Test Equipment with focus on tire

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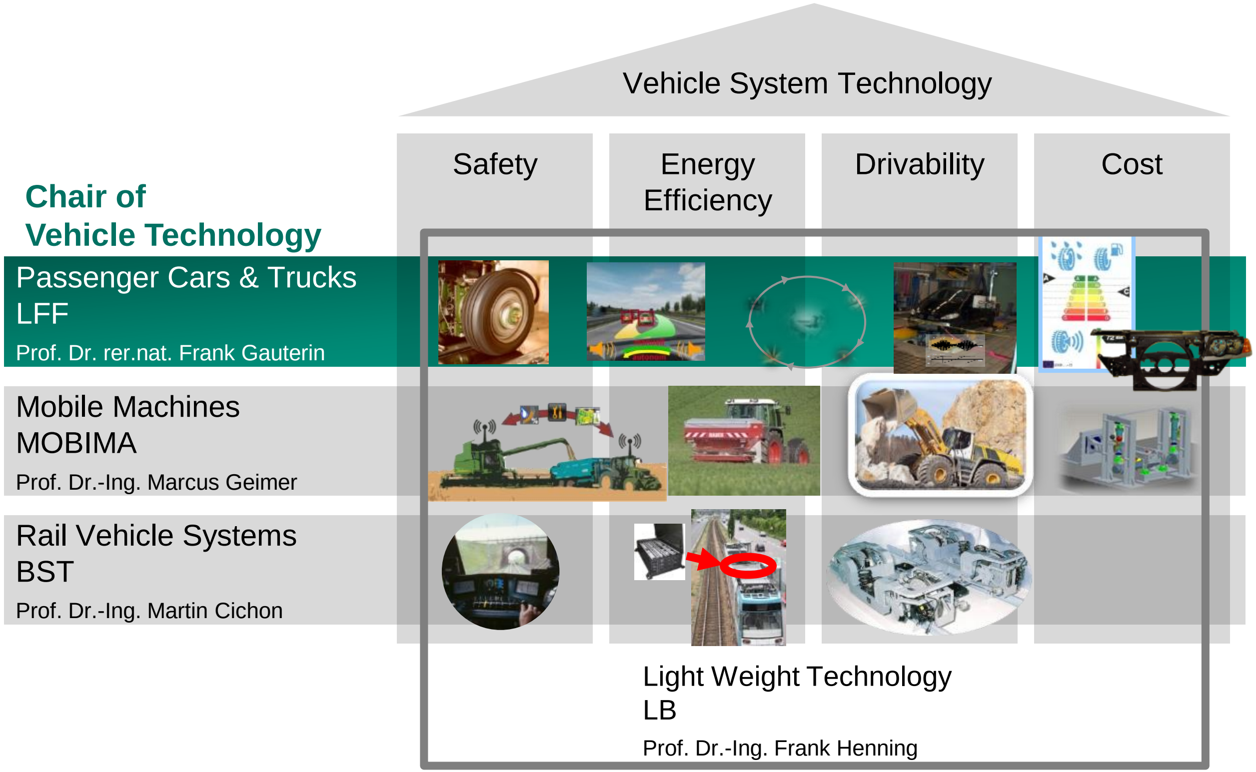
Content

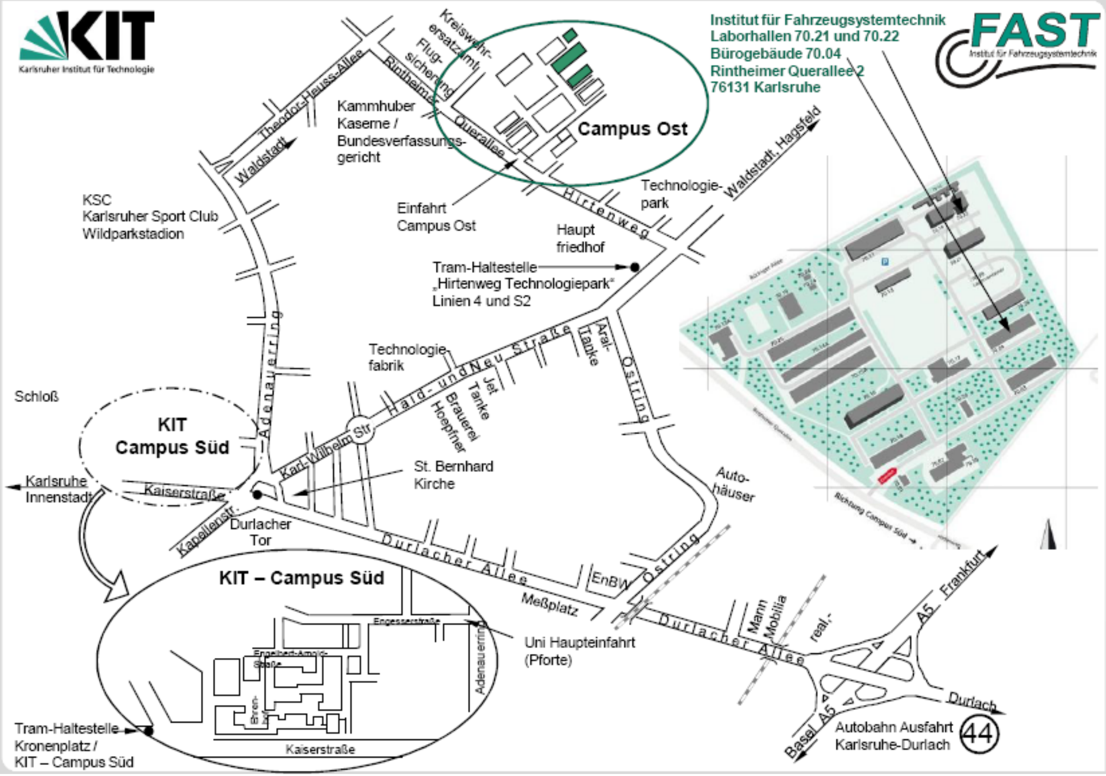
Karlsruher Institut für Technologie

- Institute Structure & Facilities
- IPS - Inner Drum Test Bench
- GRIPS - New inner drum test bench for dynamic tests of PLT and truck tires
- 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



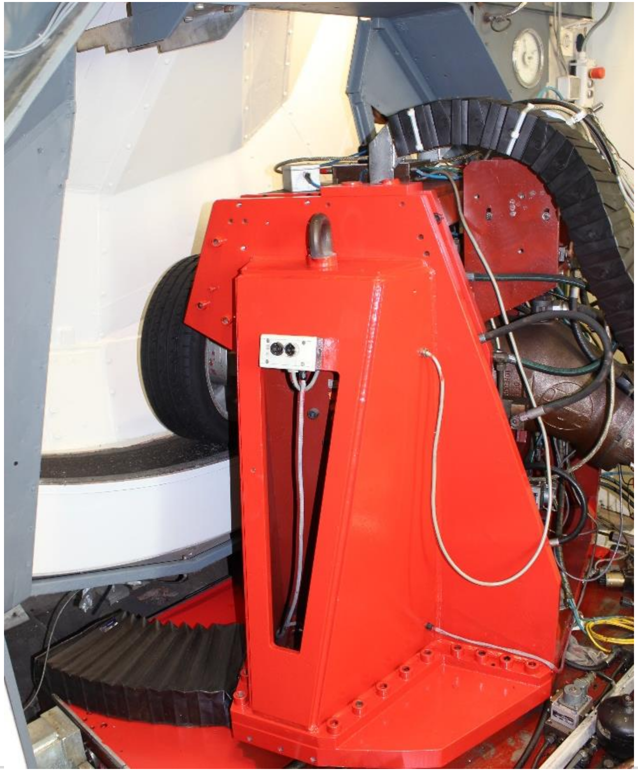
Facilities of FAST
Campus South – Campus East



