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Experimental Equipment 2024

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Introduction

The Institute of Machine Design and Tribology (IMKT) at Leibniz University Hannover conducts research on diverse topics in tribology within the framework of publicly funded research projects and direct industrial collaborations. Experimental testing techniques are accorded a high priority in this endeavor. An extensive experimental test field enables investigations on a wide spectrum of drive systems, machine elements, or experimental model setups. The experimental analyses under defined and realistic operating conditions facilitate the description of the behavior of the respective component or tribological system, provide input data for calculations, and serve to verify computational models.

Component test rigs are utilized to subject individual machine elements (e.g., rolling bearings, gears, seals, synchronizers) to experimental examination of their operational and functional behavior, as well as their service life. These types of test rigs are available for all machine elements examined at IMKT, in various configurations and sometimes in standardized or externally certified forms. At the individual experimental facilities, a multitude of test parameters (e.g., rotational speed, load magnitude and direction) and operating conditions (e.g., lubrication type, temperature, exposure to additional media) can be set, and investigations can be conducted using various methods. For more in-depth studies, the tribological conditions of the systems or machine elements under investigation are abstracted and examined on model test rigs equipped with highly precise measuring technology. Additionally, various laboratory devices are available for determining lubricant characteristics or for examining the experimentally investigated components.

With the help of in-house manufacturing, experience in the design and operation of test equipment, and the available equipment, setups can be adapted further, particularly concerning the geometry of the test subject and the employed investigation methods, or entirely new experimental facilities can be developed. Various systems for temperature control (heating and cooling) are available, which can be used in a mobile manner. Regarding investigation methods, optical examinations on rotating setups can be conducted using multiple high-speed cameras and thermography systems, with fluorescence methods also being applicable.

The following overview of the experimental equipment only covers a portion of the technical capabilities due to the multitude of existing and conceivable combinations and adaptations of the test facilities. To structure the overview, the test facilities are assigned to machine elements or research areas. However, the use of individual facilities is not necessarily limited to these areas.

If you are interested in conducting investigations or require further information and have questions, please feel free to contact us.

Garbsen, March 2024

M.Sc. Volker Schneider

Rolling Bearings

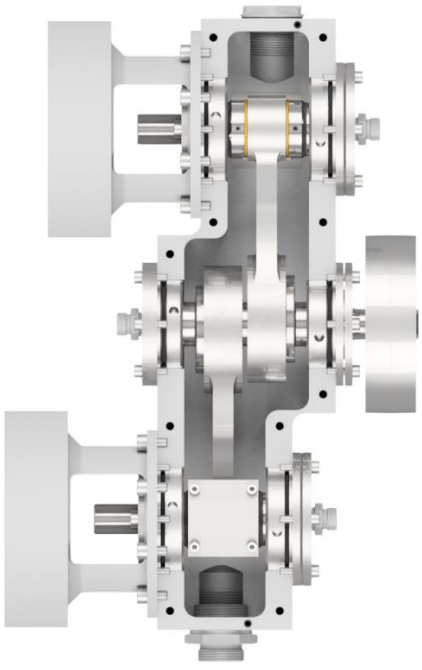
The high quality of modern rolling bearings and the presence of advanced approaches for calculating bearing life regarding different fatigue modes bring additional stresses, special events, and behavior in boundary conditions of operating conditions into focus for user interest and research.

An essential prerequisite for the high service life demanded today from rolling bearings is the optimal coordination of the bearing and lubrication. Especially under critical operating conditions, lubrication becomes a significant factor determining the service life. To investigate the effects of different lubrication methods on service life, such as oil bath, circulating oil, minimal quantity, dry, or grease lubrication, the experimental setups at IMKT can be modified accordingly to cover a broad range of applications. In the case of grease-lubricated rolling bearings, one goal is to assess the lubrication capability of greases based on friction and wear behavior even under extreme boundary conditions, such as low temperatures and oscillating motion over small angles as they occur in blade bearings from wind turbines, as well as high speeds, for example, in electromobility. Additionally, the use and behavior of novel, bio-based, or water-based lubricants are investigated.

In addition to evaluating special events such as overloading during operation and initial surface damage on the fatigue life of rolling bearings, the electrical behavior of bearings and their service life under electrical current passage damage play an important role in the rolling bearing research of the institute, especially in the application areas of electromobility and wind energy for electric drives and generators. Various methods are being investigated to increase the power density of rolling bearings, including collaboration with various institutes and companies in manufacturing technology for functionalizing boundary zones or developing tailored, rolling-loaded material zones.

Oscillating fatigue test rig

Rolling Bearings



Cross-sectional view of the coupler mechanism (pulley drive on the right, flanges for two separate bearing mounts on the left).

Experimental rig with coupler mechanism for applying oscillating movements to bearings over a large number of load cycles.

Used, for example, to determine the fatigue behavior of oscillating bearings with different contact geometries.

Simultaneous operation of two separately arranged experimental setups to increase statistical confidence.

Adaptation of bearing mounts possible for many test rigs at IMKT (FE8, Four-Bearing Radial Life Test Rig, Universal Friction Test Rig).

Damage detection with vibration-based condition monitoring.

Bearing bore diameter: d=20 - 60 mm

Bearing type: All types of radial- and thrust bearings through the use of different bearing mounts.

Load (static): Depends on bearing type & -size; up to 50 kN axial and radial up to 20 kN per bearing

Oscillating frequency: Up to 30 Hz

Oscillating angle: Up to $\pm$20°

Lubrication: Oil (injection or oil bath), grease, solid-, dry lubricants

Measurands: Vibration, temperatures

Three bearing radial load fatigue test rig

Rolling Bearings

To determine the fatigue life of radial bearings in a compact three-bearing arrangement, depending on factors such as bearing design, lubrication conditions, boundary zone properties, heat treatments, and materials.

Examination of direct bearings is efficiently possible through a compact design with minimal material requirements.

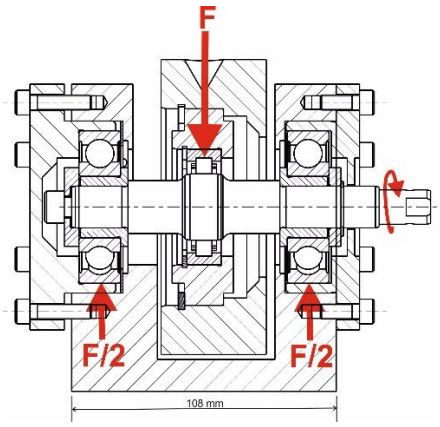
Damage detection with vibration-based condition monitoring.

Simultaneous operation of multiple units is possible.

Statistical downtime evaluation through Maximum Likelihood method.

Temperature control of lubricating oil to establish defined lubrication conditions (full lubrication and mixed lubrication).

Load application using an adjustable- and force sensor-monitored disc spring package.



