
FKFS
RESEARCH IN MOTION.
Together, we engineer the
Mobility of tomorrow.

FKFS

FKFS is both a development partner of the international automotive industry and an independent research institute. As an innovative partner, we benefit from our numerous test benches. With the help of our simulation procedures – including the application of AI – we are able to offer specialized services and consulting.
Our skilled employees contribute their outstanding expertise to each project and consistently place customer benefit at the forefront of their work.

FKFS
RESEARCH IN MOTION.

Competencies & Consulting

Overall vehicle & components

- Aerodynamics
- Driving dynamics & chassis control
- Acoustics & NVH
- Comfort
- Thermal management

Powertrain systems & -energies

- Powertrain technologies
- Battery technologies
- Renewable energy carriers
- Operating strategies

E/E & Software

- Software & AI
- Electrical system
- Charging technology
- Function development & application
- Functional safety

Smart mobility

- Automated driving
- Car2x
- Traffic modeling
- Mobility Concepts

Validation & Verification

- Environmental influences
- Quality & Reliability
- Certifications

Services

Vehicle Test Benches

- Handling Roadway
- Servo-Hydraulic 4-Post Test Stand
- Accoustic Test Chamber
- Roller Dynamometer Test Facility
- Tire-Road Noise Test Bench & Noise Measurement Trailer
- Stuttgart Driving Simulator
- Climate Road-to-Rig
- Climatic Chamber

Powertrain Test Benches

- Powertrain Test Benches for Drive Systems
- Hybrid Engine Test Bench
- Development Test Bench for High-Speed Drives
- NVH Single-Axis Test Bench
- NVH Powertrain Test Bench
- High-Performance Electrical Powertrain Test Bench
- Multi-Configuration Powertrain Test Bench
- Vehicle-Related Powertrain Superstructures

Wind Tunnels

- Vehicle Aeroacoustic Wind Tunnel
- Model Wind Tunnel
- Thermal Wind Tunnel
- Climatic Wind Tunnel

Instrumentation & Analytic Technology

- Driving Dynamics Instrumentation
- Acoustic Measurement Equipment
- Special Measurement Systems
- Aerodynamic Measurement Systems
- Thermal Comfort Manikin

Simulation

- 0D/1D-Simulation incl. longitudinal dynamics
- 3D/CFD-Simulation-QuickSim
- Life Cycle / Total Cost Analysis
- Digital Competence Development
- Artificial Intelligence & Data Science
- Virtual Driving Characteristics Development
- Simulative E/E Architecture Optimizations
- Virtual Development

Handling Roadway

The Handling Roadway is a new, innovative test bench concept enabling combined lateral, longitudinal and vertical dynamic operating states to be investigated under laboratory conditions. All four steel belt units can be steered and actuated vertically with high bandwidths. The vehicle is attached to the test bench in such a way that the heave, pitching and rolling motion can occur freely,according to the acting tire forces. The remaining degrees of freedom are calculated in the simulation, so that almost any maneuver can be driven.

Longitudinal | Lateral | Vertical

Belt speed	0,5 – 220 km/h
Peak power/continuous power	220/140 kW
Max. longitudinal force	6 kN

Application Examples

- Driving dynamics standard maneuvers
- Investigating axles and steering systems
- Vertical dynamics under simultaneous longitudinal and/or lateral excitation
- Designing control systems
- Powertrain investigations

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Longitudinal | Lateral | Vertical

Max. belt steering angle	±20°
Belt steering bandwith	15 Hz
Max. lateral force	10 kN

Application Examples

- Driving dynamics standard maneuvers
- Investigating axles and steering systems
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Longitudinal | Lateral | Vertical

Max. vertical displacement	±75 mm
Max. vertical acceleration	7 g
Max. vertical force	15 kN
Vertical excitation bandwith	15 Hz

Application Examples

- Driving dynamics standard maneuvers
- Investigating axles and steering systems
- Vertical dynamics under simultaneous longitudinal and/or lateral excitation
- Designing control systems
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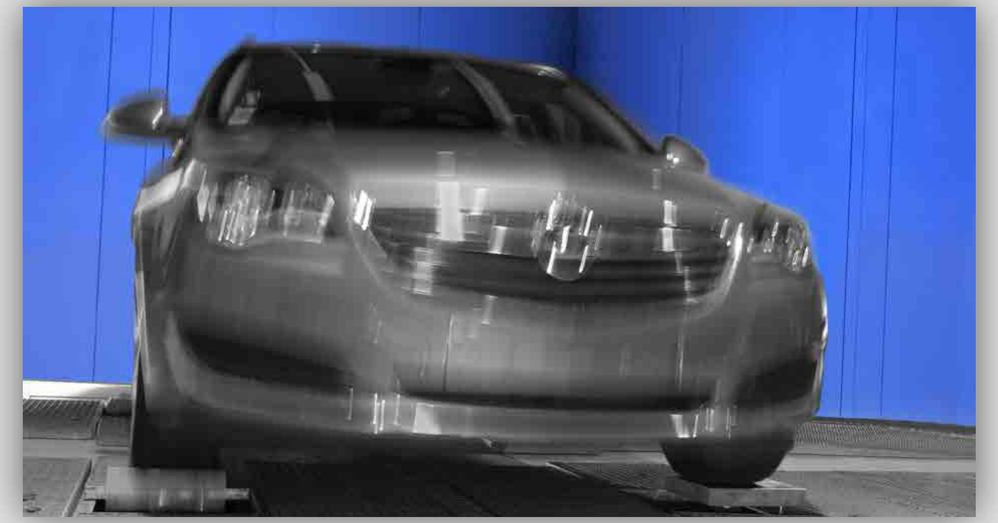

Servo-Hydraulic 4-Post Test Bench

The servo-hydraulic 4-post test bench at FKFS enables vertical excitation at all four wheels of a vehicle. The posts can be equipped with linear guides in order to avoid lateral force components acting on the wheels.

Technical Data 1 | Technical Data 2

Maximum force	± 63 kN
Maximum stroke	± 125 mm
Frequency range	0 – 200 Hz

Application Examples

- Testing of the durability of individual components
- Investigation of e.g. squeak and rattle noise
- Simulation of rolling noise excitation in the vehicle (up to approx. 150 Hz)
- Comfort testing (e.g. engine vibration or micro-jitter in convertibles)

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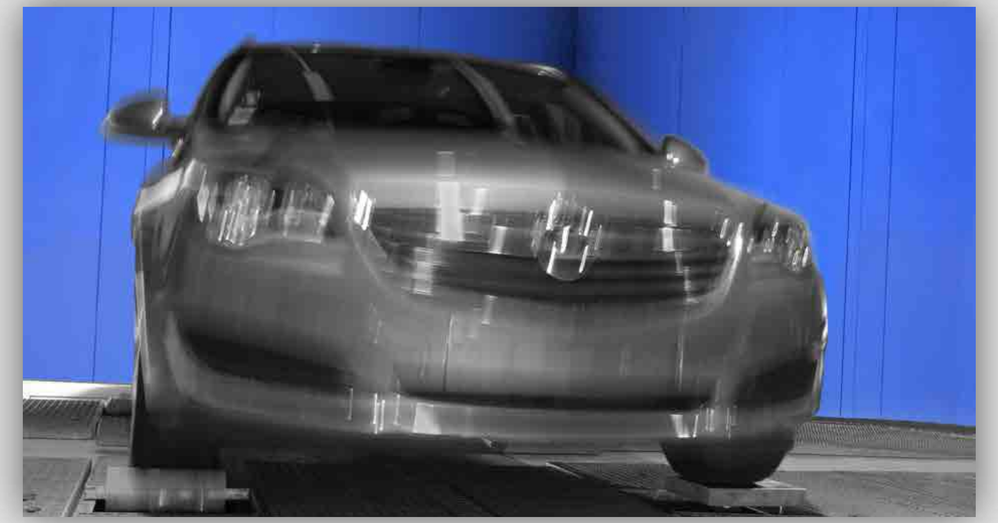

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Technical Data 1 | **Technical Data 2**

Max. wheelbase	4100 mm
Min. wheelbase	1500 mm
Max. track width	2000 mm
Min. track width	900 mm

Application Examples

- Testing of the durability of individual components
- Investigation of e.g. squeak and rattle noise
- Simulation of rolling noise excitation in the vehicle (up to approx. 150 Hz)
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Acoustic Test Chamber

An anechoic test chamber equipped with broad-band compact absorbers (semi-anechoic chamber) is available for noise measurement and noise optimization of vehicles, vehicle subsystems and other devices. The chamber is completely decoupled from the surrounding building and features an exhaust extraction system.

