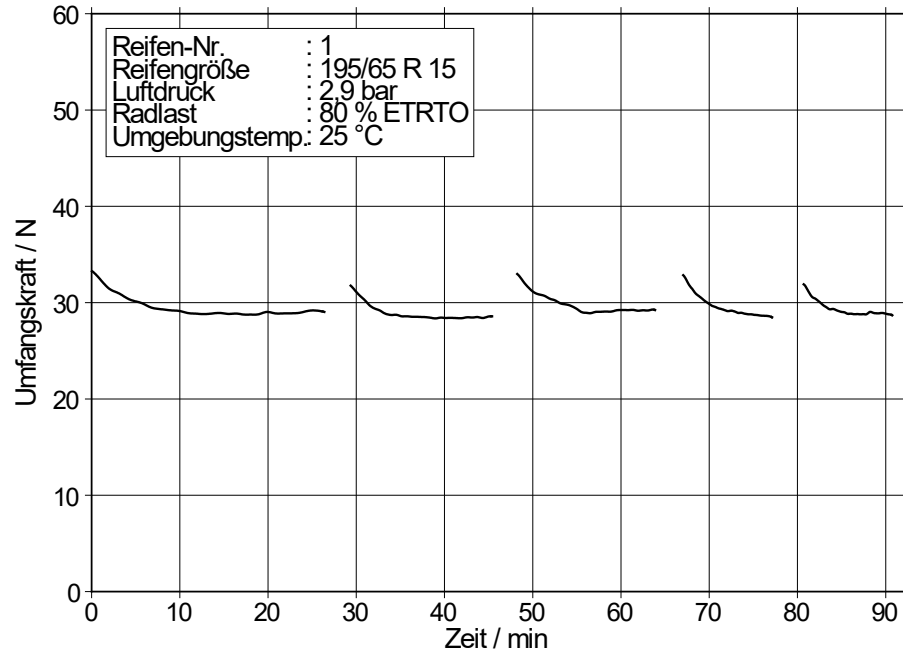


Outside diameter of the drums	2,00 m 1,71 m
Top speed	
- on the drums	300 km/h
- on the flat surface	250 km/h
Camber angle	-10°...+10°
Slip angle	-5° ... +5°
Ambient Temperature	7 °C ... 40 °C

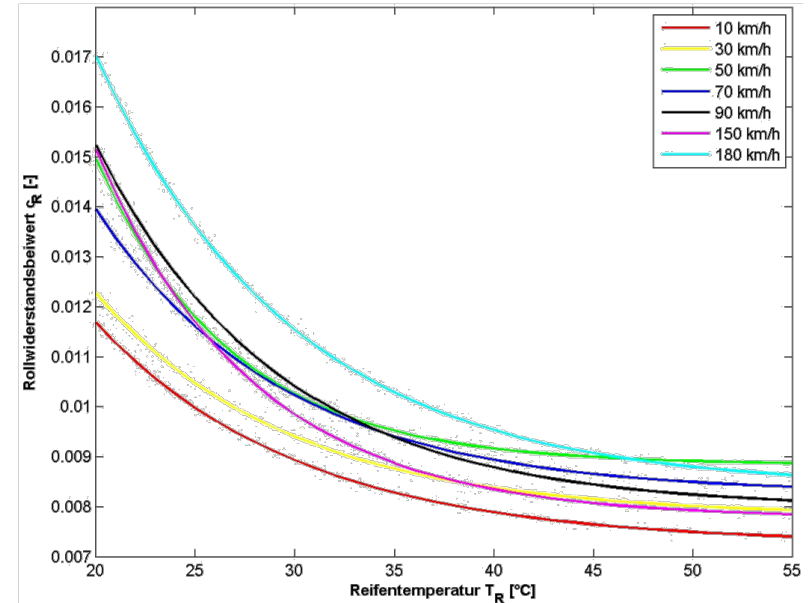
Measuring system for rolling resistance

6 component measuring system:

Max. vertical force	10.000 N
Max. lateral force, longitudinal force	1.000 N
Max. overturning torque	1.200 Nm
Max. aligning torque	300 Nm
Max. driving torque	30 Nm