Design for bearing that run directly on shaft

Bearing bore diameter: d=20 - 60 mm

Load (static): up to 20 kN

Rotational speed: up to 6000 min^{-1}

Operating temperature: +40 up to +100°C

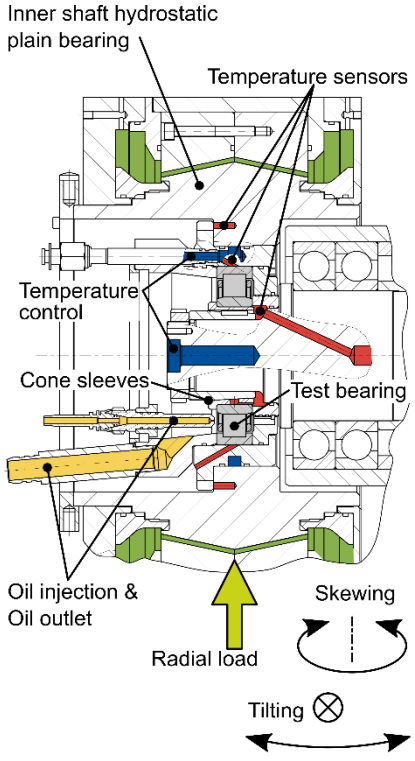
Lubrication: Oil (injection or oil bath), grease, solid-/ dry lubricants

Measurands: Vibration, temperatures, rotational speed, applied load

Capacity: 6 independent units with 3 bearings each

Single bearing test rig (ELP)

Rolling Bearings



Cross-section of bearing housing and hydrostatic plain bearing to measure e.g., frictional torque of a single bearing.

Test rig for functional investigations on a single rolling bearing with optical accessibility of one side of the bearing, enabling the direct implementation of high-speed or thermal cameras.

Setup adaptable for various types of radial bearings and angular contact bearing pairs.

Connection of bearing mount via piezoelectric 3-component force measuring platform possible.

Potential applications include examination of critical operating conditions (e.g., preload) & temperature behavior, measurement of axial thrust of misaligned cylindrical roller bearings, analysis of bearing kinematics, observation of grease distribution.

Measurement of bearing friction torque using hydrostatic plain bearing.

Temperature control of outer and inner bearing rings possible.

Bearing bore diameter: d=20 - 90 mm

Load (static): Up to 30 kN radial, yaw- and pitch angle adjustable

Rotational speed: Up to 6000 min^{-1}

Operating temperature: +10 up to +100°C

Lubrication: Oil (Oil-Air-, injection- or oil-bath), grease, solid-/ dry lubricants

Measurands: Temperatures (outer-, inner ring, oil), applied load, bearing reaction forces and moments, speed, torque, cage speed, functional investigations (rolling element kinematics, cage dynamics, temperature distribution).

FE8-test rigs

Rolling Bearings

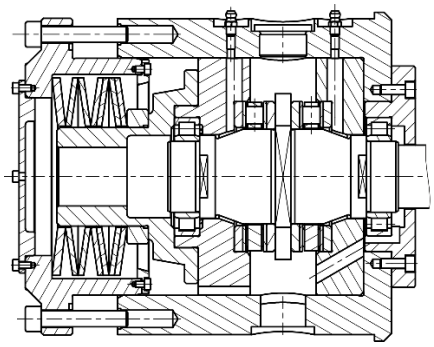
Test facilities based on FAG-FE8 design according to DIN 51819 in various technical configurations.

Examination of fatigue/wear behavior, lubricant suitability, and tribolayers, in dependency of materials, and lubricant formulation.

Conducting standardized tests, such as wear investigations according to DIN 51819 1 to 3, Pitting Test according to VW PV 1483 and ZF 0000 702 232, as well as WEA/WEC lubricant investigations.

Bearing mounts available for tapered roller bearings, angular contact ball bearings, spherical roller bearings, deep groove ball bearings, and cylindrical roller thrust bearings.

Modified setups with bearing temperature control, lubricant film thickness measurement, and optical accessibility are available.



Sectional view of bearing mount for cylindrical roller thrust bearings 81212

Bearing bore diameter: Typically, axial or angular bearings with d=60 mm; additional bearing mounts for other sizes and types of bearings are available.

Load (static): Up to 100 kN axial, mounts for radial loads are available

Rotational speed: Up to 5000 min^{-1}

Operating temperature: -25 up to +120°C

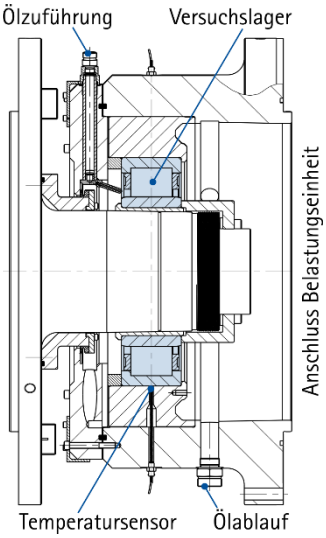
Lubrication: Oil (injection or oil bath), grease, solid-/ dry lubricants

Measurands: Vibration, temperatures, rotational speed, frictional torque, lubrication condition via electrical measurement

Capacity: 4 independent units of varying equipment

Large bearing test rig (GWLP)

Rolling Bearings



Bearing mount NU2256 with rotating outer ring.

Test rig with a broad range of applications for functional investigations on large bearings, for example, from wind turbines or the paper industry.

Possible applications include examination of critical operating conditions (e.g., preload, cold start), analysis of bearing kinematics (e.g., misalignment or slippage), testing of condition monitoring systems for large bearings.

Operation of deep groove ball, cylindrical roller, tapered roller, as well as axial and radial spherical roller bearings with a width ranging from 50 to 430 mm is possible.

Load application radially and axially, as well as tilting of the bearing mount in tension and compression direction through regulated hydraulics.

Measurements/imaging during operation possible through positioning unit at various points around the circumference of the bearing.

Bearing size: Up to 1 m outer diameter

Load (dynamic): Up to ±700 kN radial, ±100 kN axial, tilting ±1°

Rotational speed: Up to 1300 min^{-1}

Operating temperature: +40 up to +150°C

Lubrication: Oil (injection or oil bath), grease, solid-/ dry lubricants

Measurands: Temperatures, rotational speed, load and tilting angle, sensor technology for functional investigations (film thickness, rolling element kinematics, expansion of bearing rings)

Operation with rotating inner or outer ring possible.

High speed component test rig (HDL)

Rolling Bearings

Experimental setup for functional investigations on high-speed bearings (especially deep groove and angular contact ball bearings or spindle bearings) and component test stand for other components in high-speed applications.

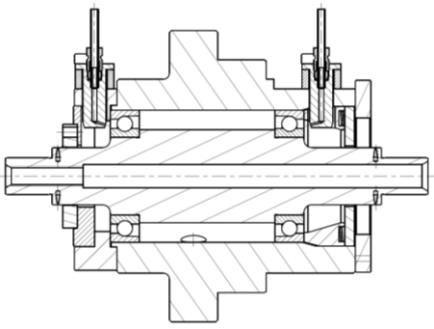
Possible applications include examination of temperature behavior and friction torque depending on bearing design, lubricant, and lubrication method, investigation of the behavior of contacting seals at high speeds.

Use of actual electric motor rotors to consider rotor dynamics is possible.