Technical Data 1

Acoustic Test Chamber internal dimensions (l x w x h)	9 m x 5 m x 4 m
lower frequency limit	125 Hz

Application Examples

- ☑ Acoustic Development on cars and vans with and without engine operation
- ☑ Measurement and optimization of funktional and operating noise
- ☑ Localization of sound sources (e.g. with microphone arrays)
- ☑ Investigation of acoustic transfer paths

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Roller Dynamometer Test Facility: Performance role

At test speeds of up to 300 km/h, it is used for dynamic and static power measurement. In addition, the test bench guarantees maximum measurement accuracy and reproducibility thanks to its active measurement of drag performance. The rolling behavior of the tire is similar to that on the road. Operating modes such as load simulation including optional modules for recording external measurement data, driving cycles etc. are possible. The test track is equipped with an airstream fan and conditioned air to simulate road driving under realistic conditions.

General

Type	2-axle parting roll
Speed	300 km/h
Power	260 kW each
Max. axle load	2500 kg

Application Examples

- Performance measurement
- Constant drive
- Various driving cycles for vehicle application under reproducible conditions
- Exhaust-gas measurement
- Use of non-vehicle-integrable measurement technology on a moving vehicle

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Tire-Road Noise Test Bench & Noise Measurement Trailer

FKFS investigates tire-road noise of vehicles not only by far field measurements using microphones at the side of the road. FKFS investigates tire-road noise also by means of a specially developed trailer. In this, the noise can be recorded with several microphones around the tire in the close range. Background noise from outside the trailer is suppressed to the greatest possible extent. Based on these tire-road noise measurements and by using the tire-road noise test bench developed at FKFS, it is possible to determine the contribution of the air-borne tire-road noise to the interior noise of a vehicle in an isolated way.

Application Examples

- Recording the tire road noise directly at the point of origin
- Investigation of the radiation behavior of the tire-road noise
- Determination of the tire road noise contribution to the interior noise

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Stuttgart Driving Simulator

With its 9-axis motion system, which is unique in the European research landscape, the Stuttgart driving simulator enables the realistic representation of interactive and autonomous driving scenarios in the city, on highways, country roads and PGs.
In addition to expert and test person studies for development and research, we offer a wide range of consulting services, e.g. the use case-based design of driving simulators and simulator centers for customers, motion cueing algorithms, scenario design, radar/lidar sensor simulation and software integration.

Technical Data 1 | **Technical Data 2**

Longitudinal and lateral movements up to 8 m/s²
Yawing movements +/- 160°
360° visualisation
Spatial sound- and NVH-system
Steering wheel and brake pedal force simulation

Application Examples

- ✓ Chassis development, active chassis systems
- ✓ Interactive optimization of driving characteristics
- ✓ Driver assistance systems and autonomous driving
- ✓ Functional safety (brakes, steering, chassis)
- ✓ User Experience, HMI, Driving Comfort, Motion Sickness
- ✓ Perception and accident research

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Technical Data 1 | **Technical Data 2**

Full vehicle mockups (cars and trucks)
HMI– and Autonom- Mockup (ID Buzz)
Customized scenario and traffic simulation
Eye- and Bodytracking, EEG, EMG, heart rate etc.

Application Examples

- ☑ Chassis development, active chassis systems
- ☑ Interactive optimization of driving characteristics
- ☑ Driver assistance systems and autonomous driving
- ☑ Functional safety (brakes, steering, chassis)
- ☑ User Experience, HMI, Driving Comfort, Motion Sickness
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Climate Road-to-Rig

This test bench enables environmental simulations on battery-powered electric vehicles (BEV) in the temperature range from -30°C to +50°C. It enables research and testing of electric powertrains in the vehicle. GPS spoofing and the CarMaker route simulation program make it possible to simulate any route. A battery simulation offers the possibility of simulating charging processes under a wide range of environmental conditions and to investigate the reactions of the vehicle systems. A fan simulates the airstream up to a speed of 210 km/h.

Technical Data 1

Environmental simulation	-30 °C bis +50°C
Battery simulation	822 kW (1000 V, 1200A)
4 highly dynamic wheel machines	4 x 650 kW , 10kHz
Fan	210 km/h

Application Examples

- Module testing during operation
- Performance measurement (-30°C – 50°C)
- Battery test during extreme requirements of load & temperature
- Method development for integration and development of components

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Climatic Chamber

Our climate chamber enables environmental tests under extreme conditions. Whether heat, cold, humidity or solar exposure – with flexible control of all climate climate parameters, realistic scenarios can be reproduced for the development and validation of modern vehicles. The combination of precise climate simulation and high-performance testing technology offers ideal conditions for reliable and reproducible test results – regardless of the type of powertrain.

Dimensions & conditions | 1-axle-dynamomenter

Test section (l x w x h)	12 m x 5 m x 5 m
Driveway (w x h)	4 m x 4 m
Temperature range between –35 °C and 55 °C	
Rel. Humidity	10 – 90 %
Solar load range	500 – 1100 W/m²

Application Examples

- Thermal Management
- Thermal Validation
- Driving Performance (stationary)
- Windshield de-icing/Defogging
- Climate Comfort
- Investigations at extreme cold

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Dimensions & conditions | **1-axle-dynamometer**

Max. continuous power	260 kW
Max. traction force roller	6 kN
Max. roller speed	200 km/h
Max. wind speed	120 km/h
Nozzle area	0,48 m² (0,8 x 0,6)

Application Examples

- ☑ Thermal Management
- ☑ Thermal Validation
- ☑ Driving Performance (stationary)
- ☑ Windshield de-icing/Defogging
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- ☑ Investigations at extreme cold

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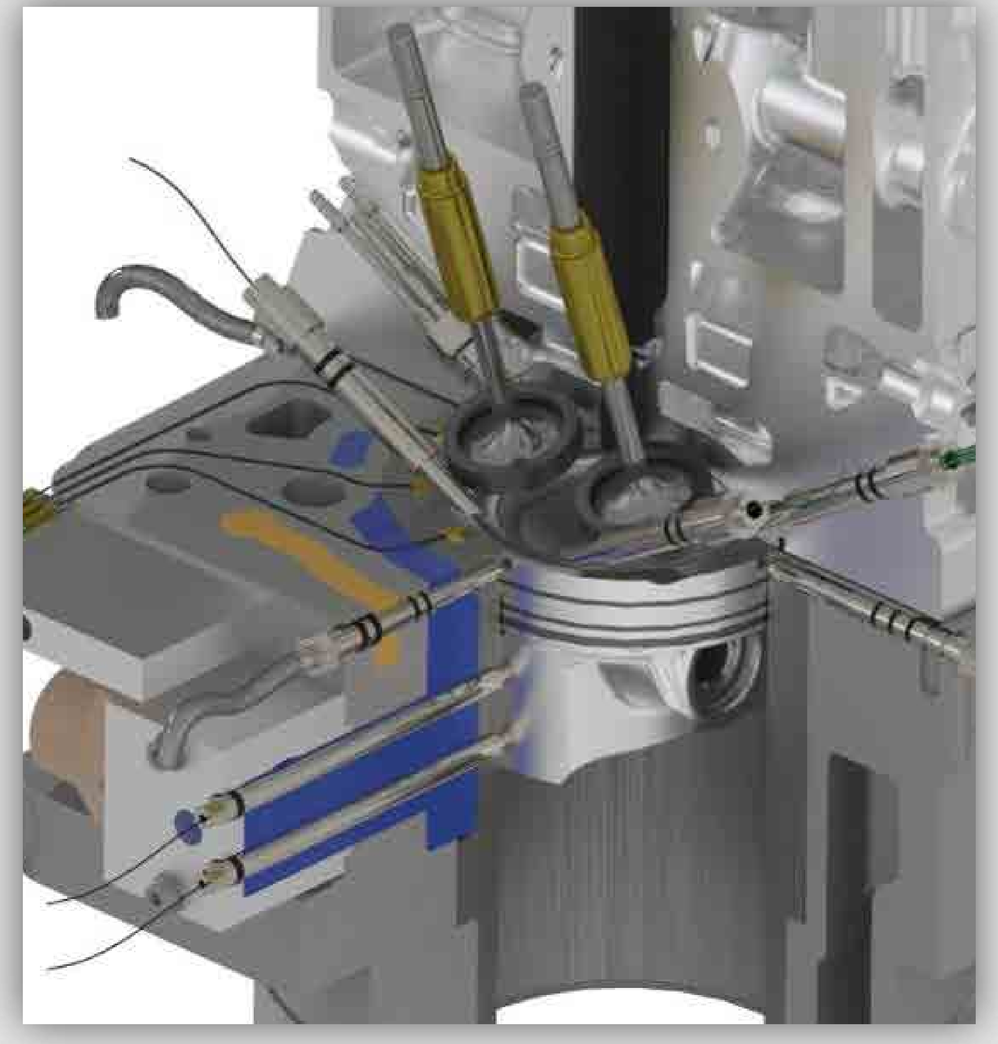

Engine test benches for powertrain systems (hydrogen engines)

The development of hydrogen-powered internal combustion engines places high demands on infrastructure and measurement technology. FKFS has has various test benches for single-cylinder units and full engines that run on hydrogen. These enable both the development of new combustion processes on externally charged, highly instrumented research engines, the operation of near-series full engines and the optimization of special exhaust gas aftertreatment systems adapted to the requirements of hydrogen combustion.