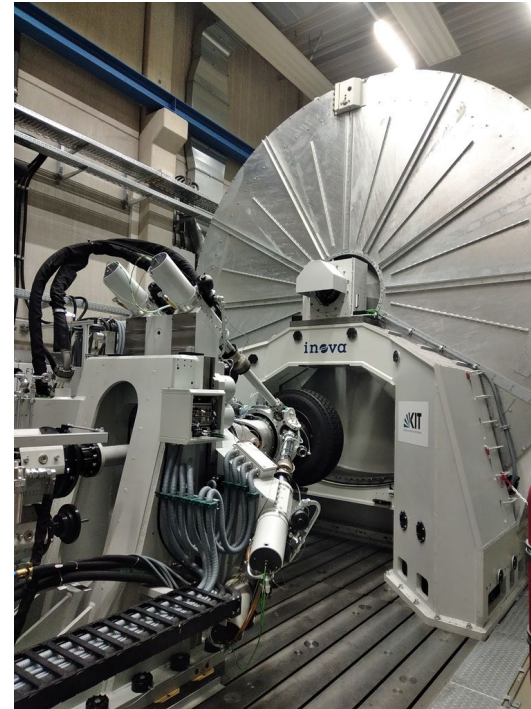
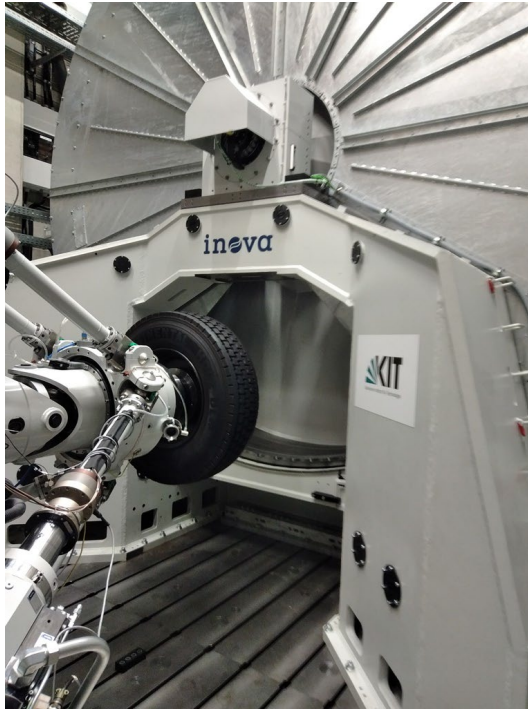
- Rolling resistance depends on temperature, road surface, drive torque, side slip, weather condition, ...
- Real life conditions differ from test conditions (ISO 28580).
- Test result is not a good predictor for real life rolling resistance.



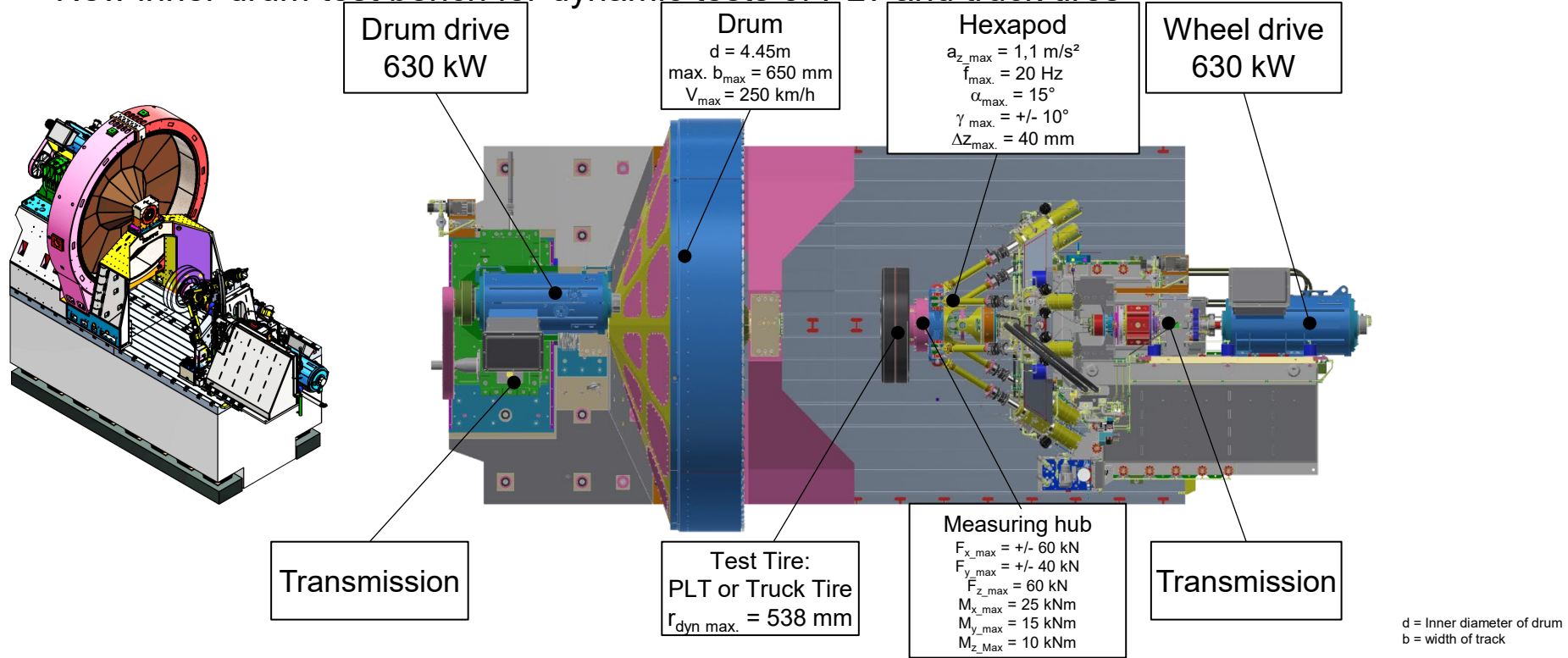
Developed method: Test method to predict tire temperature and rolling resistance in real life drive cycles.