Temperature control of outer bearing rings to establish defined operating and lubrication conditions, inner shaft cooling possible.

Determination of lubricant film thickness based on electrical capacitance measurements.

Mechanical design with open protective cover



Example of bearing mount for 7008 FEGA/HCP4A

Bearing bore diameter: Up to 100 mm outer diameter

Load (static): Up to 2 kN axial, up to 5 kN per bearing radial

Rotational speed: Up to 60 000 min^{-1}

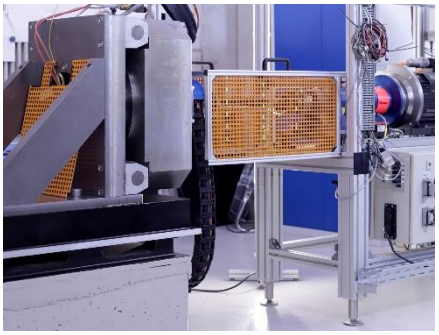
Operating temperature: +20 up to +120°C

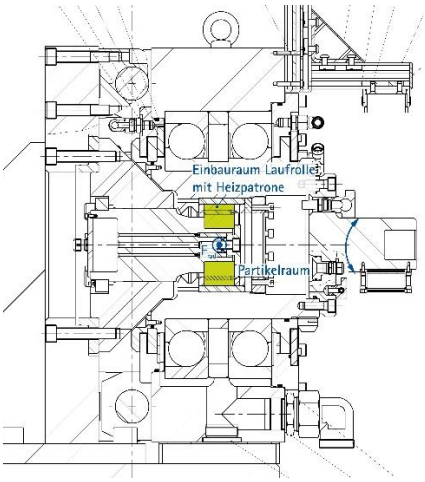
Lubrication: Oil (oil-air, injection, or oil bath), grease, solid-/ dry lubricants

Measurands: Frictional torque, bearing temperatures, rotational speed, load, lubricant film thickness, shaft displacement/deflection, vibration level

Track roller test rig

Rolling Bearings





Sectional view of track roller mount

Experimental test rig for investigating the service life of oscillating or rotating rollers, for example, to assess grease suitability, sealing effectiveness in operation, and bearing design.

Introduction of pressurized air-borne solid contaminants/particles on one side of the bearing possible.

Stationary operation with rotating outer ring.

Heating of inner ring and optionally outer ring (only in oscillating operation).

Installation with defined misalignment possible.

Bearing bore diameter: Up to 122 mm outer diameter

Load (static): Up to 200 kN

Oscillating frequency/Rotational speed: <0,2Hz (max. ±360°), rotating up to 1500 min^{-1}

Operating temperature: +40 up to +160°C

Lubrication: Grease, solid-/ dry lubricants

Measurands: Temperatures, rotational speed, frictional torque, load, optional lubricant film thickness

Wheelset bearing test rig (R3)

Rolling Bearings

Experimental test rig in a two-bearing arrangement for conducting fatigue life tests on larger rolling bearings and bearing units, as well as for conducting performance tests on wheelset bearings for railway applications according to DIN EN 12082.

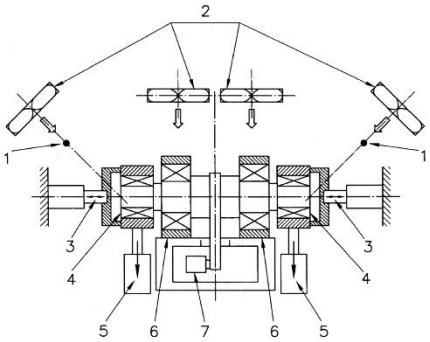
Simultaneous operation of two bearing (sets) per test setup on one shaft (symmetric configuration) with spatial separation of the bearing environments.

Adaptation of various bearing sizes and bearing housings, including bearing segments, possible.

Damage detection with vibration-based condition monitoring.

Simultaneous operation of multiple units possible.

Evaluation of statistical fatigue life examination through Maximum Likelihood Method.



Schematic diagram of test arrangement for wheelset bearings [image source DIN EN 12082:2021-09]

1 Ambient temperature sensor

2 Cooling fan

3 Axial load

4 Test bearing

5 Radial load

6 Support bearing

7 Motor

Bearing bore diameter: Up to d=200 mm

Load: Up to ±200 kN per bearing radial, ±50 kN axial

Rotational speed: Up to 3000 min^{-1}

Lubrication: Oil (injection or oil bath), grease, solid-/ dry lubricants

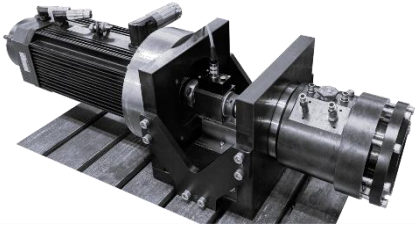
Measurands: Vibration level, temperatures, rotational speed, forces, optional lubricant film thickness

Quantity: 2 independent units with 2 test bearings/wheel set bearing units each

Operation possible under defined tilted position

Oscillating wear test rig

Rolling Bearings



Basic test setup for an oscillating test rig (bearing mount on the right, torque measuring shaft in the middle, and servo motor on the left side).

Test rig for conducting functional investigations on oscillating bearings, for example, regarding grease suitability and wear.

Complex motion profiles with varying frequency, ramp shape, pauses, and rotation programmable.

Adaptation of bearing mounts from many test rigs at IMKT possible (FE8, Four-Bearing Radial Life Test Rig, Universal Friction Test Rig).

Bearing bore diameter: d=20 - 60 mm

Bearing type: All types of radial- and axial roller bearing by using different bearing mounts

Load (static): Depends on bearing type & -size, up to 100 kN axial, per bearing up to 20 kN radial

Oscillating frequency: Up to 30 Hz

Oscillating angle: Depends on oscillating frequency, rotation possible

Lubrication: Oil (injection or oil bath), grease, solid-/ dry lubricants

Measurands: Temperatures, frictional torque, optional lubricant film thickness

Quantity: 2 independent units

Universal bearing test rig

Rolling Bearings

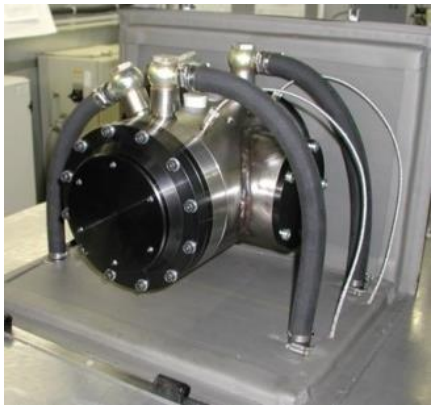
Modular experimental test setup with a wide range of applications for various types of investigations on rolling bearings.

Conducting functional investigations, for example, on grease distribution at low temperatures using optical methods on tempered bearing mounts, for building tribocoatings, or regarding friction investigations.

Examination of fatigue/wear behavior or lubricant suitability, for example, according to DIN 51819 1 to 3, VW PV 1483, or ZF 0000 702 232.