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°)

<u>Measuring system for frictional force behaviour</u>

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

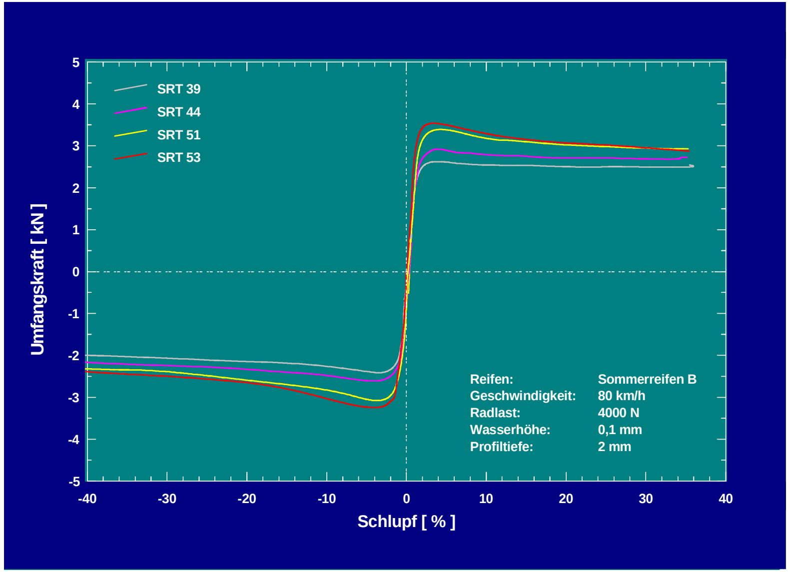
Analysis of the influence of

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

for example:

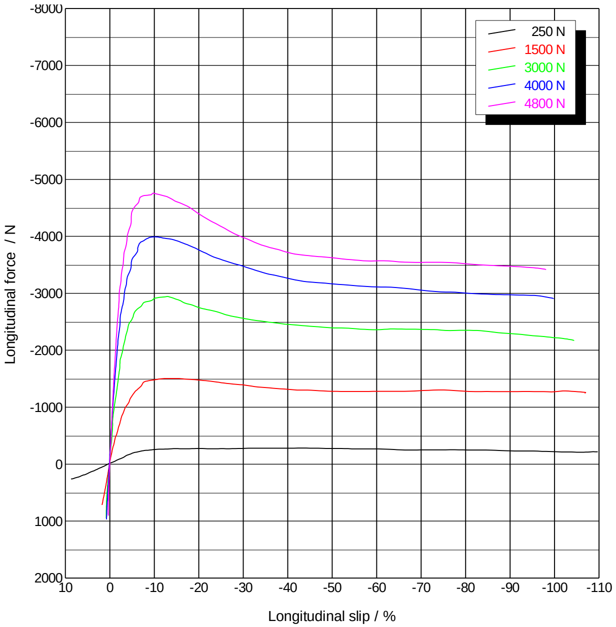
- Safety-Walk
- asphalt
- concrete

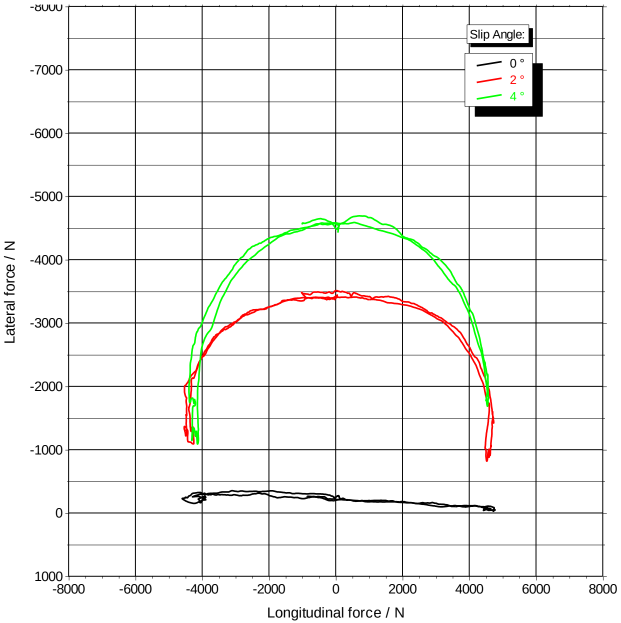
on the frictional behavior of tires on wet and dry roadway.



Variation of skid resistance,
tests on humid track surface

Internal Drum Test Bench
Longitudinal Force Measurements



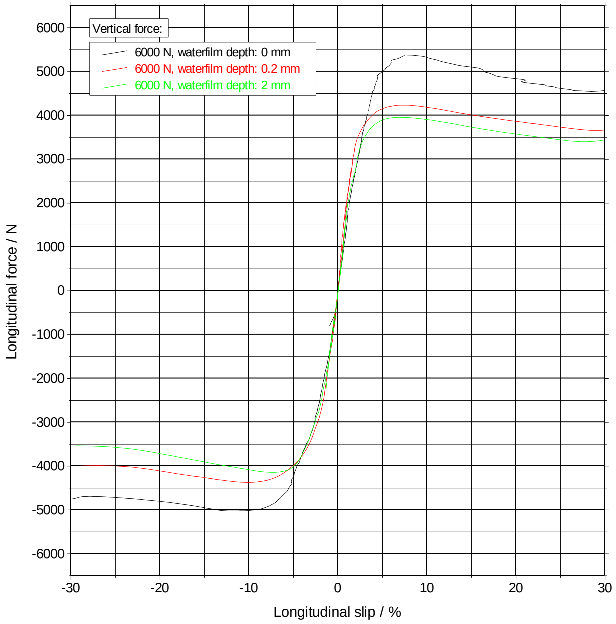


Manufacturer	:	Velocity	: 100 km/h
Tyre size	:	Inflation pressure	: 2,1 bar
Rim size	: 5,5 x 15	Slip angle	: 0°
		Waterfilm depth	: 0 mm
		Vertical force	: var.

Manufacturer	:	Velocity	: 40 km/h
Tyre size	:	Inflation pressure	: 2,2 bar
Rim size	: 7,5 x 16	Camber angle	: 0°
		Waterfilm depth	: 0 mm
		Vertical force	: 4800 N

Internal Drum Test Bench

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
Measurements on Snow and Ice Surfaces

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Internal Drum Test Bench
Measurements on Snow and Ice Surfaces