GRIPS

New inner drum test bench for dynamic tests of PLT and truck tires



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



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



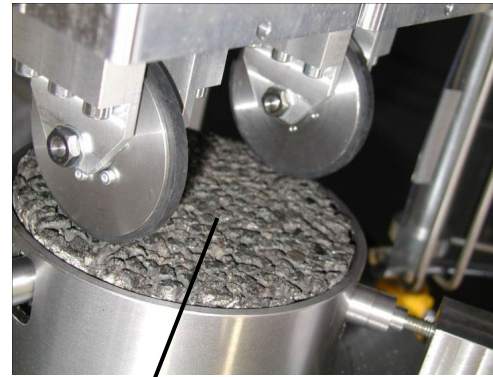
Large-scale research equipment funded by the German Research Foundation (DFG)

Parameter	Value
Inner diameter of drum	4.5 m
Max. track width	605 mm
Max. drum speed at track level	250 km/h
Max. tire radius	650 mm
Track types	On request
Slip angle	-15 ... +15°
Camber angle	-10° ... +10°
Max. frequency of change in wheel position	30 Hz
Max. power of electric motors	630 kW
Max. vertical force	60 kN
Max. longitudinal force	26 kN
Max. lateral force	40 kN
Max. torques	$M_{x_max} = 25 \text{ kNm}$ $M_{y_max} = 14 \text{ kNm}$ $M_{z_max} = 10 \text{ kNm}$

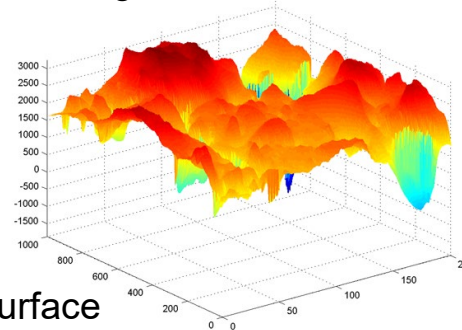
Grip- and Abrasion Teststand (GAT)