Adaptation of bearing mounts from many test rigs at IMKT possible (FE8, Four-Bearing Radial Life Test Rig, Universal Friction Test Rig).

Setups with bearing temperature control, lubricant film thickness measurement, and optical accessibility available.



Temperature-controlled bearing mount on the universal bearing test rig

Bearing bore diameter: Typically, d=20 - 60 mm

Bearing type: All types of radial- and axial roller bearing by using different bearing mounts

Load (static): Depends on bearing type & -size, up to 100 kN axial, per bearing up to 20 kN radial

Rotational speed: Up to 3000 min^{-1}

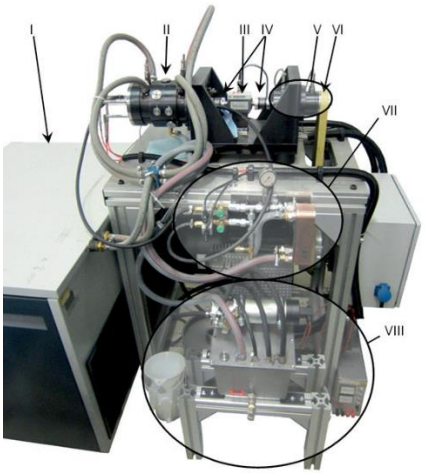
Operating temperature: -25 up to +120°C

Lubrication: Oil (injection or oil bath), grease, solid-/ dry lubricants

Measurands: Temperatures, rotational speed, frictional torque, vibration level, lubrication condition via electrical parameters

Universal friction torque test rig

Rolling Bearings



Example of a universal friction test rig for oil-lubricated bearings

1 Process thermostat
2 Bearing holder
3 Torque measuring shaft
4 Intermediate shaft
5 Belt drive
6 Oil heat exchanger
7 Oil supply

Experimental test rig for investigating the operational behavior, frictional behavior, and lubricant film formation of rolling bearings across wide operating ranges.

Temperature control of bearing mounts possible.

Torque measuring technology available in different measuring ranges.

Adaptation of bearing mounts from many test rigs at IMKT possible (FE8, Four-Bearing Radial Life Test Rig, Universal Friction Test Rig).

Bearing bore diameter: Typically, up to d=40 mm

Bearing type: All types of radial- and angular contact bearings

Load (static): Up to 40 kN axial, per bearing up to 20 kN radial

Rotational speed: Up to 16 000 min^{-1}

Operating temperature: -25 up to +100°C

Lubrication: Oil (oil-air, injection, or oil bath), grease, solid-/ dry lubricants

Measurands: Temperatures, frictional torque, lubricant film thickness

Quantity: 2 independent units

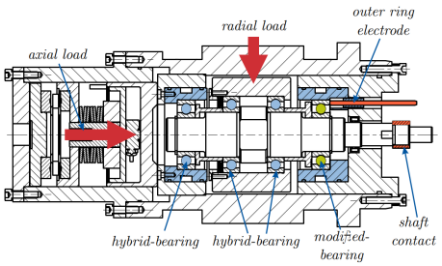
Universal electrical bearing test rig

Rolling Bearings

Modular experimental test setup with a wide range of applications for various types of electrical investigations on rolling bearings at moderate and high speeds.

Conducting functional investigations, for example, capacitance/impedance influences. Application of harmful bearing currents of rolling bearings under defined conditions.

Adaptation of bearing mounts from many test rigs at IMKT possible (FE8, Four-Bearing Radial Life Test Rig, Universal Friction Test Rig).



Exemplary modified test head for electrical investigations on rolling bearings

Bearing bore diameter: Typically, d=20 up to 60 mm

Bearing type: All types of radial- and axial roller bearing by using different bearing mounts

Load (static): Depends on bearing type & -size, up to 20 kN axial, per bearing up to 20 kN radial

Rotational speed: Up to 16 000 min^{-1}

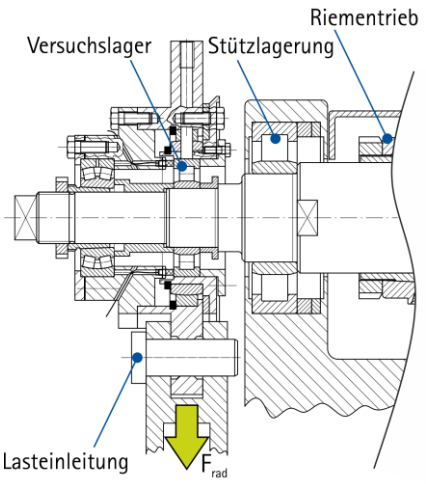
Operating temperature: -25 up to +90°C

Lubrication: Oil (injection or oil bath), grease, solid-/ dry lubricants

Measurands: Temperatures, rotational speed, frictional torque, capacitance, impedance, film thickness, breakdown voltage

Two-bearing radial fatigue test rig (R2)

Rolling Bearings



Sectional view of bearing arrangement (example design for inclined cylindrical roller bearings NU206)

Test rig for conducting fatigue life tests on radial bearings or bearing units in a two-bearing arrangement.

Simultaneous operation of the two test objects per test setup on a common shaft (symmetric configuration) with spatial separation of the bearing environments.

Cost-effective adaptation of various bearing sizes, bearing housings, and bearing segments possible.

Examination dependent on factors such as bearing design, edge zone properties/heat treatment, and materials.

Damage detection with vibration-based condition monitoring.

Simultaneous operation of multiple units possible.

Evaluation of statistical fatigue life using the Maximum Likelihood method.

Bearing bore diameter: d=30 up to 100 mm

Load (static): Radial up to 35 kN per bearing, pure torque load (e.g., for wheel bearing units) possible

Rotational speed: Up to 2500 min^{-1}

Lubrication: Grease, solid-/ dry lubricants

Measurands: Vibration, temperatures, rotational speed

Quantity: 4 independent units with 2 bearings each

Operation with defined tilting (yaw or tilt) possible

Four-bearing axial fatigue test rig

Rolling Bearings

Test rig for conducting fatigue life tests on axially loaded deep groove and angular contact ball bearings.

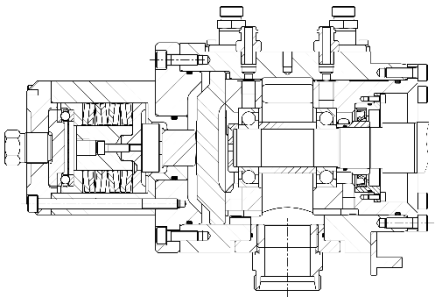
Examination dependent on factors such as bearing design, boundary zone properties/heat treatment, and materials.

Simultaneous operation of two axially loaded bearing pairs per test setup on a common shaft (symmetric configuration) with spatial separation of the two bearing pairs.

Damage detection with vibration-based condition monitoring.

Evaluation of statistical fatigue life using the Maximum Likelihood method.

Simultaneous operation of multiple units possible.