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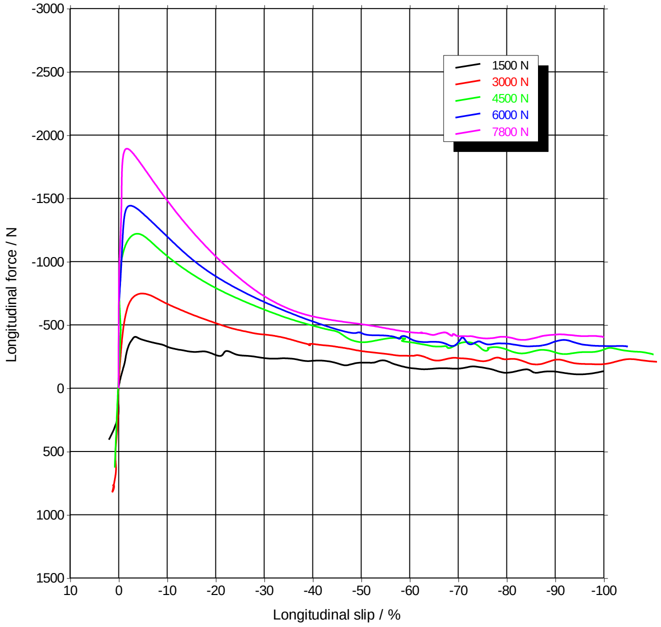
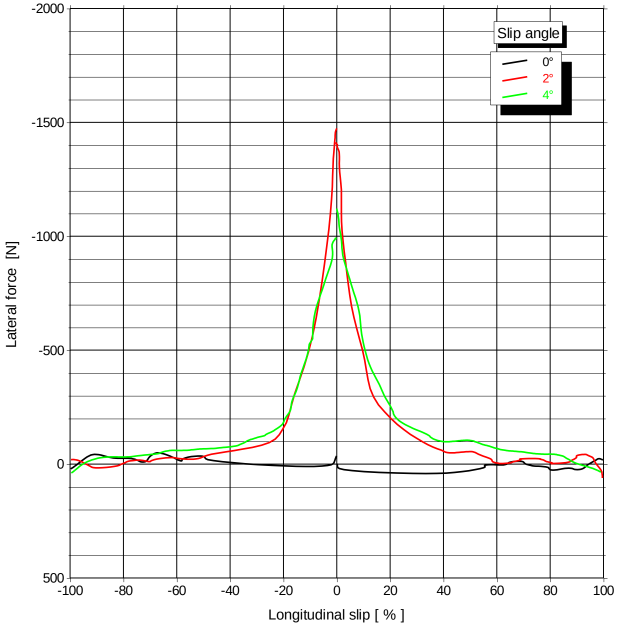
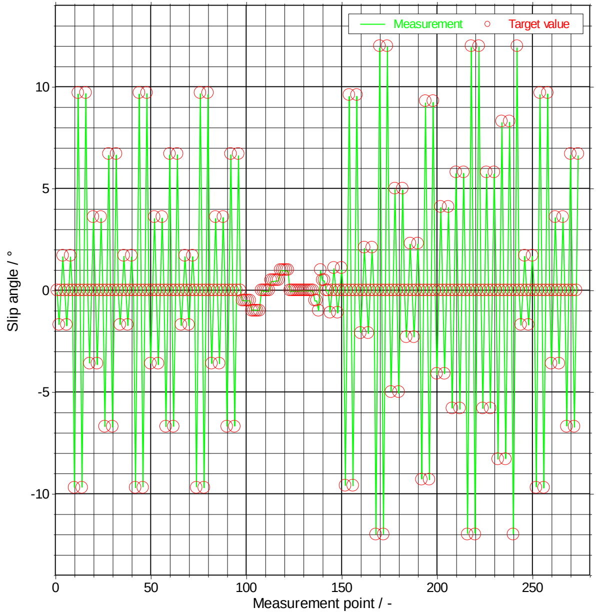




Manufacturer	:	Velocity	: 80 km/h
Tyre size	:	Slip angle	: 0°
Rim size	: 6,5 x 15	Track surface	: Ice
Inflation pressure	: 2,4 bar	Ambient temperature	-10 °C
		Vertical force	: variabel

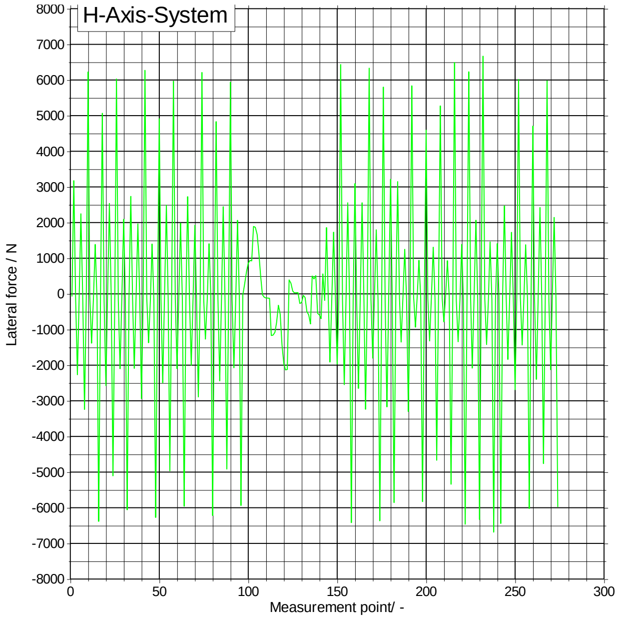
Manufacturer	:	Velocity	: 80 km/h
Tyre size	:	Slip angle	: variabel
Rim size	: 6,5 x 15	Track surface	: ice
Inflation pressure	: 2,4 bar	Ambient temperature	-10 °C
		Vertical force	: 6000 N

Internal Drum Test Bench
Measurements with the TIME Procedure



Adjustment of certain parameter combinations
(constant for 3 sec)

Manufacturer	:	Velocity	: 40 km/h
Identity	:	Inflation pressure	: 2,4 bar
Tyre size	:	Inclination angle	: var.
Rim size	: 7 x 16	Waterfilm depth	: 0 mm
		Vertical force	: var.



Measurement of tire forces
at adjusted parameter combinations

Manufacturer	:	Velocity	: 40 km/h
Identity	:	Inflation pressure	: 2,4 bar
Tyre size	:	Inclination angle	: var.
Rim size	: 7 x 16	Waterfilm depth	: 0 mm
		Vertical force	: var.