Application Examples

- Combustion process development, e.g. H_2-HD-DI
- Wall heat flow measurement possible
- Basic consulting ECU
- Controller parameterization in transient operating conditions
- Optimization of exhaust gas after treatment, e.g. H_2-SCR, H_2 mass spectroscopy/ Quantum cascade laser available
- Optimization of the overall system of hybrid topologies in real driving cycles (RDE)

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Hybrid Engine Test Bench

The Hybrid Engine Test Bench The hybrid engine test bench enables the investigation of combined powertrains consisting of thermal energy converters and electric motors. The vehicle and driver simulation xMot from FEV GmbH allows the representation of any vehicle models and driving routes on the test bench.
A CVS system enables the summary emission measurement as prescribed in certification measurements.

General | Loading system | Battery simulation

Type	ECODyn 470 H (Fa. DASYM)
Automation	Morphee 2 (Fa. FEV)
Measurement technology for electrical components	Yokogawa WT1804E Power Analyzer
Measurement technology for emissions	Horiba Mexa One (Rohabgas) + Horiba Mexa One (CVS)

Application Examples

- ☑ Measurement of powertrains with simulation of the vehicle environment
- ☑ Development of serial hybridized powertrains

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A CVS system enables the summary emission measurement as prescribed in certification measurements.

General | Loading system | Battery simulation

Max. output	470 kW
Max. speed	9000 min^{-1}
Max. torque	990 Nm
Execution	Asychronous machine

Application Examples

- Measurement of powertrains with simulation of the vehicle environment
- Development of serial hybridized powertrains

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A CVS system enables the summary emission measurement as prescribed in certification measurements.

General | Loading system | Battery simulation

Max. output	300 kW
Voltage range	0-1000 V DC
Max. power	±1200 A DC

Application Examples

- Measurement of powertrains with simulation of the vehicle environment
- Development of serial hybridized powertrains

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Development Test Bench for High-Speed Drives

The test bench enables the testing of eDrives in very early stage of development. For this it provides high speed up to 24.000 rpm but low torque. Typical applications are highly precise drag torque measurements and thermal examinations under the influence of rotational speed. In order to achieve the maximum possible flexibility during testing, the test bench has a modular and flexible design. A comprehensive range of test bench equipment is available for operating and analysing modern drivetrains.

Input eDrive 1	Input eDrive 2	Battery simulator
Power, max.		157 kW
Torque, max.		300 Nm
Speed, max.		13.000 1/min

Application Examples

- Initial commissioning
- Efficiency measurements (mechanical and electrical) and highly precise drag torque measurements
- Hardware-in-the-Loop testing
- Wide range of special tests
- Investigation of dynamic behavior as well as thermal and vibrational effects
- Testing of durability, application and function

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Input eDrive 1	Input eDrive 2	Battery simulator

Power, max.	35 kW
Torque, max.	14 Nm
Speed, max.	24.000 1/min

Application Examples

- Initial commissioning
- Efficiency measurements (mechanical and electrical) and highly precise drag torque measurements
- Hardware-in-the-Loop testing
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Input eDrive 1	Input eDrive 2	Battery simulator
Power, max.		1.160 kW
Voltage range		0...1.000 V
Current, max.		1.600 A
Dynamic		2.000 V/ms

Application Examples

- Initial commissioning
- Efficiency measurements (mechanical and electrical) and highly precise drag torque measurements
- Hardware-in-the-Loop testing
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NVH Single-Axis Test Bench

Drive noises are an essential part of the perception of a vehicle.
On the full low-reflection NVH axle test bench, all drive units from inverter e-motor transmissions to combustion engines with transmissions and hybrid components can be tested. Vibrations and radiated airborne noise are measured and analyzed to ensure the desired noise perception.

Technical Data 1 | Technical Data 2

Type	A2-NVH-Axis Test Bench
Speed	400 km/h
Power per axle	1100 kW (10 sec.)
Wheel torque max.	5500 Nm (10 sec.)
Battery simulation performance	540 kW (10 sec.)

Application Examples

- ✓ Sound pressure level measurements
- ✓ Acceleration measurements
- ✓ Laser vibrometric measurements
- ✓ Beamforming-/ Holography measurements
- ✓ Rotational uniformity measurements
- ✓ Standard FFT analysis
- ✓ Wavelet analysis
- ✓ Digital order analysis

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Tehcnical Data 1 | Technical Data 2

Voltage battery simulation	up to 1000V
Maximum current	1600 A
Fuel supply	Gasoline, diesel and liquid special fuels
Measurement technology	10 channels airbone sound, 100 channels structural sound, 2xCAN-FD

Application Examples

- Sound pressure level measurements
- Acceleration measurements
- Laser vibrometric measurements
- Beamforming-/ Holography measurements
- Rotational uniformity measurements
- Standard FFT analysis
- Wavelet analysis
- Digital order analysis

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NVH Engine Test Bench

A fully low-reflection test bench is available for acoustic tests on combustion engines. Standard powertrains and front-transverse configurations are possible. In addition to airborne and structure-borne noise, torsional vibrations or combustion excitation can also be investigated.

Technical Data 1

Type	NVH Engine Test Bench
Speed	530 kW
Torque, max.	1500 Nm
Speed, max.	7000 min^{-1}
Fuel supply	Gasoline, diesel, liquid special fuels

Application Examples

- ✓ Sound pressure level measurements
- ✓ Acceleration measurements
- ✓ Beamforming-/ Holography measurements
- ✓ Rotational uniformity measurements
- ✓ Standard FFT analysis
- ✓ Work leeway resolved analysis
- ✓ Digital order analysis

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High-Performance Electric Powertrain Test Bench

The test bench enables the testing of complete powertrains or individual components (e.g. eDrives or gearboxes) from electric vehicles. The driving resistances are simulated by two highly dynamic eDrives. The input is provided either by the drive of the device under test (DUT) or a dynamic eDrive of the test bench. A highly dynamic high-voltage battery simulator is used to supply the DUT with electrical energy. A comprehensive range of test bench equipment is available for operating and analysing modern drivetrains.

Input eDrive | Output | Battery

Power, max.	700 kW
Torque, max.	1.000 Nm
Speed, max.	20.000 1/min
Dynamic	69.000 1/min/s

Application Examples

- Initial commissioning
- Efficiency measurement (mechanical and electrical)
- Testing of durability, application and function
- Hardware-in-the-Loop testing
- Wide range of special tests
- Investigation of dynamic behaviour as well as thermal and vibration effects

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Input	Output eDrives (2x)	Battery

Power, max.	720 kW
Torque, max.	6.000 Nm
Speed, max.	3.000 1/min
Dynamic	37.000 1/min/s

Application Examples

- Initial commissioning
- Efficiency measurement (mechanical and electrical)
- Testing of durability, application and function
- Hardware-in-the-Loop testing
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- Investigation of dynamic behaviour as well as thermal and vibration effects

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Input | Output | **Battery simulator**

Power, max.	1.160 kW
Voltage range	0...1.000 V
Current, max.	1.600 A
Dynamic	2.000 V/ms

Application Examples

- ✓ Initial commissioning
- ✓ Efficiency measurement (mechanical and electrical)
- ✓ Testing of durability, application and function
- ✓ Hardware-in-the-Loop testing
- ✓ Wide range of special tests
- ✓ Investigation of dynamic behaviour as well as thermal and vibration effects

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Multi-Configuration Powertrain Test Bench

The test bench enables testing of complete powertrains up to 4WD configurations or individual components (e.g. eDrives or gearboxes) from conventional, hybrid and electric vehicles. The driving resistances are simulated by four dynamic eDrives. The input is carried out either by the device under test (DUT) or a dynamic eDrive of the test bench. Highly dynamic high-voltage battery simulators are used to supply the DUT with electrical energy. A comprehensive range of test bench equipment is available for operating and analysing modern drivetrains.