Sectional view of bearing arrangement (example 7206, two pairs of bearings per test setup)

Typical bearing bore diameter: 7206 & 7208

Load (static): Up to 40 kN

Rotational speed: Up to 3000 min^{-1}

Operating temperature: +40 up to +140°C

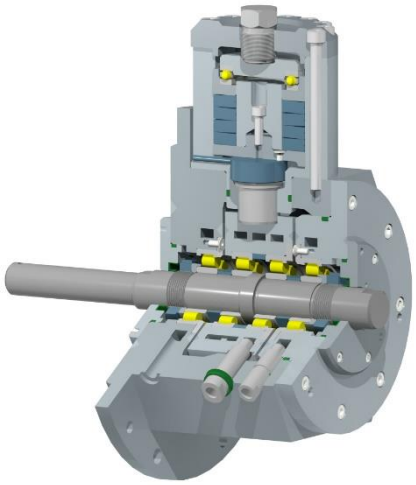
Lubrication: Oil (injection or oil bath), grease, solid-/ dry lubricants

Measurands: Vibration level, temperatures, rotational speed, load, frictional torque, optional lubricant film thickness

Quantity: 4 independent units with 4 bearings each

Four-bearing radial fatigue test rig

Rolling Bearings



Sectional view of bearing arrangement (example NU206)

To determine the fatigue life of radial bearings in a four-bearing arrangement, considering factors such as preloading (overload, slippage, damage, current passage, etc.), boundary zone properties/heat treatment, and materials.

Evaluation of statistical fatigue life using the Maximum Likelihood method.

Damage detection with vibration-based condition monitoring.

Simultaneous operation of multiple units possible.

Temperature control of outer bearing rings and lubricating oil to establish defined lubrication conditions (full lubrication and mixed lubrication).

Load application using an adjustable disc spring package monitored by a force sensor.

Typical bearing bore diameter: d=30 mm (Cylindrical roller bearing 206 & 1006)

Load (static): Radial up to 20 kN per bearing ≙ C/P=2,3 for NU206

Rotational speed: Up to 4050 min^{-1}

Operating temperature: +40 up to +100°C

Lubrication: Oil (injection or oil bath), grease, solid-/ dry lubricants

Measurands: Vibration level, bearing & oil temperatures, rotational speed, load, optional friction torque & lubricant film thickness

Quantity: 6 independent units

Adaption of an axial loaded bearing arrangement with up to 50 kN axial load

Rolling bearing fatigue life rig for complex loads

Test setup for determining the fatigue life of bearings without inner rings that directly run on shafts under complex structural mechanical loading in the rolling contact zone, depending on factors such as geometry, boundary zone properties, heat treatment, and materials.

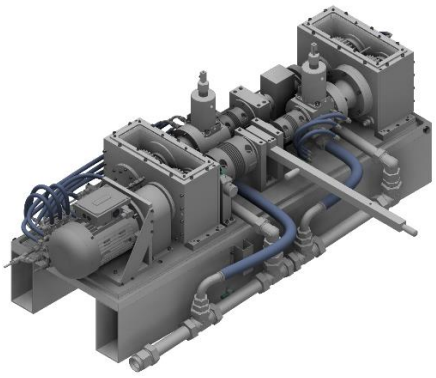
Application of torsional stresses through a mechanical clamping circle, introduction of bending stresses through targeted circumferential bending under radial load.

Two separate bearing mounts arranged in a three-bearing configuration (identical to Three-Bearing Radial Life Test Rig) arranged in the clamping circle.

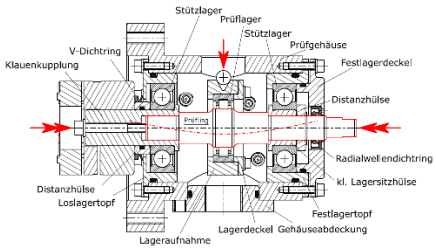
Damage detection with vibration-based condition monitoring.

Evaluation of statistical fatigue life using the Maximum Likelihood method.

Load application using adjustable disc spring packages monitored by force sensors.



Overall structure to apply tension.



Bearing bore diameter: d=20 up to 50 mm

Load (static): Up to 15 kN radial, up to 300 Nm torsion torque

Rotational speed: Up to 6000 min^{-1}

Operating temperature: +40 up to +120°C

Lubrication: Oil (injection or oil bath), grease, solid-/ dry lubricants

Measurands: Vibration level, bearing & oil temperatures, rotational speed, radial force, shaft displacement

Quantity: 2 simultaneously operated bearing arrangements

Rheology/EHL & Lubrication analysis

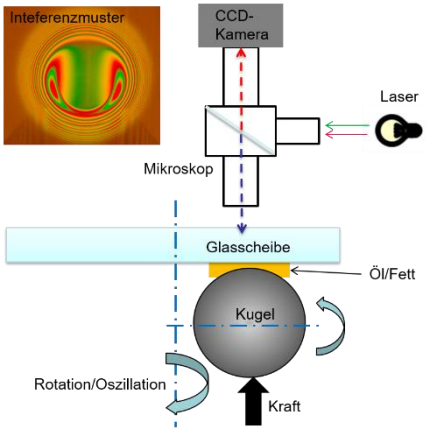
In the field of rheology and elastohydrodynamic lubrication (EHL), the research focusses on understanding the physical phenomena that occur in lubricated highly loaded contacts of machine elements (such as bearings, gears, and cam followers). These are investigated both theoretically through the development of computational models and through experimental methods.

A key focus is on friction losses occurring in EHL contacts, which are significantly influenced by the behavior of lubricants under high pressures, temperatures, and shear rates. By exploring lubricant behavior and the interactions between individual contact partners, understanding of losses in such machine elements can be increased, while simultaneously exploring ways to reduce these losses. Furthermore, insights can be used to better understand wear processes and thus enable long-term reduction of wear. Additionally, in the field of lubricants, the flow behavior of lubricants and the influence of operating conditions in the near-contact area are investigated to obtain insights into lubricant film formation and losses. For example, studies are conducted on lubricant film formation in lubricated oscillating EHL contacts, with a focus on the physical properties of lubricating greases.

Thus, describing the lubricant in physical models – and understanding this machine element better – forms the core of the research. Typically, the behavior of the lubricant is examined using model experiments, such as those conducted on twin-disc test rigs or in the ball-disc experiment. Such studies are supplemented by measuring or directly observing processes in EHL contacts, for example, using laser-induced fluorescence, infrared thermography, and interference methods.

EHL-tribometer

Rheology/EHL



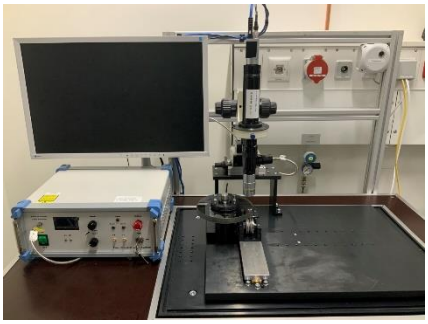
Principle

The ball-disc setup is used to investigate the lubricant film formation and lubricant distribution in an EHL (elastohydrodynamic lubrication) contact.

It involves determining the locally resolved lubricant film thickness and observing lubricant spreading in and around the contact using interferometry.

The disc and counterbody (ball) are independently driven.

Oscillating or rotating operation is possible.