Internal Drum Test Bench
Measurements for Tire Comfort Models

- **Rolling over Cleats**

Changeable Pavement

and

changeable cleats

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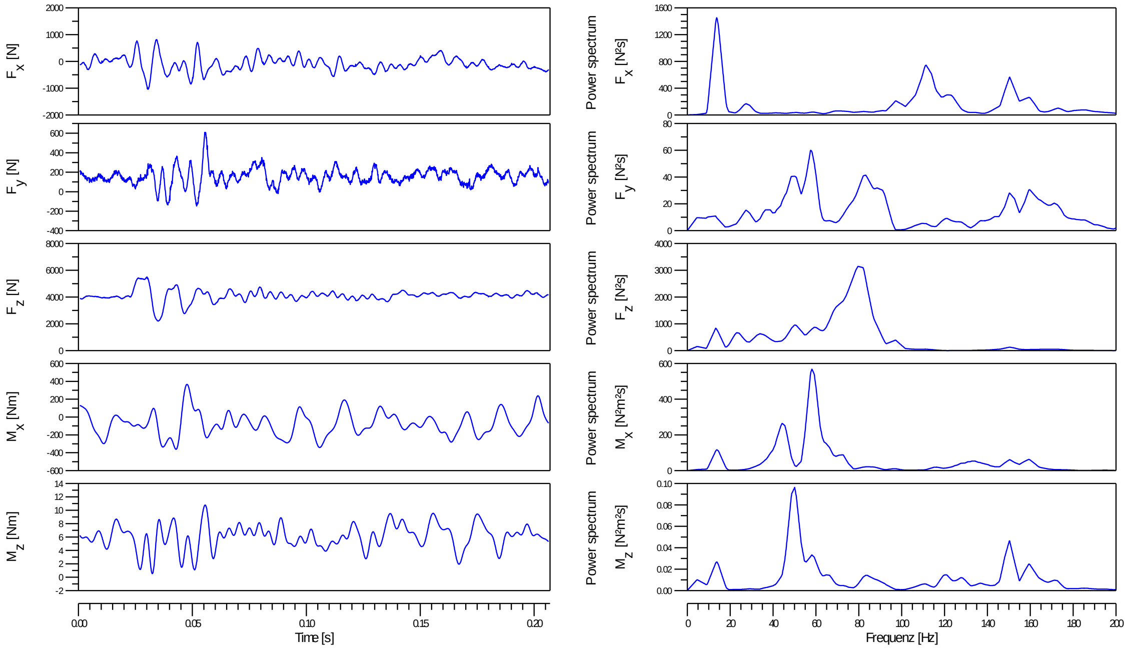
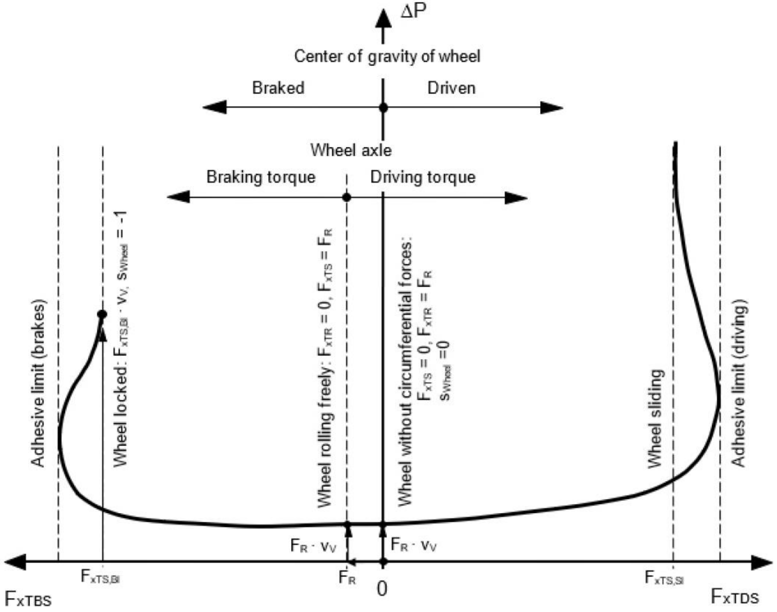
Internal Drum Test Bench
Measurements for Tire Comfort Models

- **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



Braking

Driving

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

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

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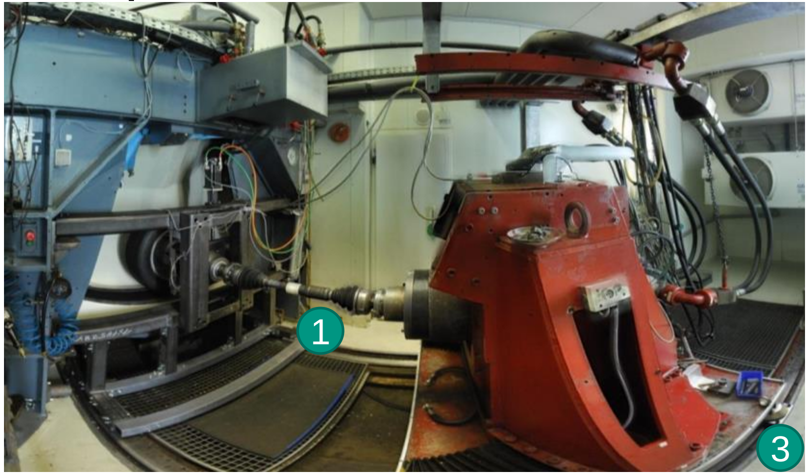
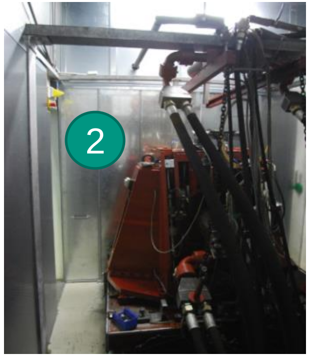
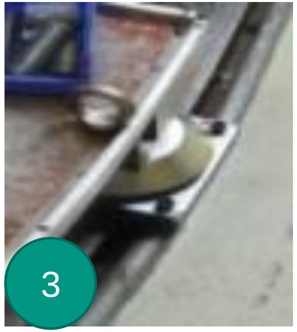
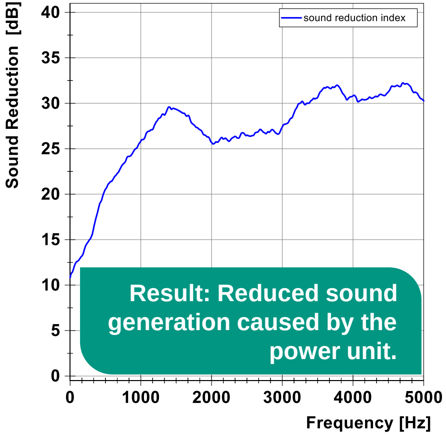
Inner Drum Test Rig
Setup for Acoustic Test









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

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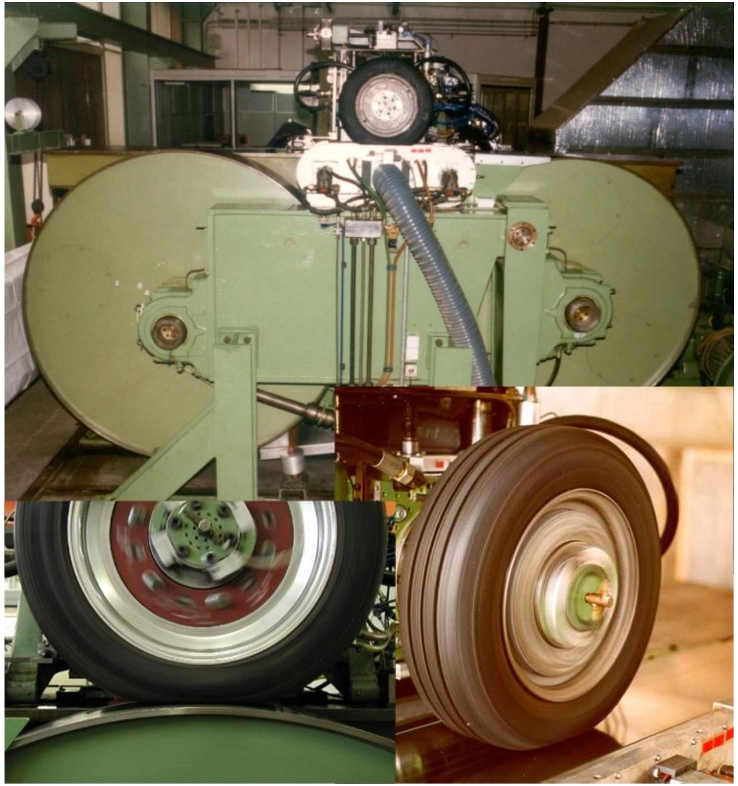
FPS