Input eDrive 1	Input 2	Output	Battery

Power, max.	600 kW
Torque, max.	1.300 Nm
Speed, max.	8.000 1/min
Dynamic	113.000 1/min/s

Application Examples

- Initial commissioning
- Hardware-in-the-Loop testing
- Efficiency measurements (mechanical and electrical)
- Wide range of special tests
- Testing of durability, application and function
- Investigation of dynamic behavior as well as thermal and vibrational effects

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Input 1	Alternative input eDrive	Output	Battery

Power, max.	600 kW
Torque, max.	520 Nm
Speed, max.	20.000 1/min

Application Examples

- Initial commissioning
- Hardware-in-the-Loop testing
- Efficiency measurements (mechanical and electrical)
- Wide range of special tests
- Testing of durability, application and function
- Investigation of dynamic behavior as well as thermal and vibrational effects

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Multi-Configuration Powertrain Test Bench

The test bench enables testing of complete powertrains up to 4WD configurations or individual components (e.g. eDrives or gearboxes) from conventional, hybrid and electric vehicles. The driving resistances are simulated by four dynamic eDrives. The input is carried out either by the device under test (DUT) or a dynamic eDrive of the test bench. Highly dynamic high-voltage battery simulators are used to supply the DUT with electrical energy. A comprehensive range of test bench equipment is available for operating and analysing modern drivetrains.

Input 1 | Input 2 | **Output eDrives (4x)** | Battery

Power, max.	450 kW
Torque, max.	4.500 Nm
Speed, max.	3.000 1/min
Dynamic	40.000 1/min/s

Application Examples

- ✓ Initial commissioning
- ✓ Efficiency measurements (mechanical and electrical)
- ✓ Testing of durability, application and function
- ✓ Hardware-in-the-Loop testing
- ✓ Wide range of special tests
- ✓ Investigation of dynamic behavior as well as thermal and vibrational effects

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Input 1 | Input 2 | Output | **Battery simulator**

Power max.	1.160 kW
Voltage range	0...1.000 V
Current, max.	1.600 A
Dynamic	2.000 V/ms

Application Examples

- Initial commissioning
- Hardware-in-the-Loop testing
- Efficiency measurements (mechanical and electrical)
- Wide range of special tests
- Testing of durability, application and function
- Investigation of dynamic behavior as well as thermal and vibrational effects

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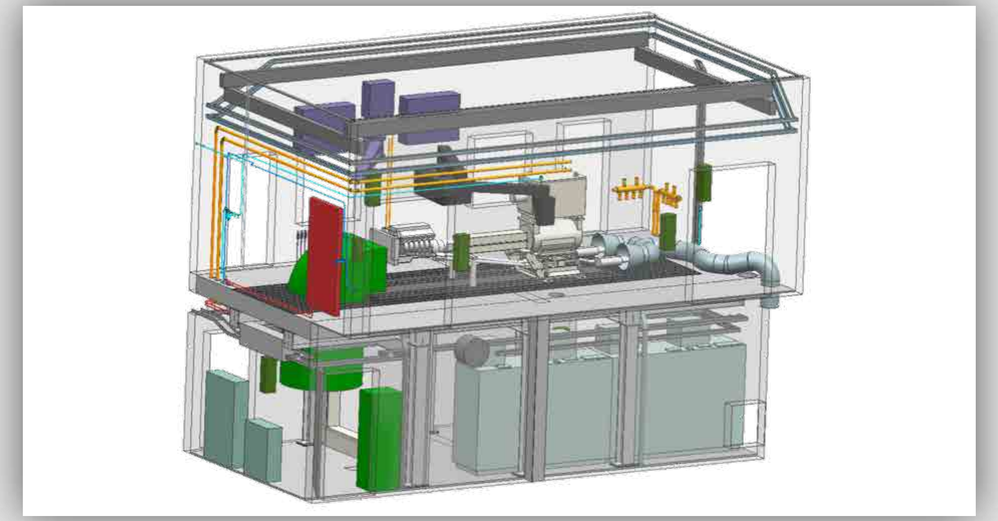

Similar to the vehicle Drive train superstructures

The targeted dissipation of thermal energy is of great importance for conventional drives powered by renewable fuels, as well as for hydrogen fuel cell systems and battery electric drives. The FKFS therefore has test benches that allow the vehicle-related construction of drives (H2ICE, BEV, FCV). These are characterized by a blowing of the drive unit proportional to the vehicle speed and thus allow the experimental representation of realistic component temperatures.

Technical Data 1 | **Technical Data 2**

Type	A1 test stand with blow-in
Wind speed up to	180 km/h
Max. volume flow	187.000 m^3/h
Blower Power	160 kW

Application Examples

- Validation/optimization of thermal management
- Investigation of degradation FC during simulated uphill travel
- Operating strategy for exhaust gas aftertreatment in RDE cycles
- Emission-optimized operating strategy for hybrid concepts
- Pre-emission EU7 legislation

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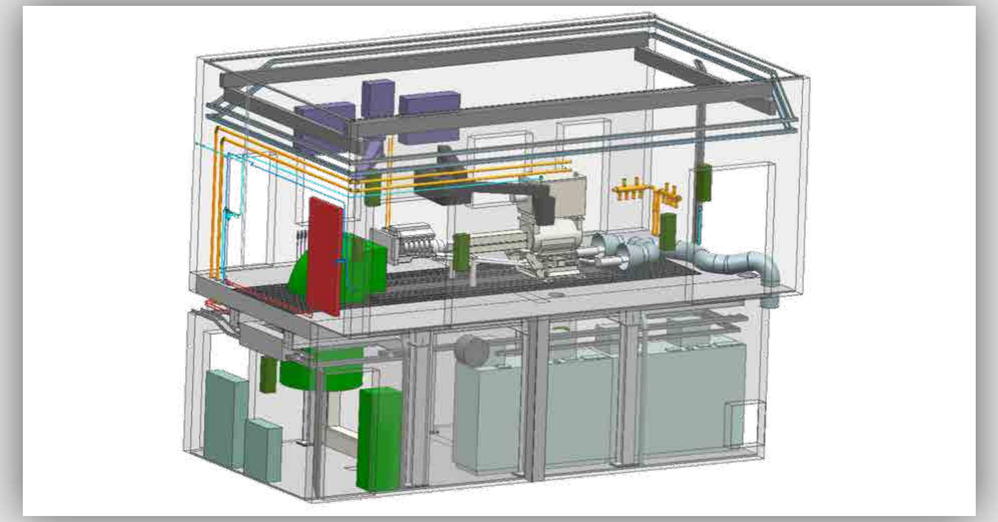

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Technical Data 1 | **Technical Data 2**

Max. power	470 kW
Max. torque	990 Nm
Max. speed	9.000 min^{-1}

Application Examples

- Validation/optimization of thermal management
- Investigation of degradation FC during simulated uphill travel
- Operating strategy for exhaust gas aftertreatment in RDE cycles
- Emission-optimized operating strategy for hybrid concepts
- Pre-emission EU7 legislation

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Vehicle Aeroacoustics Wind Tunnel

The FKFS aeroacoustic vehicle wind tunnel (Göttingen-type wind tunnel) is one of the most modern of its kind in Europe for aerodynamic testing of cars, vans and racing vehicles. In addition to acoustic methods, other extensive test facilities are available for measuring forces, pressures and speeds as well as for flow visualization.
The standard use of a 5-belt system is to simulate road travel with rotating wheels and moving ground in the vehicle wind tunnel.