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



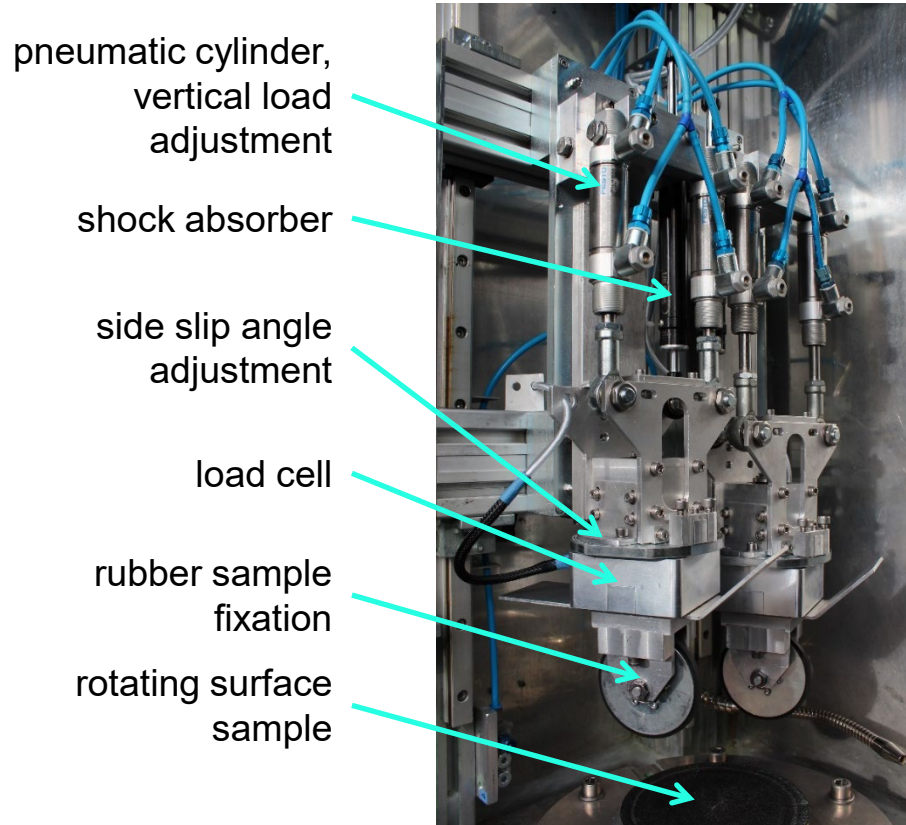
drilling core



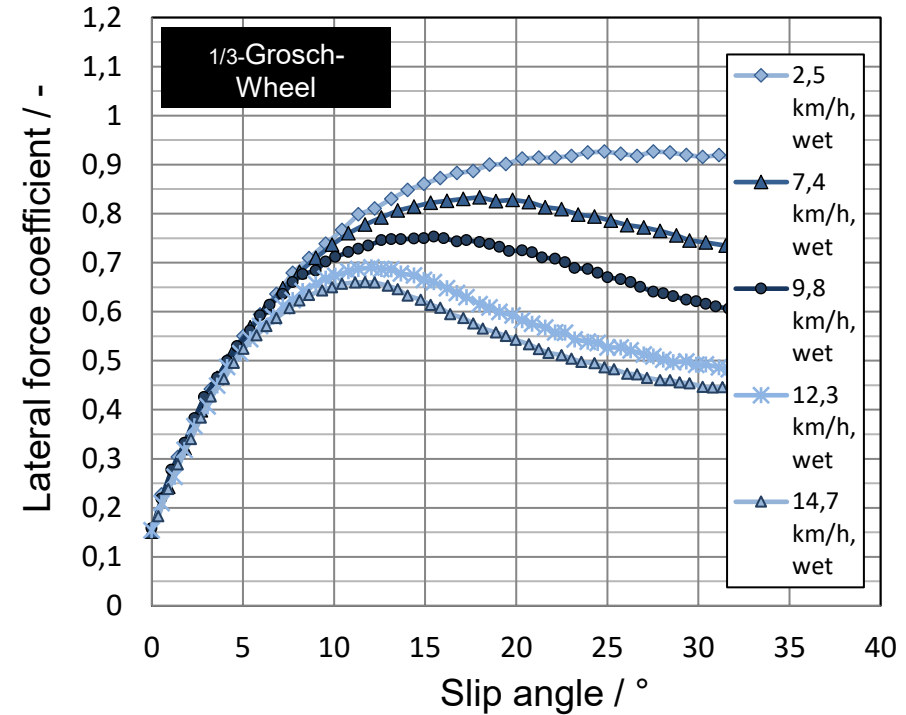
3d profile of road surface



Grip- and Abrasion Teststand (GAT)



Lateral force coefficient: variation of velocity





Test Rig	Max. Vehicle Weight	12.000 kg
	Max. Wheel Load	3.000 kg
	Wheel base	1,8 - 4,9 m
	Track width	1,2 - 3,9 m
Dynos (load engines) (1)	Max. wheel speed	2.000 min-1 (200...260 km/h)
	Max. wheel load torque	2.500 Nm
	Max. wheel load power	209 kW
Steering Simulator (2)	Max. steering angle front wheels	+/- 20°
	Max. aligning load torque front wheels	1.000 Nm
Fan (3)	Max. fan speed	135 km/h