Flat Track Outer Drum Test Bench



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

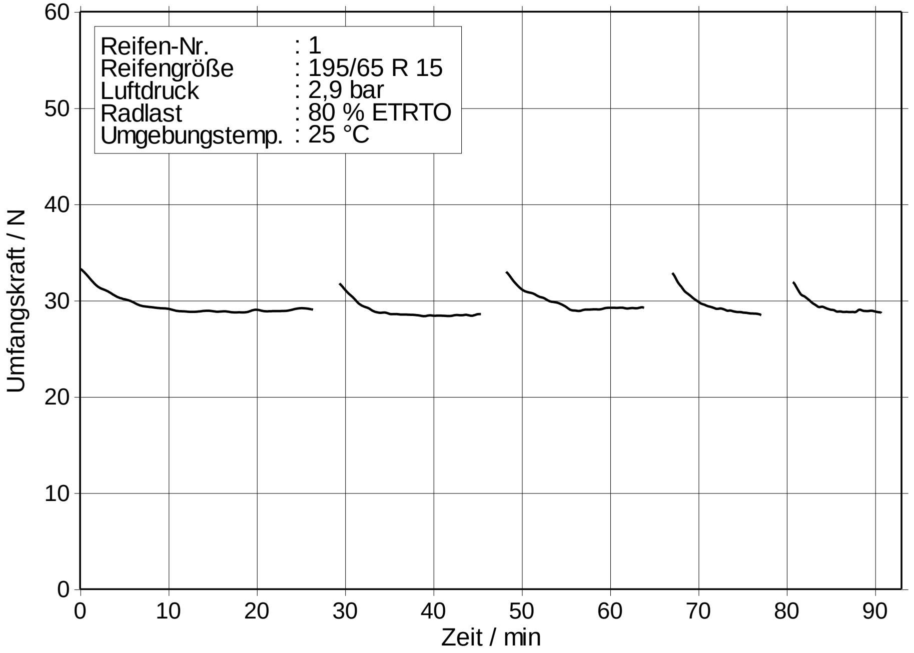
<u>Measuring system for rolling resistance</u>

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

FPS

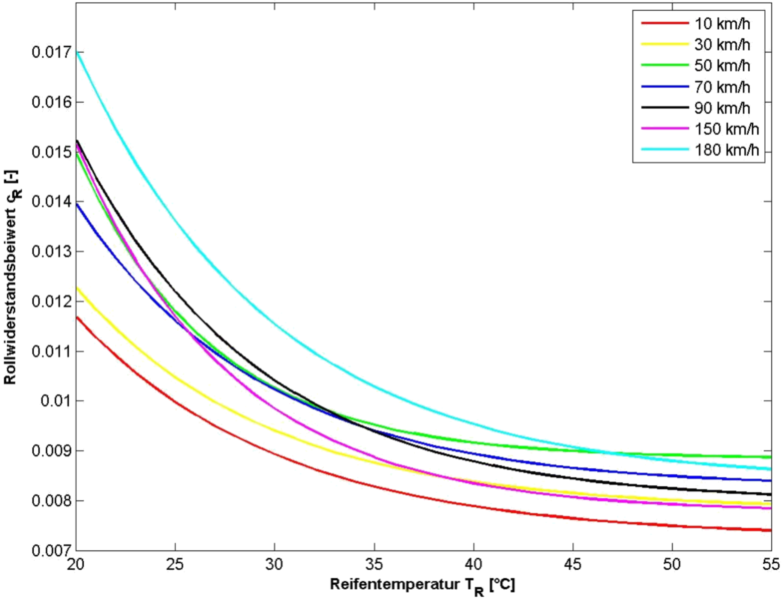
Flat Track Outer Drum Test Bench



FPS

Flat Track Outer Drum Test Bench

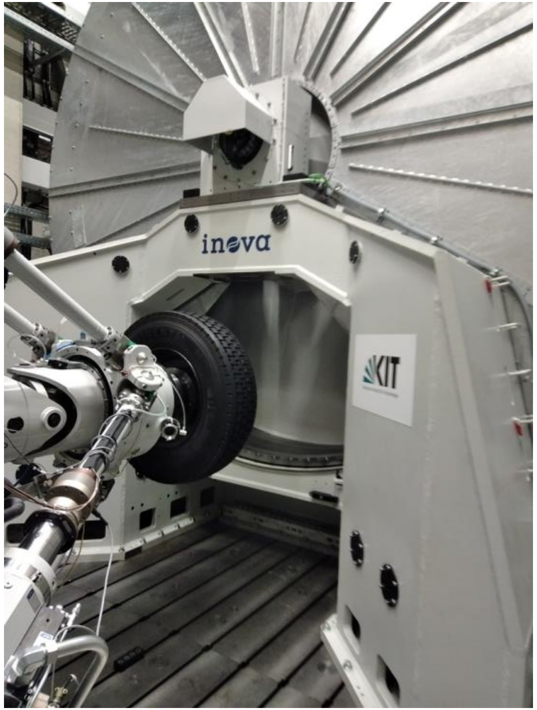
- Rolling resistance depends on temperature, road surface, drive torque, side slip, weather condition, …
- Real life conditions differ from test conditions (ISO 28580).
- Test result is not a good predictor for real life rolling resistance.

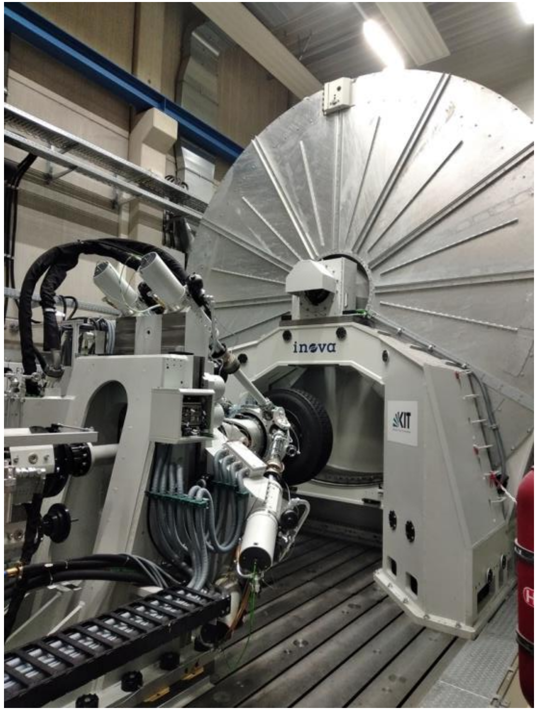


Developed method: Test method to predict tire temperature and rolling resistance in real life drive cycles.