Dimensions 1 | Dimensions 2 | Sound-pressure level

Dimensions of nozzle (w x h)	5,8 m x 3,87 m
Exit area of nozzle	22,45 m^2
Contraction ratio	4,41
Length of open jet test section	9,95 m

Application Examples

- Measurement of aerodynamic coefficients (stationary & transient)
- Flow field and surface pressure measurement
- Aeroacoustic measurements at the car's surface and in its interior
- Surface vibration measurements with laser vibrometers
- Noise source localization with microphone arrays and an acoustic mirror

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Dimensions 1 | **Dimensions 2** | **Sound-pressure level**

Diameter of axial fan	7,1 m
Operating output	3,3 MW (335 1/m)
Max. flow velocity	260 km/h

Application Examples

- Measurement of aerodynamic coefficients (stationary & transient)
- Flow field and surface pressure measurement
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Dimensions 1 | Dimensions 2 | Sound-pressure level

Sound-pressure level of empty test section at 140 km/h	
- Out-of-Flow	64,7 dB(A)

Application Examples

- Measurement of aerodynamic coefficients (stationary & transient)
- Flow field and surface pressure measurement
- Aeroacoustic measurements at the car's surface and in its interior
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Model Wind Tunnel

For the aerodynamic investigation of vehicle models, the FKFS a 1:4/1:5 model windtunnel (Göttingen-type wind tunnel) with a 5-belt system for simulating the road surface and rotating wheels. Flow field measurements with Particle Image Velocimetry (PIV) or single and multi-hole probes can carried out with the traversing device. Facilities for model preparation and modelling, as well as the possibility of model digitization using 3D surface scans are also part of the system.

Dimensions 1 | **Dimensions 2**

Dimensions of nozzle (w x h)	1,575 m x 1,05 m
Exit area of nozzle	1,654 m^2
Length of open-nozzle test section	2,585 m
Max. flow velocity	288 km/h
Turn table diameter	2080 mm

Application Examples

- Aerodynamic force measurements on passenger car models in quarter scale and 20% scale
- Aerodynamic shape optimization
- Surface pressure measurements
- Flow field measurements with PIV or multi-hole probes
- Calibration of flow measurement devices (e.g. anemometers)
- Frontal area measurements
- 3D surface scans

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Dimensions 1 | **Dimensions 2**

Center belt length	1700 mm
Available center belt widths	225 mm / 250 mm / 312 mm
Available wheel drive unit belts widths	69 mm / 85 mm / 115 mm
Maximum wheel base	800 mm

Application Examples

- Aerodynamic force measurements on passenger car models in quarter scale and 20% scale
- Aerodynamic shape optimization
- Surface pressure measurements
- Flow field measurements with PIV or multi-hole probes
- Calibration of flow measurement devices (e.g. anemometers)
- Frontal area measurements
- 3D surface scans

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Thermal Wind Tunnel

The FKFS thermal wind tunnel is a high-performance 2-axis roller test bench with closed air flow. A large number of different complete vehicle tests can be carried out here regardless of the season and weather conditions and driving tests can be realistically simulated. Typical areas of application include performance and thermal management tests, pollution experiments and brake and component function tests. Various options for irrigation, including visualization, enable many special uses.

Dimensions 2-axle-dynamometer	2-axl-d.	Air.
Test section (l x w x h)	15,8 m x 6,8 m x 5,5 m	
Entrance (w x h)	2,9 m x 4,0 m	
Dynamometer diameter	1,6 m	
Dynamometer speed	max. 300 km/h	
Driving/braking power	respectively max. 300 kW front and 500 kW rear.	

Application Examples

- ☑ Thermal Management
- ☑ Driving performance test (stationary and cyclical)
- ☑ Pollution investigation
- ☑ Break performance (dry and wet)
- ☑ Wiper function test, wiper motor design
- ☑ Air intake, water separation
- ☑ Sensor function test (e.g. in wet conditions)

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Dim. 2-axle dyn.	2-axle-dynamometer	Air.
Traction force when under braking	20 kN	
The test bench has two identical sets of rollers (for the front and rear axles).		
The rollers can be moved in the longitudinal direction.		

Application Examples

- Thermal Management
- Driving performance test (stationary and cyclical)
- Pollution investigation
- Break performance (dry and wet)
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Dim. 2-axle-dyn. | 2-axle-dyn. | Air path

	large nozzle	small nozzle
Air flow velocity	max. 210 km/h	max. 240 km/h
Nozzle cross section	6 m^2 (2,45 x 2,45)	4 m^2 (2,45 x 1,60)
Air temperature regulation between 20 °C and 50 °C.		
Deviating operating conditions on request.		

Application Examples

- ✓ Thermal Management
- ✓ Driving performance test (stationary and cyclical)
- ✓ Pollution investigation
- ✓ Break performance (dry and wet)
- ✓ Wiper function test, wiper motor design
- ✓ Air intake, water separation
- ✓ Sensor function test (e.g. in wet conditions)

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Climatic Wind Tunnel

The Climatic Wind Tunnel is a closed wind tunnel of Göttingen design with a powerful 2-axis roller test rig. A large number of different vehicle tests can be carried out regardless of the season and weather conditions and driving tests can be realistically simulated. The climatic wind tunnel is primarily used for thermal tests in the temperature range between 10 and 55 °C.

Dimensions 2-axle-dynamometer	2-axl-d.	Air.
Test section (l x w x h)	15,8 m x 11,6 m x 7,5 m	
Entrance (w x h)	4 m x 4 m	
Dynamometer diameter	2 m	
Dynamometer speed	max. 280 km/h	
Driving/braking power	front 300 kW rear 450 kW	

Application Examples

- Thermal Management
- Thermal Validation
- Driving performance test (stationary and cyclical)
- Braking performance in the driving cycle test
- Climate Comfort
- HV charging tests

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Dim. 2-axle dyn.	2-axle-dynamometer	Air.

Traction in breaking	front 13 kN rear 26 kN
The test bench has two identical sets of rollers (for the front and rear axles).	
Wheel base	2,3 – 6,9 m
HPC charger	280 kW@800 V

Application Examples

- Thermal Management
- Thermal Validation
- Driving performance test (stationary and cyclical)
- Braking performance in the driving cycle test
- Climate Comfort
- HV charging tests

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Dim. 2-axle-dyn. | 2-axle-dyn. | Air path

	truck nozzle	car nozzle
Air flow velocity	max. 135 km/h	max. 265 km/h
Nozzle cross section	12 m² (3 x 4)	4,7 m² (2,3 x 3,05)
Air temperature regulation between 10 °C and 55 °C		
rel. humidity		10 – 90 %

Application Examples

- ✓ Thermal Management
- ✓ Thermal Validation
- ✓ Driving performance test (stationary and cyclical)
- ✓ Braking performance in the driving cycle test
- ✓ Climate Comfort
- ✓ HV charging tests

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Driving Dynamics Instrumentation

FKFS has a comprehensive, mobile and up-to-date selection of instrumentation for extensive driving dynamics and vehicle testing.The equipment is constantly being expanded and modernized so that it always remains up-to-date and efficient. A selection of different systems is available for data acquisition, including compact, modular and particularly high-scanning systems. The customer benefits from FKFS's many years of experience in the targeted, flexible and efficient use and operation of the technology and evaluation of the data.

Movement Sizes | **Forces & Moments**

Inertial measurement systems (gyro-stabilized platforms)	Laser distance sensors
Contactless speed measurement	Acceleration sensors
differential GPS (dGPS)	Cable-actuated travel sensors

Application Examples

- ☑ Objektive measurement of driving dynamics paramenters
- ☑ Driving comfort tests
- ☑ Determination of load spectra in customer-oriented driving profiles
- ☑ Driving resistance measurements
- ☑ Tire characterization

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Movement Sizes | **Forces & Moments**

- Measuring rims
- Measuring steering wheel
- Component application with strain gages
- Wheel load scales
- Pressure instrumentation (wind excitation)

Application Examples

- ☑ Objektive measurement of driving dynamics paramenters
- ☑ Driving comfort tests
- ☑ Determination of load spectra in customer-oriented driving profiles
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- ☑ Tire characterization