AARPS

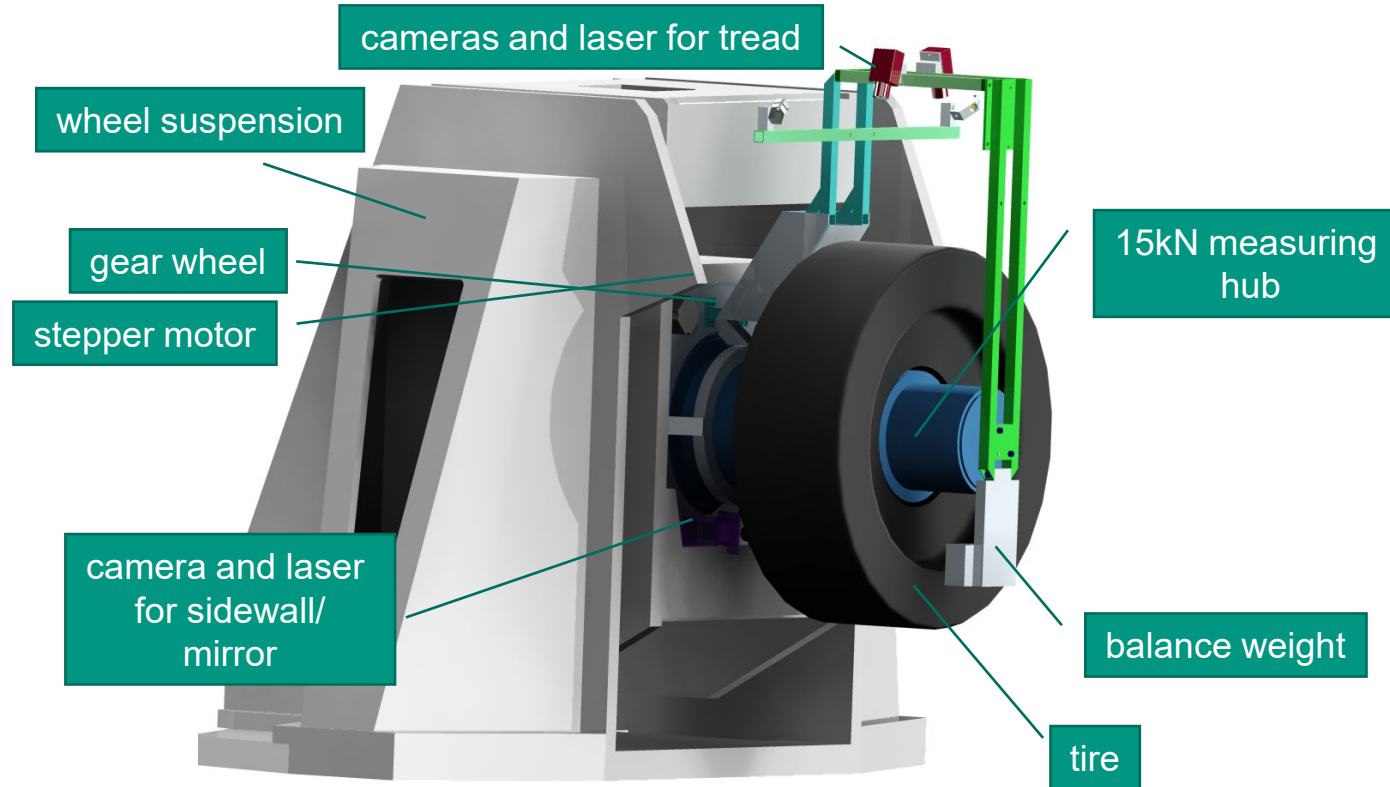
Acoustic 4WD Chassis Dyno



vehicle weight	40 t
Axle load	28 t
Wheel base	2,05 m – 8,00 m
Traction force per wheel	110 kN
Total max. power	1,1 MW
Max. speed	160 km /h
Cooling air flow	until 180 000 m ³ /h
acust. Cut-off frequency	63 Hz -17 000 Hz