EHL-Tribometer

Contact load (static): Up to 200 N

Rotational contact speed during: Up to 2 m/s

Oscillating frequency: Up to 5 Hz

Oscillating angle: Up to ±15°

Lubrication: Oil, grease

Temperature oil reservoir: Up to 80°C

Two disc test rig

Rheology/EHL

The experimental setup is designed to investigate the fluid behavior in a single EHL (Elastohydrodynamic Lubrication) contact between two radially contacting, driven contact bodies (disks or rings).

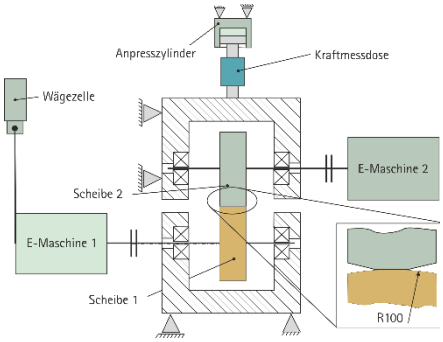
It involves recording traction curves for fluids based on the inlet velocity profile, defined adjustable speed difference (slip), and fluid or disk temperature.

Key fluid properties are derived from traction curves, for example, to model the friction behavior of rolling and sliding contacts and determine power losses, for instance, in pumps.

An optical setup for finely resolved contact temperature measurement and observation of lubricant film formation with a transparent sapphire disk is available.

Automated adjustment of the traction curve points during operation.

The setup includes an additional contact partner between the driven ones (ring-rolling element-ring configuration).



Schematic layout of the two-disc test rig

Contact load (static): Up to 15 kN ≙ 3 GPa with suitable contact geometry

Speed in contact: Up to 15 m/s

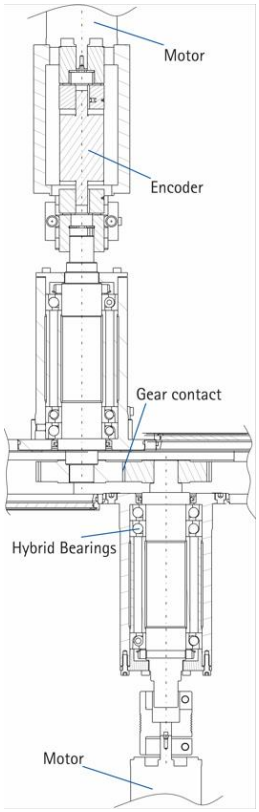
Oil inlet temperature: -10 up to +130°C

Disc temperature: 20 up to +100°C

Measurands: Contact load, frictional force, rotational speed, oil temperatures, disc temperature, optional contact temperature via thermography

Two disc/gear test rig

Rheology/EHL



Sectional view of electrical two disc/gear test rig

The experimental setup is originally designed to investigate the electrical behavior of a contact between two radially contacting, driven contact bodies (gear stage, discs, rings).

The support bearings of the shafts are hybrid so that no electrical path can form between the shaft and housing. The contact can therefore be accurately measured electrically. This includes measuring the capacitance, impedance, lubricant film thickness and breakdown voltage. Furthermore, tests can be carried out to investigate the damage mechanism by applying a specific electrical load.

All measurements are angularly resolved due to the built-in encoder. This means, for example, that the electrical properties in the tooth contact can be measured resolved over the meshing distance.

Bore diameter: Typically d=30 mm

Contact partner: Gear stage, discs, rings

Load (static): Up to 10 kN radial (discs, rings), up to 2 Nm (gear stage)

Rotational speed: Up to 6000 min^{-1}

Operating temperature: +20 up to +800°C

Lubrication: Oil (injection), grease, solid-/ dry lubricants

Measurands: Temperatures, capacitance, impedance, breakdown voltage, lubricant film thickness

Dynamic Seals

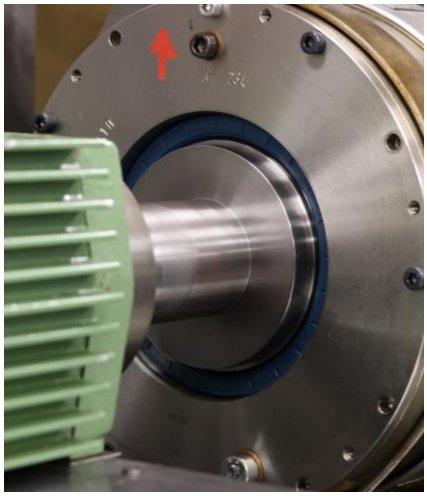
Achieving a reliable seal between moving components presents a challenging task, especially at high relative velocities, in the presence of pressure differentials during operation, imperfections on sealing surfaces, or extreme operating conditions. Therefore, the research activities of the IMKT regarding seals focus on analyzing their behavior and, based on this analysis, developing physically justified design methods for standard elements, special designs, and specific seals. Radial shaft seals (RSS) and rotary joints are the focal points of the considered sealing systems.

In addition to investigating leakage behavior during operation, friction behavior is also studied, and work is conducted on novel, energy-efficient sealing concepts. In addition to calculation approaches and simulation models of the sealing contact down to the microscale, various test rigs and devices are available for characterizing dynamic seals.

Endurance test rig

Endurance test bench in accordance with the FLENDER test specifications for carrying out long-term tests to investigate sealing system leakage and the compatibility between elastomers and lubricants. The onset of leakage is monitored using a camera and subsequent image analysis. The amount of leakage is determined gravimetrically. Optionally, the reverse pumping rate of elastomer seals can be measured when the test seals are installed inversely.

Simultaneous operation of 24 independent positions is possible.



Assembled test unit

Sealing size: d=30 up to 120 mm

Rotational speed: Up to 8 000 min^{-1} (20 test units), 17 500 min^{-1} (4 test units)

Operating temperature: up to +120°C

Lubrication: Oil bath

Measurands: Rotational speed, oil sump temperature, time of leakage, optional leakage curve and leakage quantity (gravimetric or volumetric)

Quantity: In total 24 independent test units

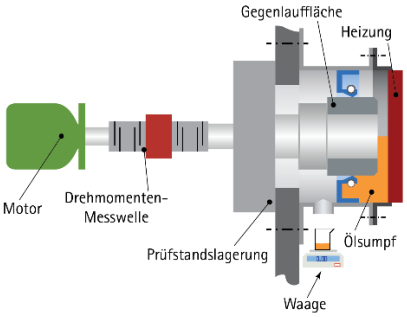
Horizontal pumping test rig

Dynamic Seals

Experimental setup for the measurement of the reverse pumping rate of rotary shaft seals. By fully flooding the test chambers on both sides of the test seal, the pump rate is measured by means of connected riser pipes via the change in hydrostatic pressure; user-defined pressure gradients can be specifically applied and controlled across the sealing contact.

In addition, the pumping rate can be measured gravimetrically when oil is applied to only one side of the seal. The seal friction is always recorded on this test bench with the aid of a torque measuring shaft integrated into the drive train.

With regular (i.e. sealing) installation of the RSS, leakage tests are also possible with simultaneous measurement of the seal friction.