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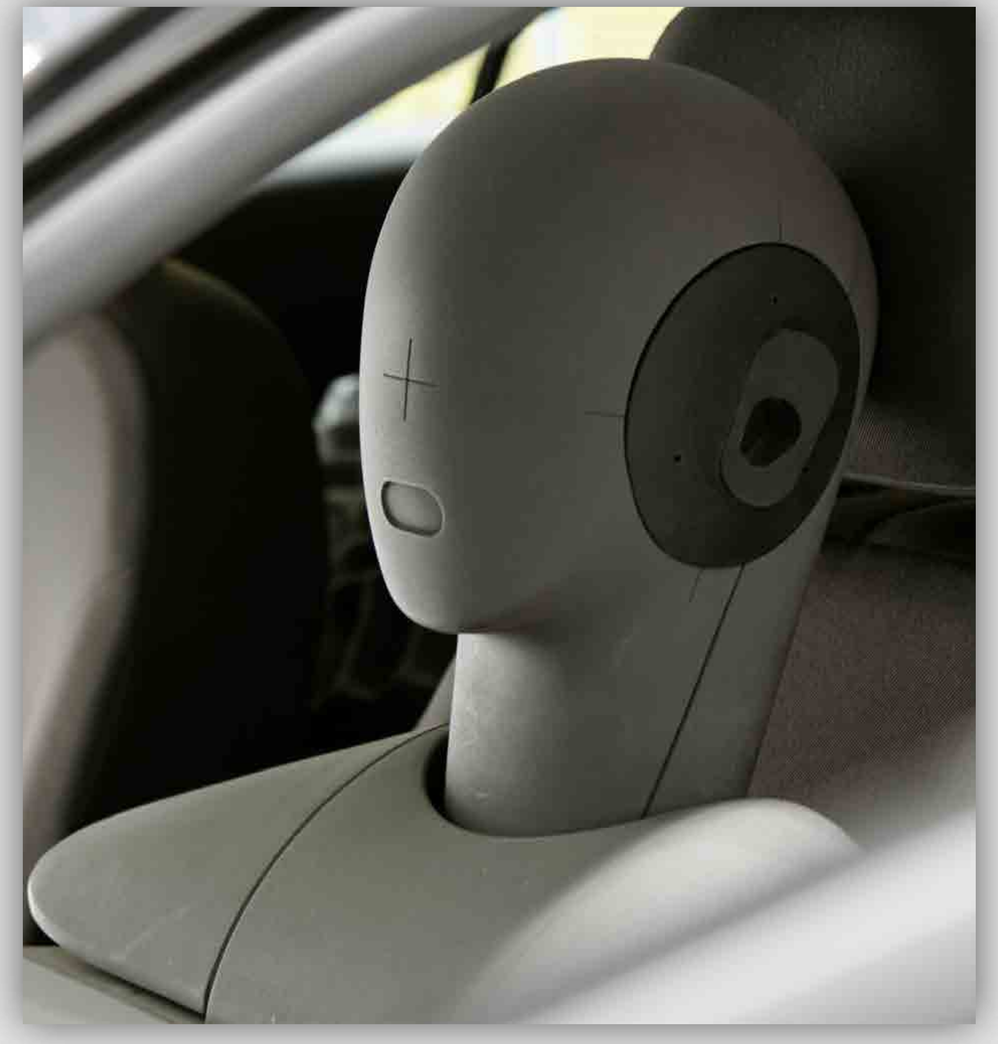

Acoustic Measurement Equipment

FKFS has a wide range of standard and special acoustic measurement equipment, as well as the software tools needed to perform signal and modal analysis.

Applicaton Examples

- artificial heads to record binaural sound signals and the possibility of aurally accurate reproduction
- Laser vibrometers and laser scanning vibrometers for determining, among other things of operating vibration modes of sound-emitting surfaces
- Microphone array systems for localizing sound sources in the vehicle interior and for investigating exterior noise
- Microphones (including surface microphones) and acceleration sensors (uni- and triaxial) for targeted sound and vibration measurements
- Torsional uniformity analysis (torsional vibrations)

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Special Measurement Technology

FKFS special measurement technology is both within the drive train and far beyond. FKFS offers „everything from a single source“ - from design, layout and production to the application of your measurement technology, including sensor or component-specific calibration. From the idea to the measurement result, you will find a competent contact at FKFS who will support you in the implementation of your development task or take it over completely for you.

Application Examples

- Distance measurement
- Component temperature measurement
- Strain measurement
- Signal transmission systems
- Fast surface temperature measurement
- Digital application

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Aerodynamic Measurement Systems

In the field of aerodynamics, FKFS has extensive measurement equipment for analyzing the flow around and through the vehicle. In addition, we also offer the possibility of visualizing and quantifying flow situations in the vehicle cabin and components.

Application Examples

- Mobile systems for simultaneous pressure measurement at over 500 measuring points
- Multi-hole probes for the temporally high-resolution spatial determination of flow velocity and angle
- Specially developed radiator probes for cooling air volume flow measurements (see below) on the installed vehicle radiator
- 3D PIV system
- Evaluating the air flow rates on vehicle comfort seats with seat ventilation
- Recording the volume flow at air vents for conditioning the interior of the vehicle cabin

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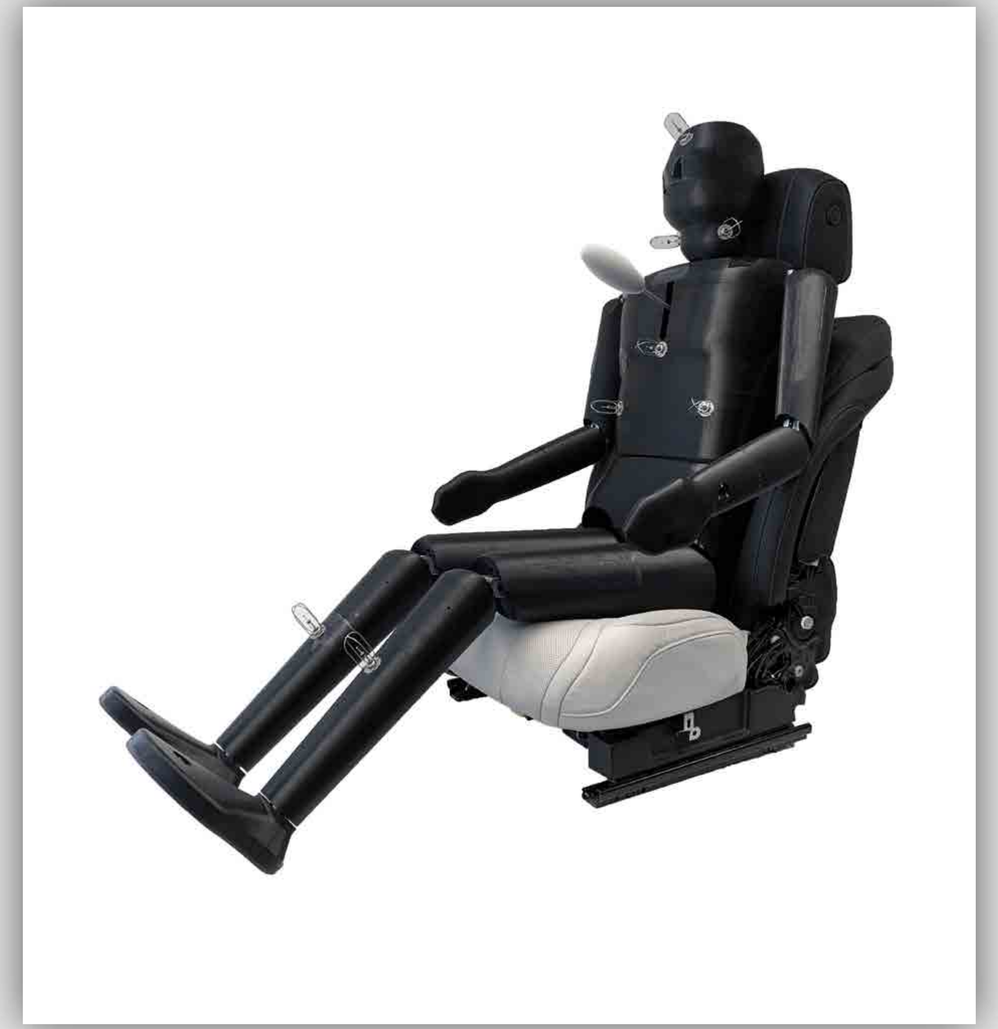

Thermal Comfort Manikin

The FKFS Thermal Comfort Manikin can be used together with its digital twin at all stages of development to objectively assess passenger comfort. The direct measurement of air velocities at selected parts of the body records the flow field in the vehicle cabin and enables isothermal investigations into draught-free conditions in convertibles.