GRIPS

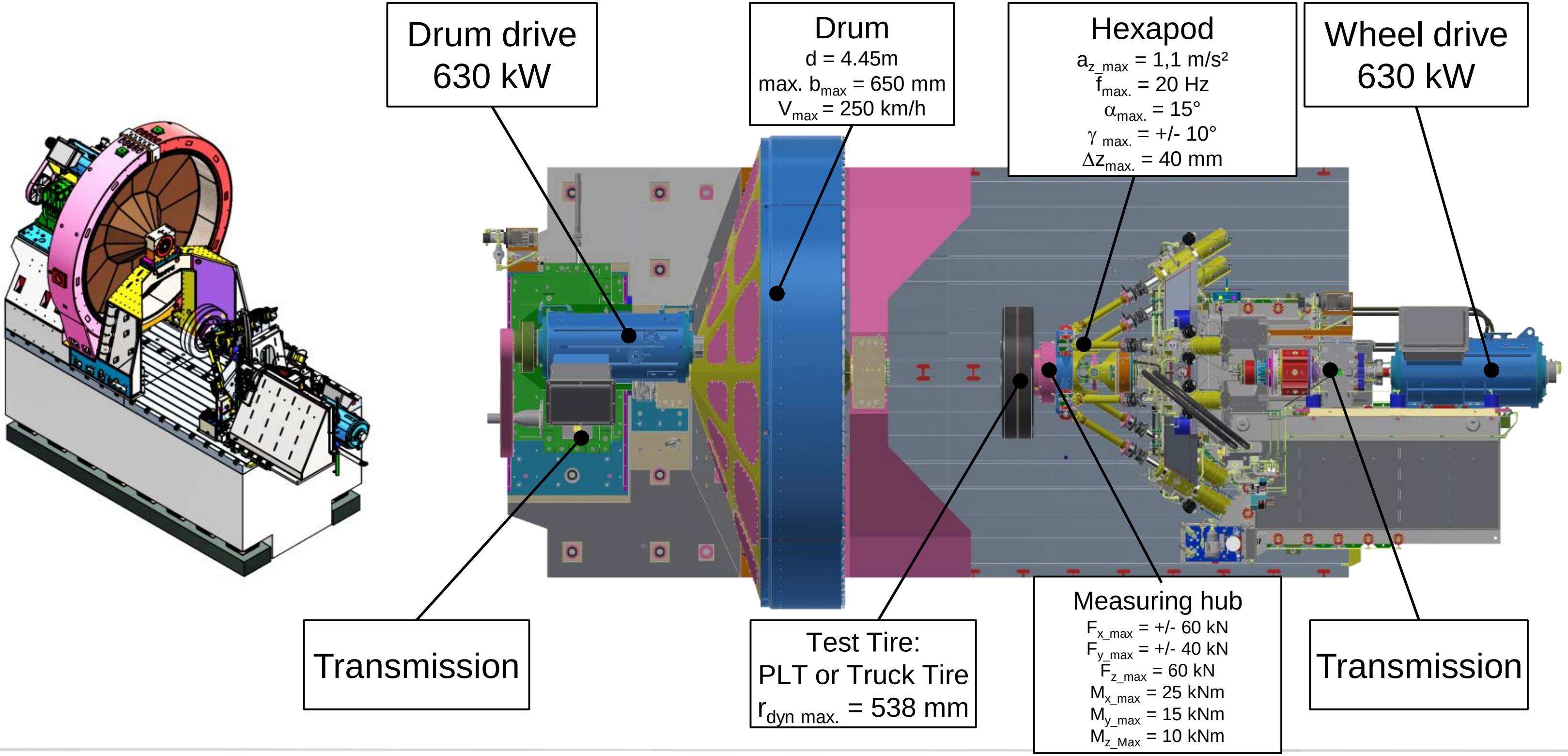
New inner drum test bench for dynamic tests of PLT and truck tires





GRIPS

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



d = Inner diameter of drum
b = width of track

GRIPS

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

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 kNm M_{y_max} = 14 kNm M_{z_max} = 10 kNm

Grip- and Abrasion Teststand (GAT)

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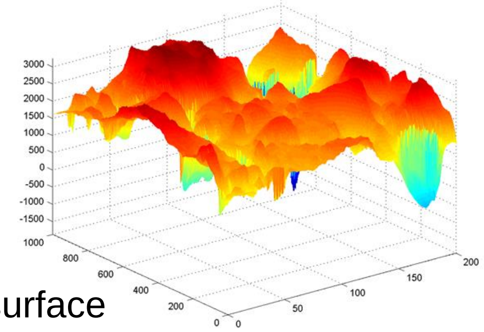
Rubber road friction test stand

- 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

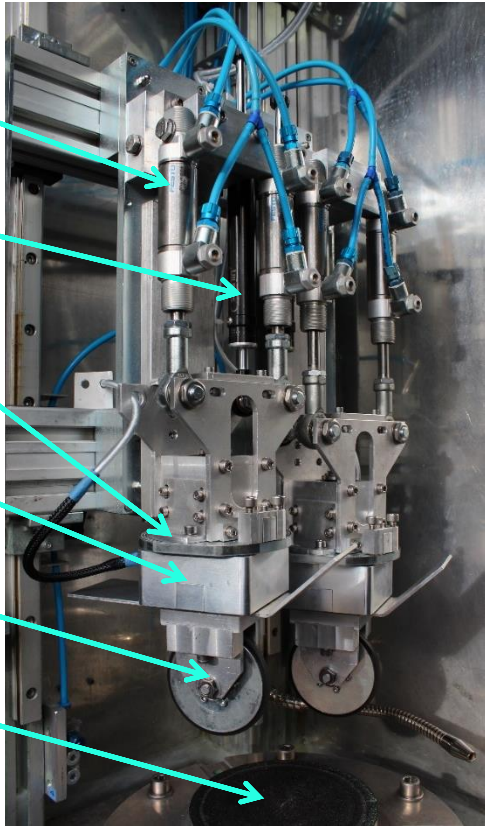
shock absorber

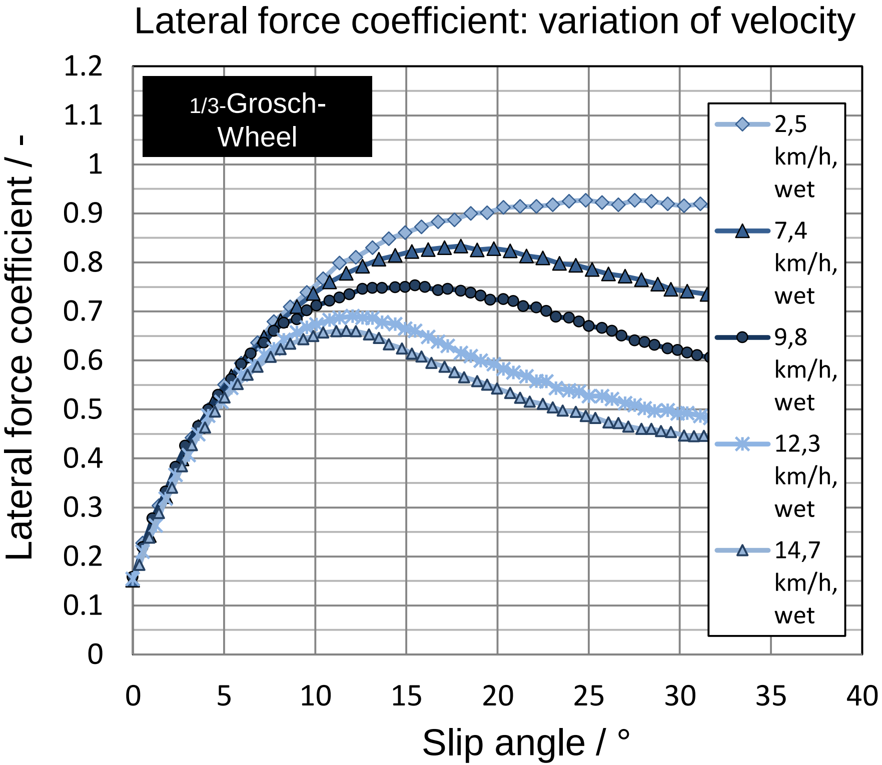
side slip angle adjustment

load cell

rubber sample fixation

rotating surface sample





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VIL
Vehicle in the Loop Test Bench