Schematic design of the sealing test rig

Sealing size: *d*=30 up to 105 mm

Rotational speed: up to 6 000 min^{-1}

Operating temperature: up to +100°C

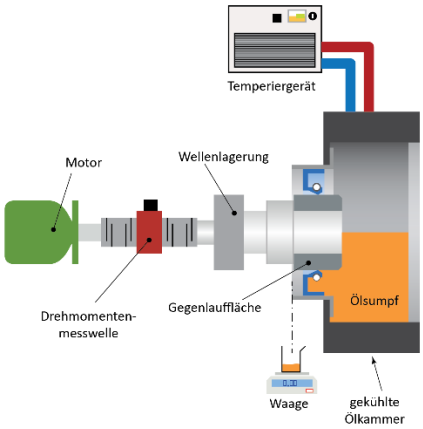
Lubrication: Oil sump or complete oil filling

Maximum Torque: 2 up to 10 Nm

Measurands: RSS pumping rate, rotational speed, seal friction torque, oil sump temperature, optional: leakage time, leakage progression

Low temperature horizontal pumping test rig

Dynamic Seals



Schematic design of the sealing test rig

Test rig for investigating the pumping rate and leakage behavior of rotary shaft seals at low temperatures.

The design is similar to that of the horizontal pumping test rig, whereby the oil sump can be cooled down to a minimum temperature of up to -30 °C using a temperature control unit (depending on the sliding speed).

The seal friction can also be monitored on this test rig.

Sealing size: *d*=30 up to 105 mm

Rotational speed: Up to 6 000 min^{-1}

Operating temperature: -30 up to +100°C

Lubrication: Oil sump or complete oil filling

Maximum Torque: 2 up to 10 Nm

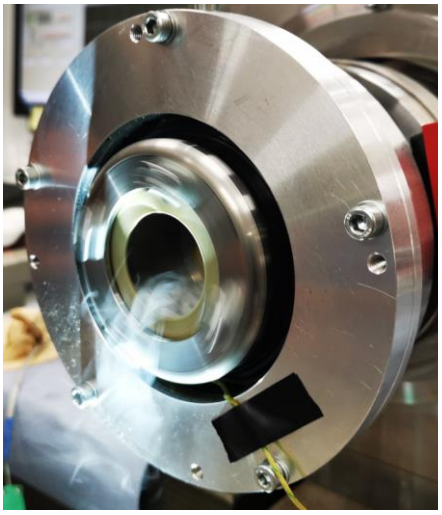
Measurands: RSS pumping rate, rotational speed, seal friction torque, oil sump temperature, optional: leakage time, leakage progression

Low-temperature functional test rig

Dynamic Seals

Test setup for simultaneous measurement of seal friction and temperature in the seal contact. The seal counterface, which is designed as a hollow shaft, is cooled down using dry ice, allowing contact temperatures of below -50 °C to be reached. The contact temperature is measured telemetrically via a miniature thermocouple integrated into the counterface.

The sealing contact is lubricated manually by injecting lubricant onto the fluid side of the seal. This eliminates drag losses, whose frictional behavior can hardly be separated from the frictional behavior in the seal contact zone, especially at low temperatures. The friction measured in this way can therefore exclusively be associated with the seal contact.



Sealing test rig in operation

Sealing size: d=80 mm, larger sealings possible

Rotational speed: Up to 600 min^{-1}, currently limited by telemetry unit

Operating temperature: Cooling of the sealing contact to below -50 °C possible

Lubrication: Oil sump or complete oil filling

Maximum Torque: 2,5 Nm, measured with torque flange by reaction torque on the sealing ring

Measurands: Rotational speed, sealing friction torque, sealing contact temperature, optional: delivery rate using injection method

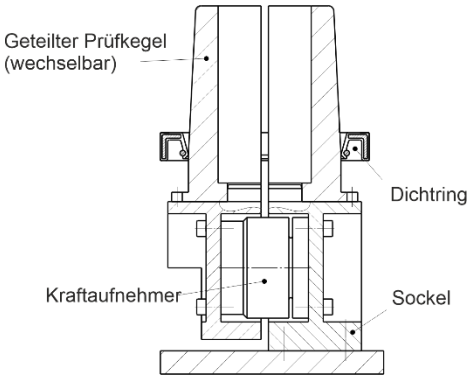
Radial force measurement

Dynamic Seals

Momentary picture of the radial force measurement

Device for measuring the radial force of a seal. This allows the comparability of test seals to be examined. It can also be used to record changes in the radial force, for example after an elastomer-lubricant compatibility test. These parameter changes provide indications of wear, permanent changes in shape or ageing processes.

The radial forces measured on this device also serve as input parameters for simulation models, e.g. for estimating sealing friction.



Schematic design of the radial force measurement

Drive Train

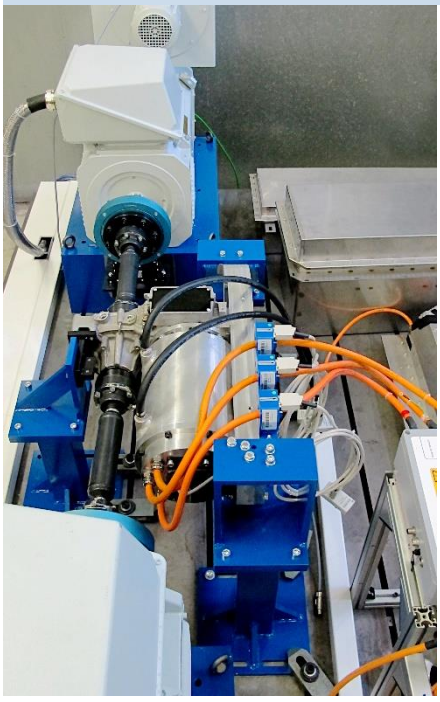
The IMKT investigates ways to increase the efficiency of electric drive systems, focusing on components with high drive speeds. Multiple, mass-reduced high-speed electric machines are mechanically interconnected with a gearbox, resulting in numerous advantages in terms of operational strategy and efficiency improvement.

For comprehensive examination of this area, a test rig is available to accommodate a fully instrumented drive train of a passenger car or light commercial vehicle. It can be operated and analyzed under defined conditions. Additionally, critical individual aspects of electromobility are also examined in detail, such as bearing and sealing friction at high speeds and current flow through rolling bearings.

Clutches are utilized in electric drive systems with multiple drive machines or gear stages, which are also investigated at the IMKT. These studies and experimental setups build upon extensive research experience in vehicle transmission synchronizations.

Drive train test rig

Drive Train



Drive train between load machines

Test bench for operation and investigation of electric vehicle drivetrains (drive machine, power electronics, gearbox including differential) as well as vehicle or industrial transmissions.

Operation with simulation of wheel torque loads, torque/speed control, or towing operation by load machines possible.

High-voltage DC power supply for power electronics of the drivetrain components available.

Recuperation operation possible.

Infrastructure for hybrid drivetrains available.

Examination of various thermal concepts possible, separate temperature control of drive machine and gearbox lubricant.