Application Examples

- Thermal comfort rating
- Coordination of the HVAC control strategy
- Draught control Cabrio
- Measuring the temperature distribution
- Draught assessment of Ventilation concepts

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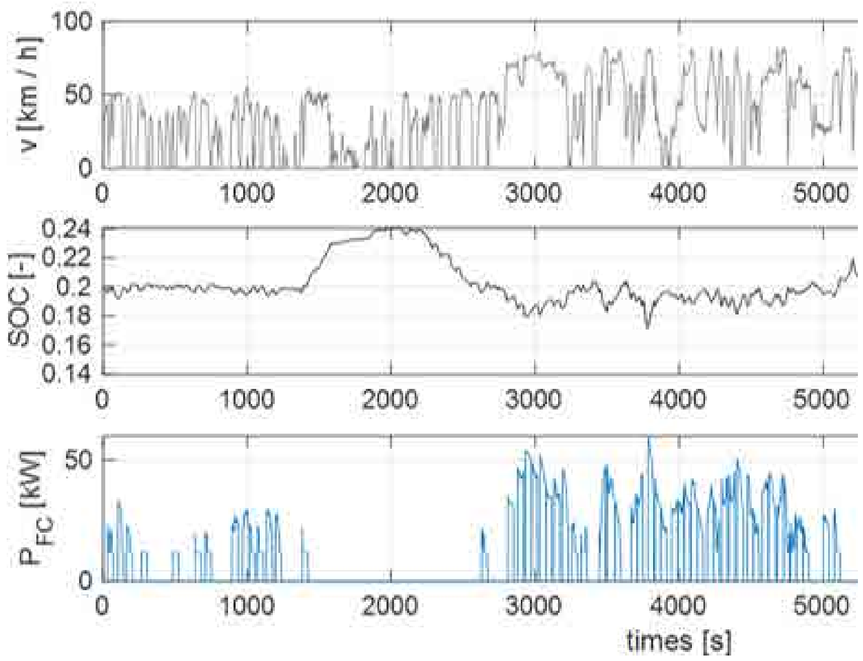

OD/1D-Simulation incl. longitudinal dynamics

The selection and design of drive concepts for vehicles requires knowledge of the performance requirements and the dynamic requirements in different driving situations, the heat flows to be dissipated and the energy to be expended in each case and the associated emissions. For this purpose, longitudinal dynamics simulations are being developed at the FKFS on the basis of a modular simulation kit, which enables the rapid dimensioning and optimization of a wide variety of drives and topologies for a wide range of vehicle classes.

Application Examples

- A wide variety of vehicles (motorcycles, cars, commercial vehicles, construction machinery, ships)
- Various powertrains: BEV, (P)HEV, FCV, H_2/eF-ICE
- Hybrid topologies: parallel, serial, power-split
- Energy source: battery, H2, e-Fuel (Methanol, FT, NH_3, etc.)
- Basis for LCA

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Motors | Fuel | Motorsport | Special motors

- Development of all engine types (cars, trucks, ships, airplanes, etc.)
- Flow dynamics, combustion, cooling, injection, Multiphase flow etc.
- Flexible network generation and motion simulation (cylinders, valves, turbocharger, etc.)
- Optimization of motor efficiency through calibration up to 50 %

3D/CFD-Simulation-QuickSim

With our powerful simulation tool QuickSim, a 3D CFD software developed in-house, we carry out precise virtual investigations that encompass the entire engine system.

Thanks to QuickSim's modular structure, you can respond flexibly to your specific requirements, while our in-house development resources – supported by our synergies between the OD department and our testbench capacities – enable you to implement your projects comprehensively, efficiently and quickly.

Application Examples

- ✓ Full engine and multicylinder simulation
- ✓ Pre-chamber and cylinder head optimization
- ✓ CFD + CHT + FEM Simulation coupling
- ✓ Every fuel displayable
- ✓ Injection simulation and PDA measurement
- ✓ Complete construction incl. component design

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Motors | Fuel | Motorsport | Special motors

- Analysis and application of different fuels (liquid and gaseous)
- Analysis of SMD, droplet distribution and spray development
- Calibration of the injection by adjusting the measurements at the PDA laboratory
- Optimization of the composition of different fuels

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Motors | Fuel | Motorsport | Special motors

Active in MotoGP, F1, WRC, & high performance models from leading OEMs.

Optimized workflow for fast prototyping & fast simulations

Automated optimization of injector and injection

Advanced analysis: knock detection, mixture formation, engine dynamics, etc.

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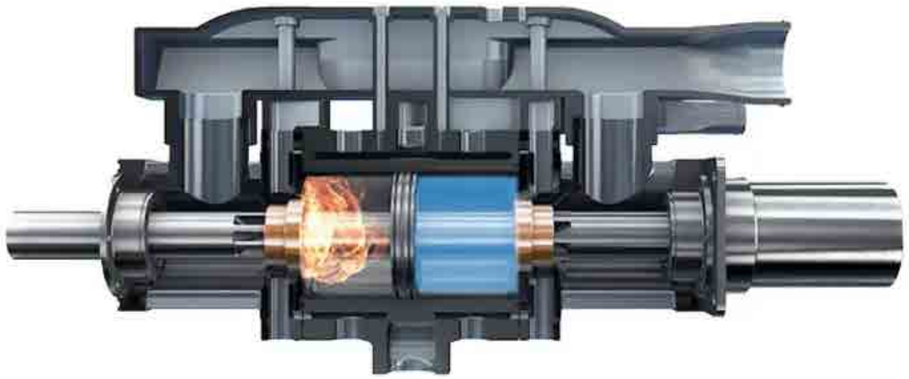

Motors | Fuel | Motorsport | Special motors

We are not limited to reciprocating engines:
Wankel, Linear, Rotary, etc.

Experience in various disciplines: road transportation, energy, and aviation.

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- Pre-chamber and cylinder head optimization
- CFD + CHT + FEM Simulation coupling
- Every fuel displayable
- Injection simulation and PDA measurement
- Complete construction incl. component design

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Life Cycle Assessment/ Total Cost of Ownership

Especially in the development of new vehicle powertrain systems, the ecological consideration over the entire life cycle of the product is a central tool. Together with a consideration of the total costs for the user, important criteria are available for the comparative evaluation of vehicle concepts. FKFS offers detailed analyses (Life Cycle Assessment &Total Cost of Ownership) for this purpose, which are generated using tools that have been specially adapted to the balancing of vehicle powertrains.

Application Examples

- LCA according to DIN ISO 14040 and 14044
- Balancing the production paths of energy sources
- Forecasting energy consumption during the utilization phase using-longitudinal dynamics simulation
- Quantification of the costs for Production and use (TCO)
- Emission-optimized design ofdrive topologies
- Comparative evaluation of powertrain concepts

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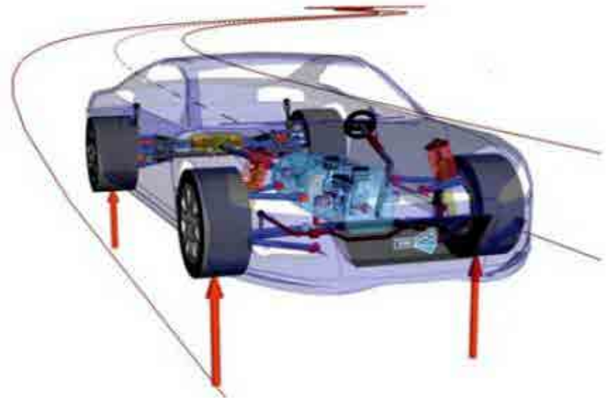

Modeling

- Complete vehicle models
- Component models
- Environment models
- Models of active chassis systems

Digital Skills Development

The use of suitable models is of crucial importance for theoretical and simulative investigations. Application-specific modelling is necessary in order to achieve an optimum balance between mapping quality and parameterization effort. FKFS uses established simulation tools from the automotive industry and develops individual solutions as required.

Application Examples

- ☑ Driving dynamics and driving comfort examinations
- ☑ Chassis parameterization, K&C

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Virtual Driving Characteristics Development

By integrating the driving characteristics into the virtual development process, vehicle concepts can be designed much more efficiently. This makes it possible to analyze and optimize the vehicle with respect to all customer- and brand-specific characteristics before a physical model exists. Virtual development processes allow the integration of innovative methods such as AI-based modeling and optimization processes, sensitivity analyses, and solution space methods. They support systematic and systems engineering-oriented vehicle development in all development phases - from early characteristics oriented chassis design to virtual application and homologation methods, as well as many digital twin-based analyses.