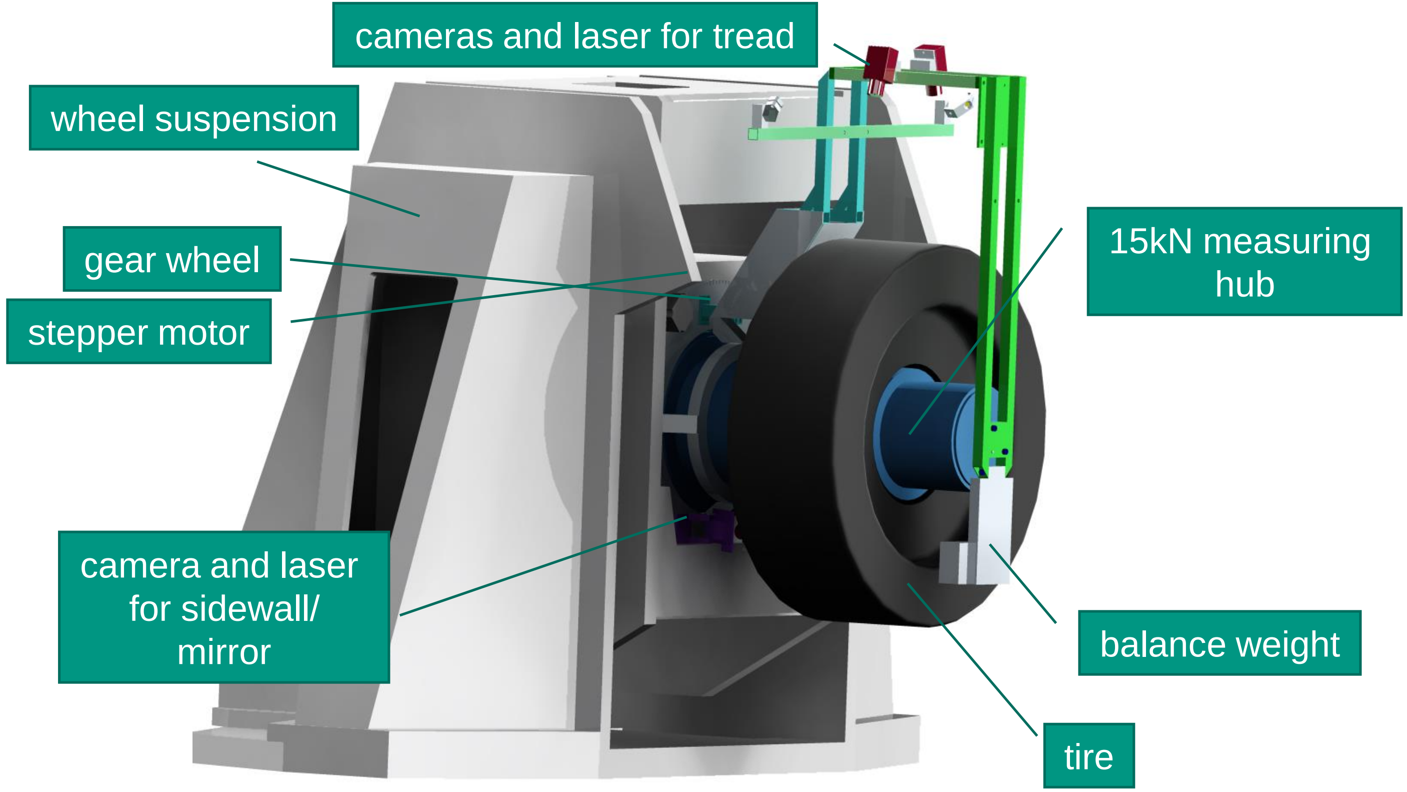
Test Rig	Max. Vehicle Weight	12.000 kg
	Max. Wheel Load	3.000 kg
	Wheel base	1,8 - 4,9 m
	Track width	1,2 - 3,9 m
Dynos (load engines) (1)	Max. wheel speed	2.000 min-1 (200...260 km/h)
	Max. wheel load torque	2.500 Nm
	Max. wheel load power	209 kW
Steering Simulator (2)	Max. steering angle front wheels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

AARPS

Acoustic 4WD Chassis Dyno

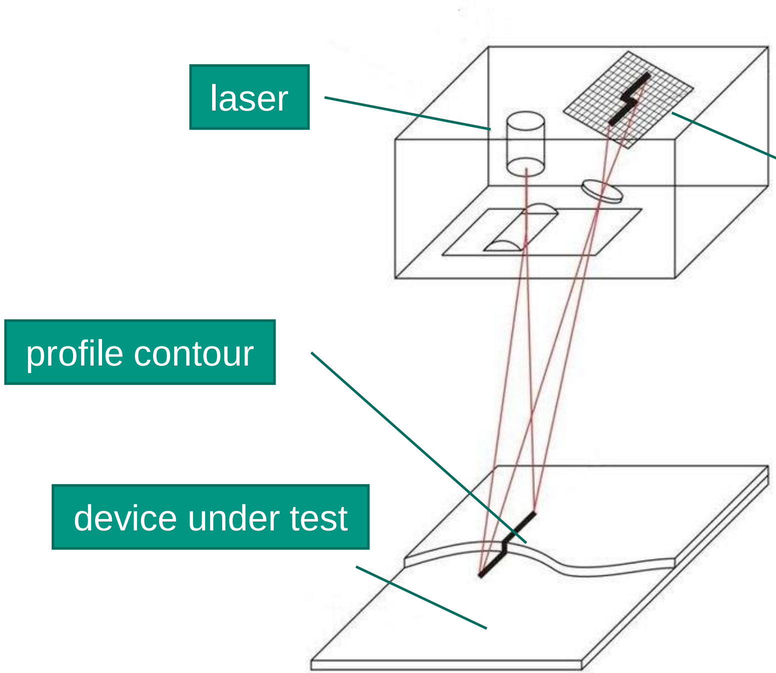
vehicle weight	40 t
Axle load	28 t
Wheel base	2,05 m – 8,00 m
Traction force per wheel	110 kN
Total max. power	1,1 MW
Max. speed	160 km /h
Cooling air flow	until 180 000 m³/h
acust. Cut-off frequency	63 Hz -17 000 Hz

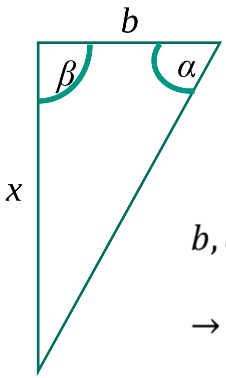
Special Equipment
Determination of Tire Envelopes



Special Equipment
Determination of Tire Envelopes

- Light Section Triangulation Method





b, α, β known

$\rightarrow x$

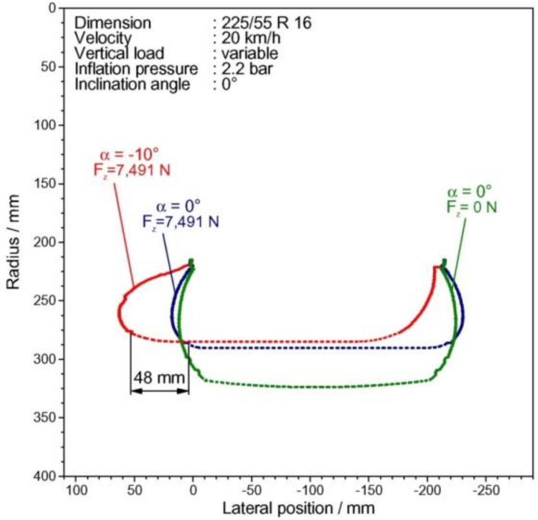
Special Equipment
Determination of Tire Envelopes

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

  Non-contact measurement of tire contour

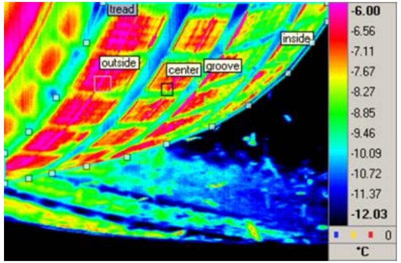
  - under real (even extreme) driving conditions
  - on real track surfaces