Power load machine: 2x103 kW at 1800 min^{-1}

Torque load machine: Both 1200 Nm (S2), max. 2000 Nm

Rotational speed load machine: Up to 1800 min^{-1}

Voltage DC-source: 325, 565 or 705 V

Power DC-source: Up to 111 kW (depends on output voltage)

Lubrication: Oil (injection- or oil-bath), grease

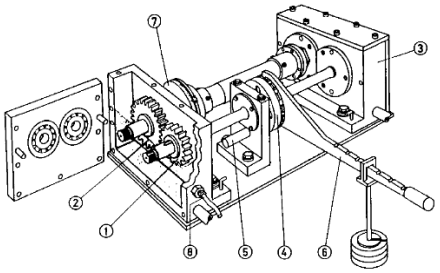
Operating temperature components: -20°C up to +110°C

Measurands: Vibration levels, temperatures, rotational speeds, torques of components and machines, currents in the drivetrain, optionally lubricant film thicknesses, recordings with high-speed cameras/thermography.

FZG-Tensioning test rig

Drive Train

Test rig according to DIN EN ISO 14635 for investigating the load capacity of lubricants and materials on gears (pitting resistance, micropitting life, gray spot formation). Loading of test gears via mechanical tension device, driven by a variable-speed electric motor. Fretting test according to DIN ISO 14635-1, micro pitting test according to FVA-54, fretting test according to FVA 243.

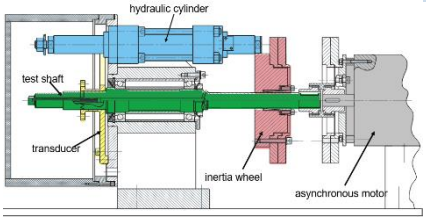


Exploded view of test setup
[Image source DIN ISO 14635-1]
1 Test pinion
2 Test wheel
3 Transmission gear
4 Load clutch
5 Locking bolt
6 Load lever with weights
7 Torsion clutch
8 Temperature sensor

Torque: Up to 600 Nm
Rotational speed: Up to 3000 min^{-1}
Centre distance: 91,5 mm
Lubrication: Oil-bath, optional grease
Oil temperature: Up to 120°C

Universal friction surface test rig.

Drive Train



Sectional view of test setup without friction partner

Test rig for investigating the friction and shifting behavior of shiftable clutches, synchronizers, or brakes (μ-comp).

Switching of the respective shifting/friction element from a driven shaft with a flywheel to a housing-mounted measuring transducer.

Conducting durability and functional tests.

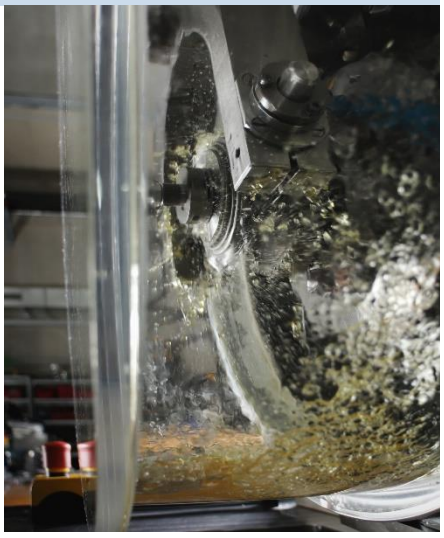
Actuation of shifting/braking process by a controlled hydraulic system.

Axial load: 150 up to 4000 N
Differential rotational speed: 500 up to 5000 min^{-1}
Moment of inertia: 0,006 up to 0,5 kgm^2
Clutch diameter: Typically, up to 150 mm
Oil injection temperature: Up to 120°C
Oil flow rate: Up to 5 l/min
Cycle time shift operation: ≥3 s
Measurands: Friction torque, axial force, axial displacement of actuation, optionally temperatures, optional displacement of clutch elements radially & axially, optional use of high-speed cameras and thermography.

Dual-shaft universal friction surface test rig

Drive Train

Test stand for investigating the friction and shifting behavior of shiftable clutches, synchronizers, or brakes in rotating operation. Shifting of the respective shifting/friction element between two concentric rotating shafts with flywheels. Recording of the test object by a rotating transducer. Durability and functional tests can be conducted. Actuation of the shifting/braking process by a controlled hydraulic system.



Dual-shaft universal friction surface test rig during operation

Axial load: 150 up to 4000 N

Differential rotational speed: 50 up to 12000 min^{-1}

Moment of inertia inner shaft: 0,009 up to 0,5 kgm^2

Moment of inertia outer shaft: 0,62 up to 5 kgm^2

Clutch diameter: Typically, up to 250 mm

Oil injection temperature: Up to 120°C

Oil flow rate: Up to 5 l/min

Cycle time shift operation: ≥3 s

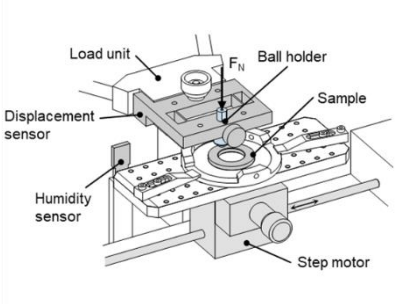
Measurands: Friction torque, axial force, axial displacement of actuation, optionally temperatures, optional displacement of clutch element radial & axial, optional use of high-speed cameras and thermography.

Microtribology

In the field of microtribology, physical and chemical principles of dry and lubricated contacts are studied from the nanoscale to the macroscale. This includes the formation of tribochemical boundary layers by lubricant additives, the structure of the surface layer of contacting partners, the effect of surface structuring to reduce friction, as well as the use of dry lubricants and nanoparticles. The subject area is closely linked to investigations of machine elements on the macroscale and also finds application in biotribology.

Milli-tribometer

Microtribology



Milli-tribometer with mounted sample

Linear/oscillating friction contact measurement with low contact pressures

Oscillating sliding test for investigating friction behavior and wear, e.g., for various materials, coatings, lubricants, and tribological layers

Different sample body geometries & prepared sections of larger machine elements mountable

Applicable for dry or lubricated contacts

Movement distance: Up to 20 mm

Speed: 0,08 up to 8 mm/s

Frequency: 0,01 up to 1 Hz

Load: 0,01 up to 3 N

Measurands: Frictional force, Coefficient of friction

Ball-on-ring tribometer

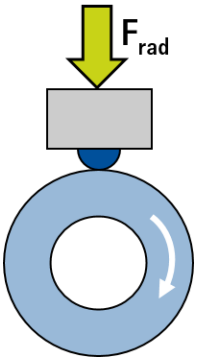
Microtribology

Friction contact measurement with low contact pressures at the contact between a stationary ball and a rotating, annular counterbody

For investigating friction behavior and wear, e.g., for various materials, coatings, lubricants, and tribological layers

Different counterbodies mountable, e.g., inner ring of cylindrical roller bearings

Applicable for dry or lubricated contacts



Schematic diagram of the ball-on-ring tribometer

Rotational speed: 200 up to 1000 min^{-1}

Load: up to 3 N

Ball diameter: 3, 6 or 10 mm

Measurands: Frictional force, Coefficient of friction