Virtual chassis design | **Application** | **Homologation**

- Modular toolkit
- Integration into customer-specific development environment
- Target Cascading
- Target Evaluation
- Solution-Space-Method

Application Examples

- ☑ Design in early concept phase
- ☑ Virtual Validation
- ☑ Efficient vehicle and controller parameterization
- ☑ Subjective-objective correlation

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Virtual chassis design | **Application** | Homologation

- Subjective application of driving comfort functions
- Objective application in simulation
- Integration of modern test benches
- Highly efficient optimization algorithms
- Black-Box-Approaches

Application Examples

- ☑ Design in early concept phase
- ☑ Virtual Validation
- ☑ Efficient vehicle and controller parameterization
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Virtual chassis design | Application | Homologation

Virtual development and virtual testing of environmental sensors for ADAS
Approval of software updates
Increased accuracy and reliability

Application Examples

- ☑ Design in early concept phase
- ☑ Virtual Validation
- ☑ Efficient vehicle and controller parameterization
- ☑ Subjective-objective correlation

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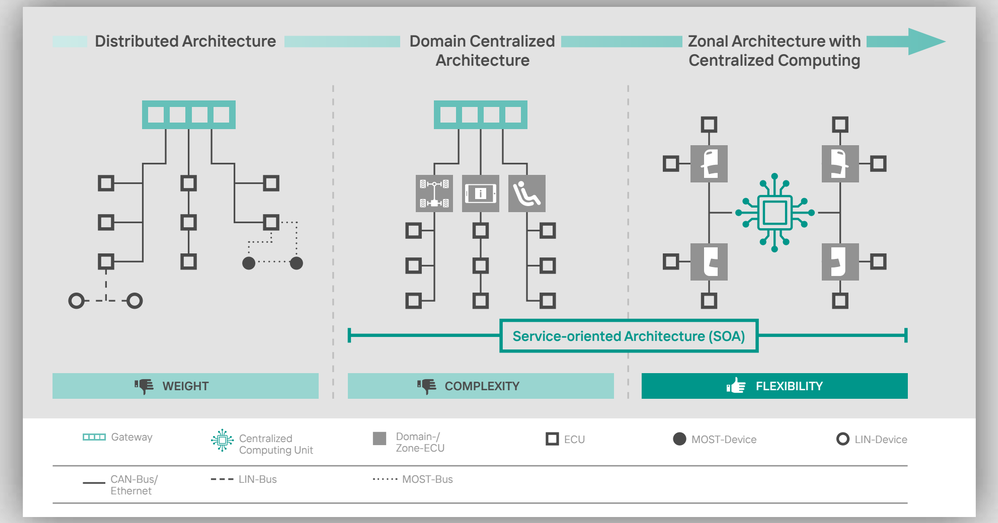

Simulative E/E Architecture Optimization

FKFS offers solutions for the design of optimized architectures that save costs, development and maintenance effort, reduce weight and resources and take into account the requirements for maintainability, flexibility and security.

Methods | Aspects

- Complete vehicle simulation
- Virtual control units
- Model-based optimization
- Environment simulation

Application Examples

- Variant comparisons
- HW/SW mapping optimizations
- ASIL decomposition variations
- Virtual testing
- Cable harness optimizations
- ... answering your questions

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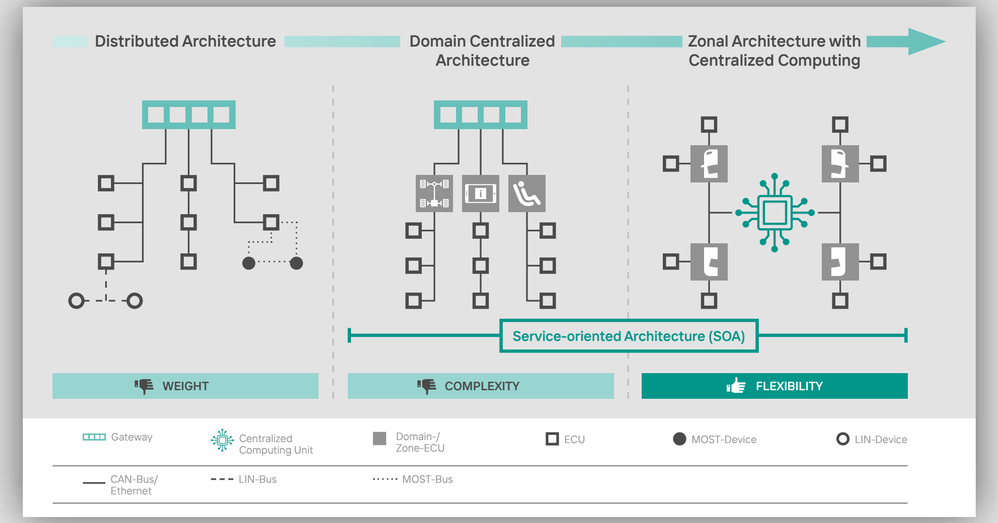

Simulative E/E Architecture Optimization

FKFS offers solutions for the design of optimized architectures that save costs, development and maintenance effort, reduce weight and resources and take into account the requirements for maintainability, flexibility and security.

Methods | Aspects

- ISO 26262
- Hardware costs
- Reliability
- Energy consumption

Application Examples

- Variant comparisons
- HW/SW mapping optimizations
- ASIL decomposition variations
- Virtual testing
- Cable harness optimizations
- ... answering your questions

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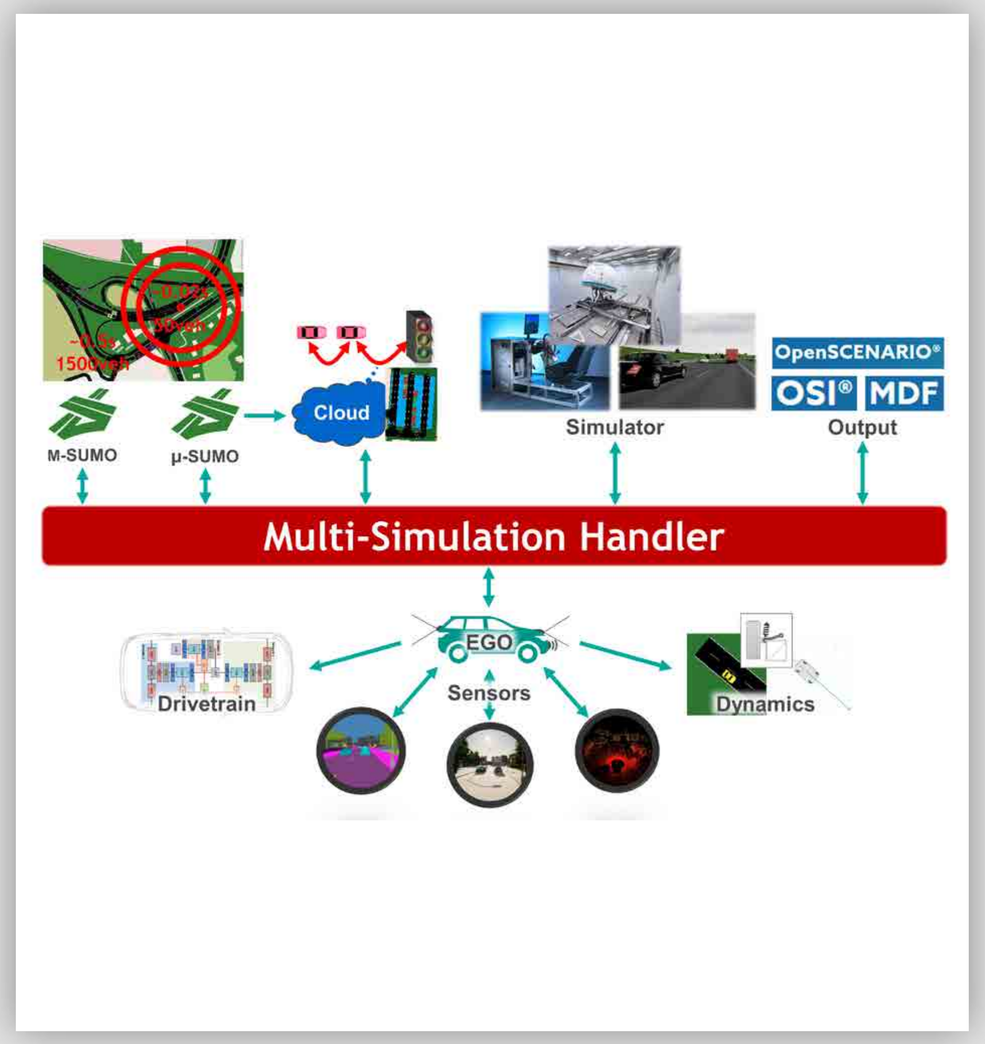

Virtual Development

The interaction between the vehicle and its environment requires a comprehensive simulation of the overall system of vehicle and environment for the virtual development of vehicle functions. This can only be achieved through the combination and integration of a wide range of tools.

Application Examples

- Generation of training data
- Scenario generation
- Experience of ADAS functions
- FuSa/SOTIF-investigations
- HIL applications
- Virtual application

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