Special Equipment

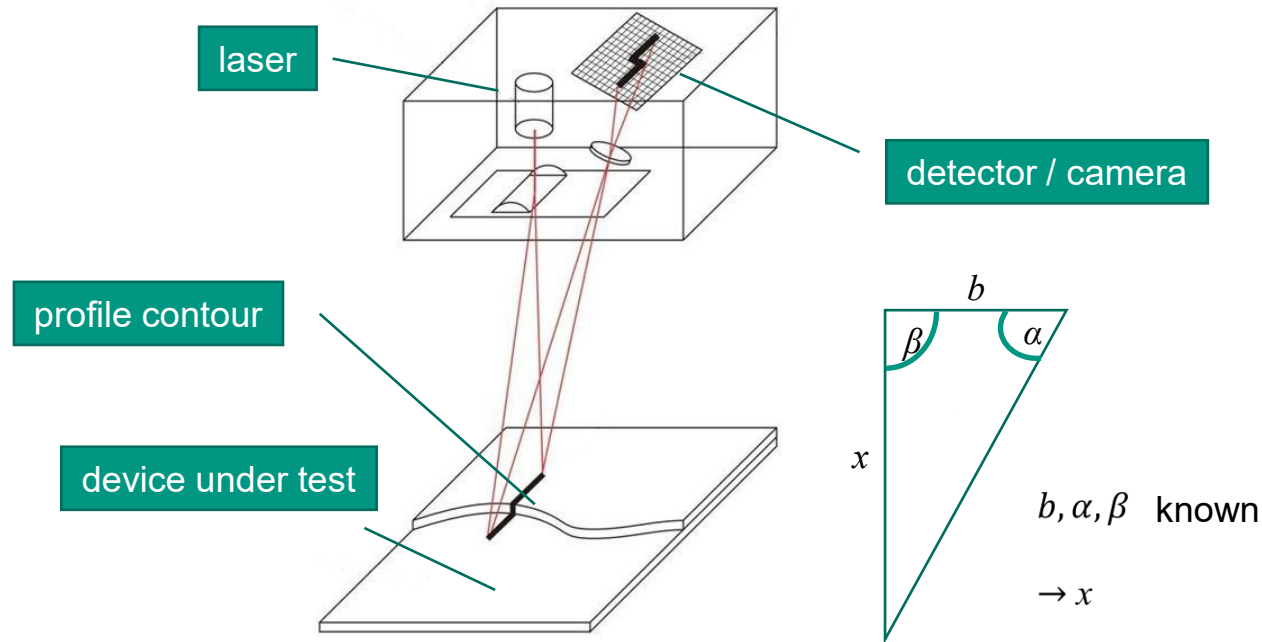
Determination of Tire Envelopes



Special Equipment

Determination of Tire Envelopes

■ Light Section Triangulation Method



Special Equipment

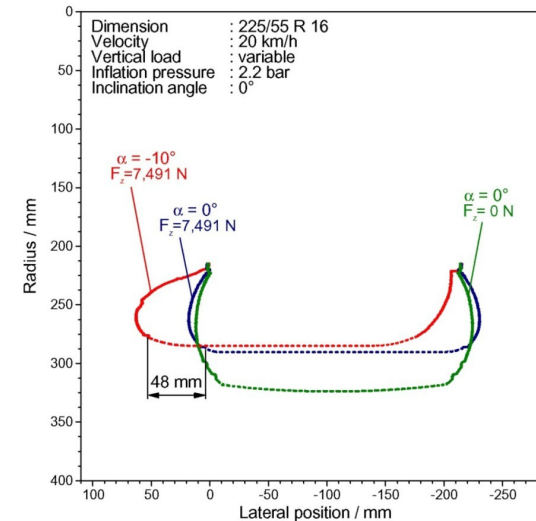
Determination of Tire Envelopes

■ 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

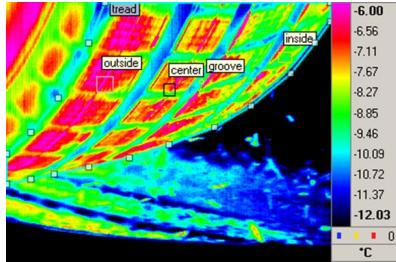
with measurement of tire forces and moments at the same time.