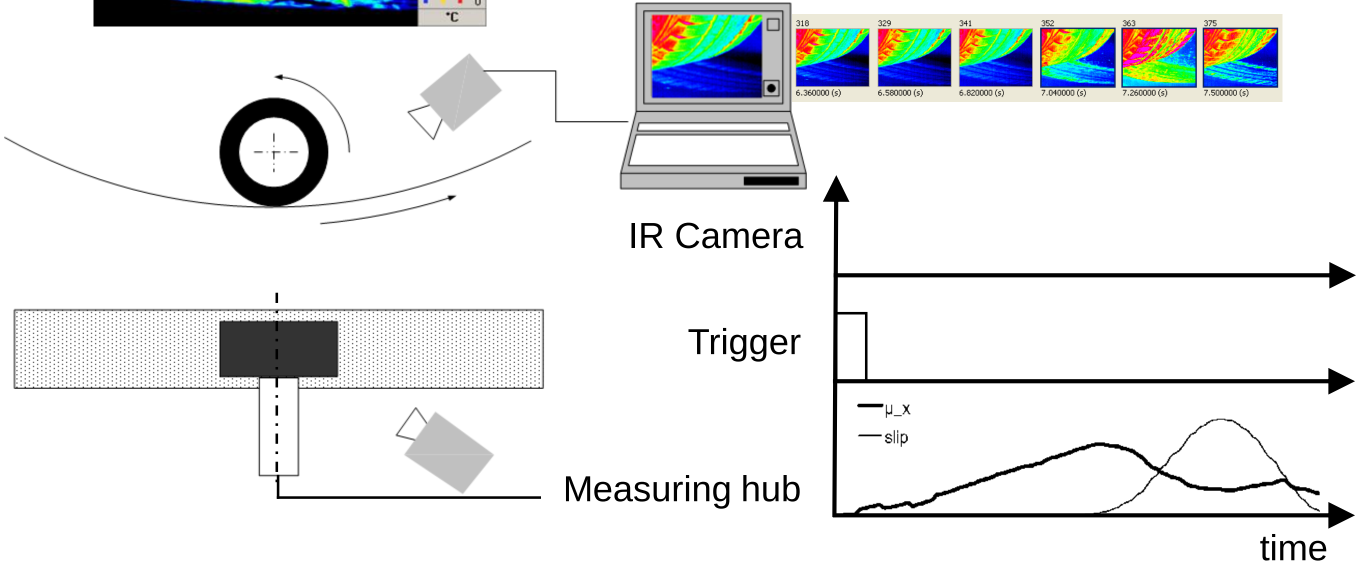
  with measurement of tire forces and moments
  at the same time.



Measured tire contour for several load and slip angle conditions

Special Equipment
High Speed Infrared Camera

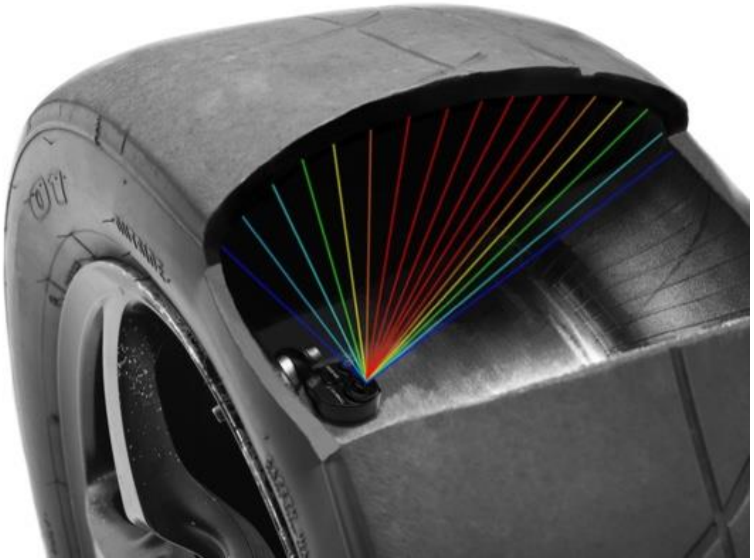




Technical Specification:

- 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

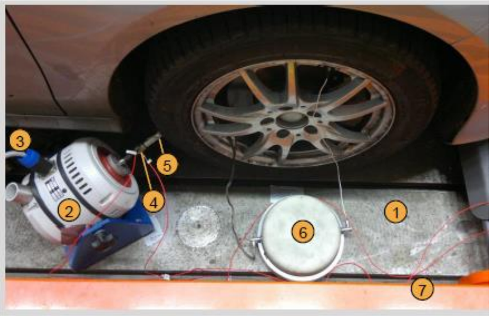
Source: Promo® 3000 - Produktlinien - Palas

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
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
NVH Tests

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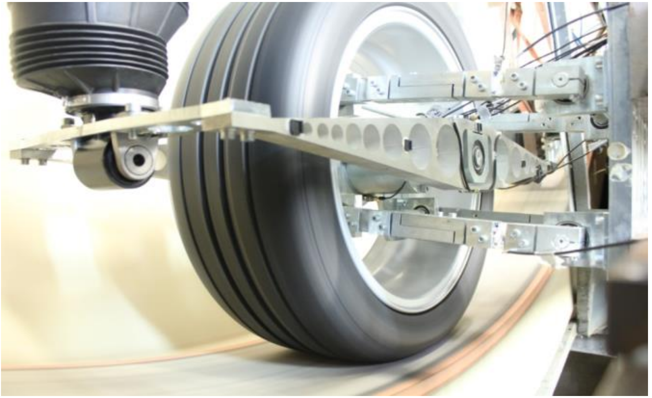
Sensors

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

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[2] DE102013107018.3

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

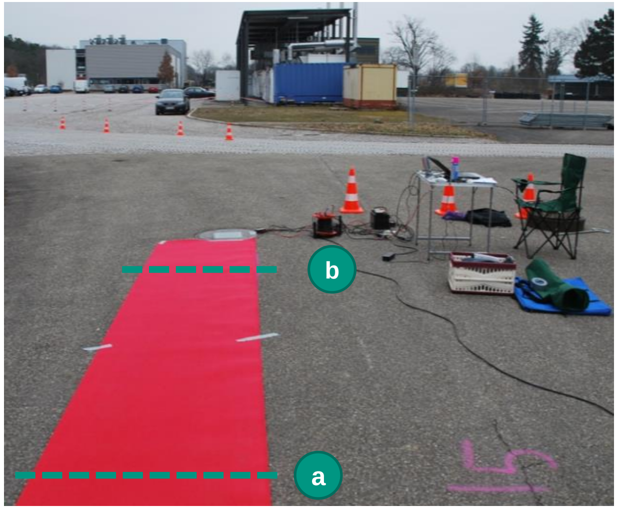
illumination with > 14.000 Lumen
recording of tire crossing > 2,300 fps

easy integration

simple handling

Special Equipment
Visualization of the tire tread deformation

mobile under-floor laboratory



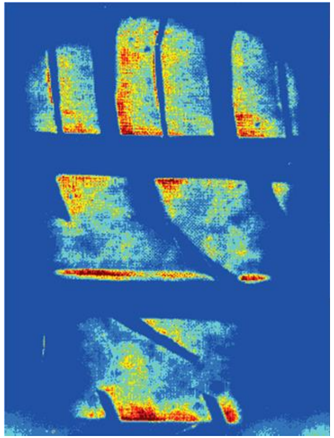
start-up carpet avoids collecting stones and dust particles by the tire during drive up

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

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Contact
Tire tests

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