Measured tire contour for several load and slip angle conditions

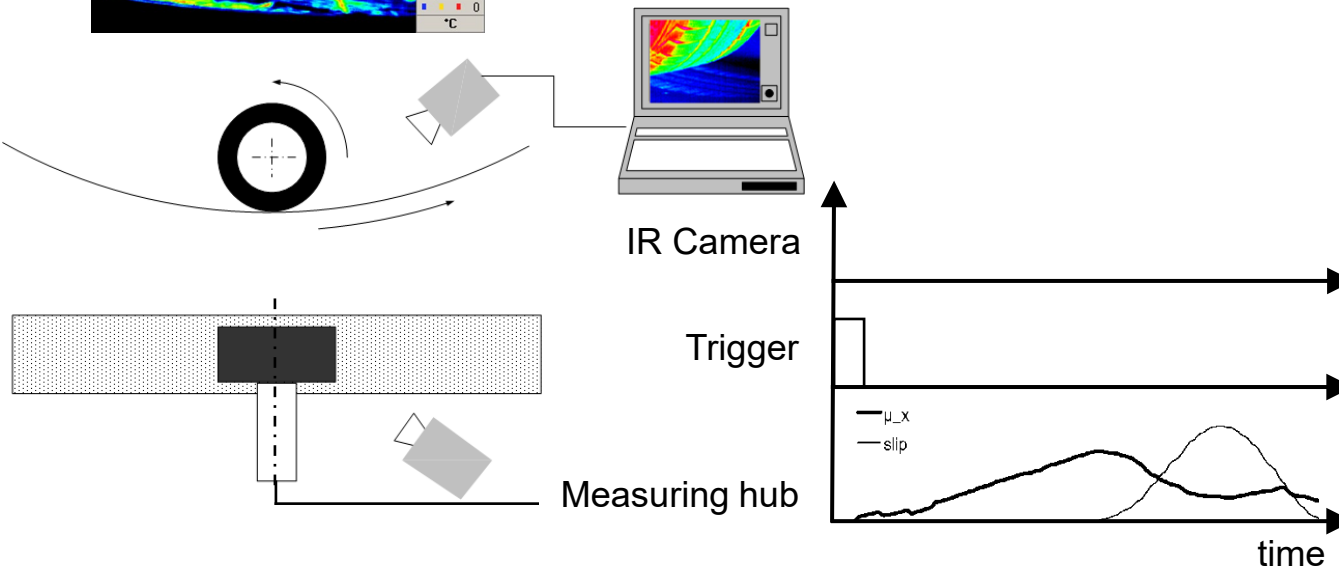
Special Equipment

High Speed Infrared Camera



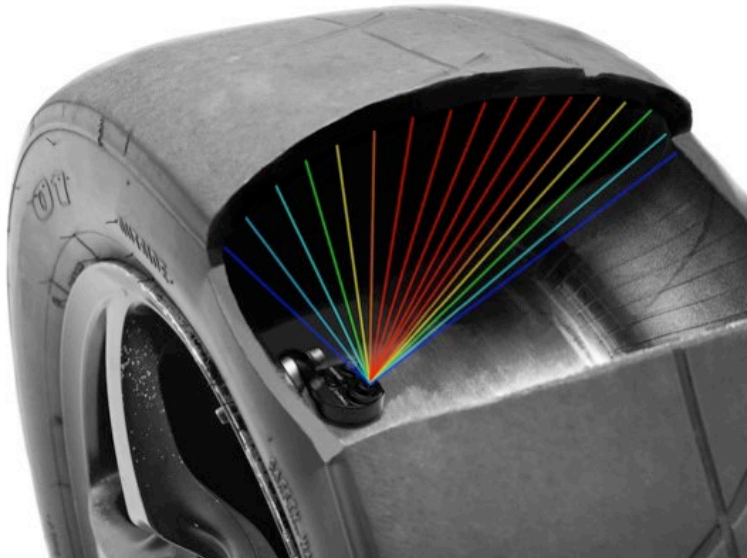
Technical Specification:

- 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 3 μs to 20 ms
- Trigger Input and Output: 0-3 V,
- Jitter <250ns,
- Analog video output: CCIR (50 Hz) or RS 170 (60Hz)
- 14 Bit digital 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: $-50^{\circ}\text{C} \dots 975^{\circ}\text{C}$
- Spectral range: $8 \dots 14 \mu\text{m}$

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

Particle Measurement

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



PALASCOUNTS

- Resolution (number C_N): $< 1 \cdot 10^6$ Particle /cm³
- Channels: 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 Channels

Source: [Promo® 3000 - Produktlinien - Palas](#)

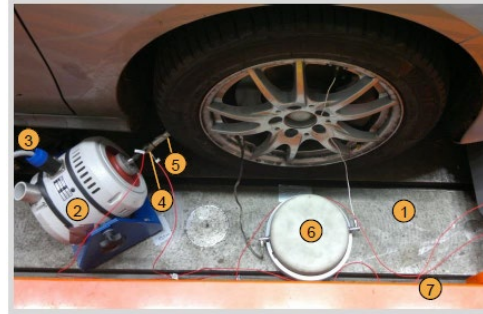
Article:

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

Analysis of



Car vibration

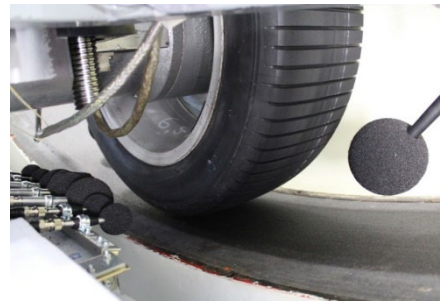


1. Seismic mass (300t)
2. Shaker
3. Power cable
4. Sensor
5. Adapter
6. Acoustic torus measurement device

Tire vibration



Car noise



Tire noise

Special Equipment

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

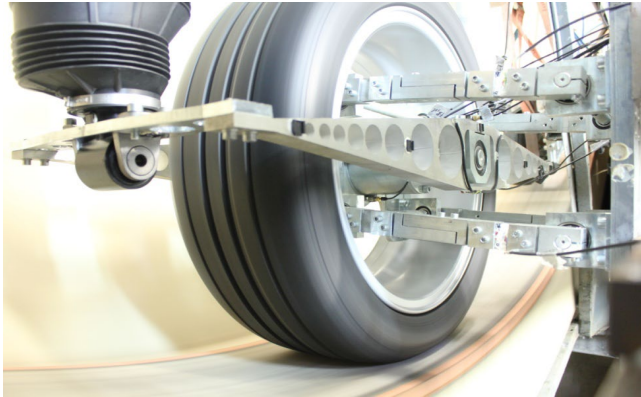


Data Acquisition

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

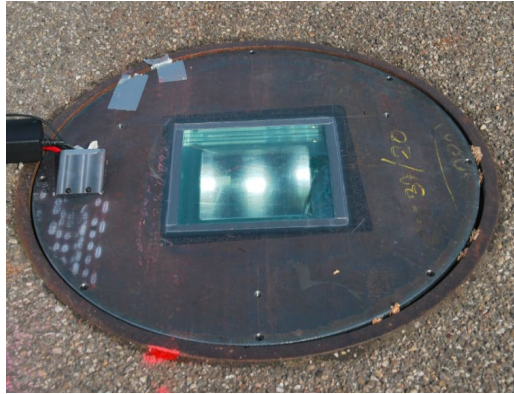


Noise and vibrations measured by multiple triaxial accelerator sensors, microphones and 3D-Scanningvibrometer (see complete list next slide).

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

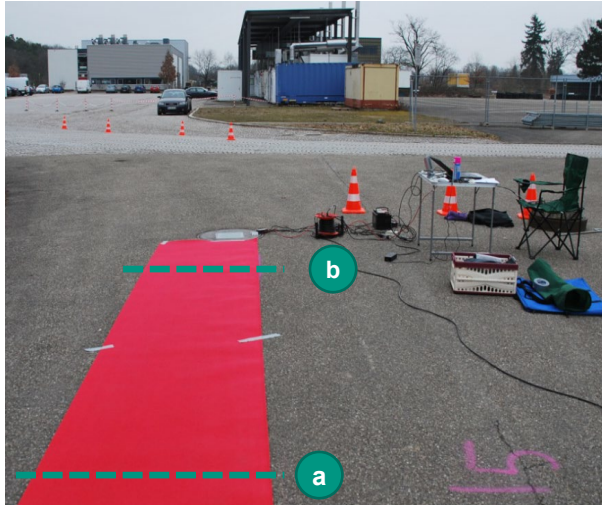
illumination with > 14.000 Lumen
recording of tire crossing > 2,300
fps

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

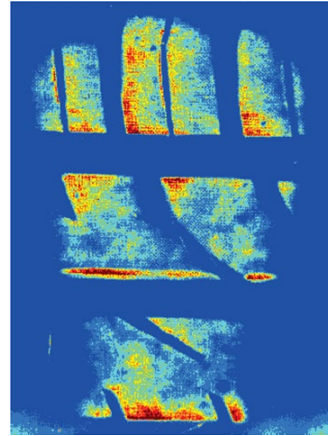
light barrier (a) activates pre-defined torque at electric vehicle automatically
⇒ reproducible tangential forces can be applied

light barrier (b) activates camera recording

fully automated

Special Equipment

High Speed Camera



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

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

Contact

Tire tests



Institut für Fahrzeugsystemtechnik

Institutsteil Fahrzeugtechnik

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